W.L. STUTZMAN

NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL
of the
UNITED STATES OF AMERICA
UNITED STATES NATIONAL COMMITTEE
International Union of Radio Science

1976 Annual Meeting
October 11-15

Sponsored by USNC/URSI
in cooperation with
Institute of Electrical and Electronics Engineers
Society on Antennas and Propagation
University of Massachusetts
Amherst, Massachusetts

Price $5.00

MONDAY EVENING, OCTOBER 11, 2000-2400

2000	U.S. National Committee (USNC) Meeting	101
2000	American National Standards Institute (ANSI), C-95 Subcommittee Meeting	172

TUESDAY MORNING, OCTOBER 12, 0900-1215

AP-S1	Reflector and Subreflector Antennas	161
AP-S2	Array Pattern Analysis and Control	163-173
AP-S3	EM Theory	174-176
AB-1A	Auditory and Other Sensory Effects,	Commonwealth Room
AB-1B	Prompt Behavioral Effects	Commonwealth Room
B-1	Transmission Lines and Propagation	101
F-1	Remote Sensing	168-172
G-1	M.F. and H.F. Propagation	165-169
J-1	Communication with Extra Terrestrial Intelligence I	917

TUESDAY AFTERNOON, OCTOBER 12, 1400-1715

AP-S4	Spacecraft Antennas	161
AP-S5	Array Techniques	163-173
AP-S6	Wire Antennas	174-176
AB-2A	CNS Effects	Commonwealth Room
AB-2B	Immunologic and Hematopoietic Effects,	Commonwealth Room
B-2	Numerical Solution of Scattering Problems	101
C-1	Signaling and Processing	165-169
F-2	New Satellite Beacon Propagation Experiments above 10 GHz	168-172
J-2	Communication with Extra Terrestrial Intelligence II	917

TUESDAY EVENING, OCTOBER 12, 1400-2400

1400	URSI Commission G Business Meeting	804-808
1600	URSI Commission J Business Meeting	917
1730	Chapter Chairmen of AP Society	903
1730	URSI Commission C Business Meeting	165-169
1930	Meeting of the Administrative Committee of the Antennas and Propagation Society (AP-S) of the IEEE	1101
2000	American National Standards Institute (ANSI) C-95.1 Subcommittee Meeting	172

WEDNESDAY MORNING, OCTOBER 13, 0900-1215

	Joint AP-S/URSI Session	161
AP-S7	Miscellaneous Antenna Systems	163-173
AP-S8	Near Field Theory and Measurements	174-176

WEDNESDAY AFTERNOON, OCTOBER 13, 1300-1830

1300	Tour to Sturbridge Village - from third floor lobby	
1400	Tour of Five College Radio Astronomy Observatory at Quabbin Reservoir - from third floor lobby	
AP-S9A	Satellite and Remote Measurements	161
AP-S9B	Special Measurement Techniques	161
AP-S10A	Antenna Techniques for Limited Sector Coverage	163-173
AP-S10B	Special Array Considerations	163-173
AB-3A	Dosimetry	Commonwealth Room
AB-3B	Dosimetry	Commonwealth Room
A-1	Antenna Measurements	174-176
A-2	Dielectric Measurements	174-176
B-3	Electromagnetism	101
E-1	ATS-6 Electromagnetic Survey	165-169
E-2	Radio Noise and Interference	165-169
F-3	Some Applications and Effects of EM and Acoustic Waves in the Earth Environment	168-172
G-2	Transionospheric Propagation and Ionospheric Irregularities	917

WEDNESDAY EVENING, OCTOBER 13, 1730-2400

1730	Committee on Man and Radiation IEEE COMAR	804-808
1730	URSI Commission A Business Meeting	174-176
1730	URSI Commission E Business Meeting	165-169
1730	URSI Commission F Business Meeting	168-172
1830	Reception, Cash Bar,	Student Union Ballroom
1970	Banquet, Henry Steele Commager, speaker	Student Union Ballroom

THURSDAY MORNING, OCTOBER 14, 0900-1215

AP-S11	High Frequency Diffraction	174-176
AP-S12	Microstrip and Low Profile Antennas	163-173
AB-4A	Microwave Measurements and Exposure Systems,	Commonwealth Room
AB-4B	Instrumentation - Probes	Commonwealth Room
B-4	Antennas and Arrays	101
B-5	Ground Effects on Antennas	168-172
F-4	Radio Meteorology	161
G-3	Ionospheric Structure	165-169
J-3	Astronomical Image Formation I	917
	IEEE/AP-S Standards Committee on Antennas	177

THURSOAY AFTERNOON, OCTOBER 14, 1300-1715

1300	Tour to Deerfield Village - from third floor lobby	
AP-S13	Scattering and Radiation in Material Media	174-176
AP-S14	Adaptive Antennas	163-173
AB-5A	Physiological and Behavioral Effects	Commonwealth Room
AB-5B	Behavioral Effects	Commonwealth Room
B-6	Poles and Transients	101
B-7	Fiber and Integrated Optics I	168-172
F-5	Radio Oceanography	161
F-6	Doppler Radar Studies of the Atmosphere	165-169
J-4	Astronomical Image Formation II	917
J-5	Instrumentation	917

THURSOAY EVENING, OCTOBER 14, 1400-2400

1400	(CCIR) International Radio Consultative Committee	804-808
1730	URSI Commission B Business Meeting	163-173
1830	Special Informal Meeting on EMP Interaction Handbook	163-173
1900	Meeting of the IEEE/AP-S Standards Committee on Propagation	805
2000	AP-S Special Meeting on Professional Activities and the IEEE	163-173
2000	American National Standards Institute (ANSI) C-95.4 Subcommittee Meeting	172

FRIDAY MORNING, OCTOBER 15, 0900-1215

AP-S15A	Antenna Synthesis and Design	161
AP-S15B	Special Topics	161
AP-S16A	Numerical Techniques	174-176
AP-S16B	Transients	174-176
AB-6A	Selected Topics	Commonwealth Room
AB-6B	Selected Topics	Commonwealth Room
B-8	Fiber and Integrated Optics II	163-173
CE-1	Electromagnetic Coupling to Leaky Cables	165-169
F-7	Scintillations and the Turbulent Atmosphere	101
F-8	EM Devices, Measurements and Theory	168-172
J-6	Solar System and Galactic Radio Astronomy	917

FRIDAY AFTERNOON, OCTOBER 15, 1330-1715

1330	Dedication Ceremony for the Five College Radio Astronomy Observatory Millimeter Telescope, Quabbin Reservoir -	from third floor lobby
AP-S17A	Adaptive Antenna Systems	163-173
AP-S17B	Aircraft-Mounted Antennas	163-173
AP-S18	Propagation	174-176
AB-7A	Hyperthermia	Commonwealth Room
AB-7B	Therapeutic and Diagnostic Applications	Commonwealth Room
AB-8A	Developmental and Mutagenic Effects	917
AB-8B	ELF Effects	917
B-9	Fiber and Integrated Optics, III	168-172
CE-2	Telecommunications via Leaky Cables	165-169
F-9	Scattering Observations and Effects	101

United States National Committee

INTERNATIONAL UNION OF RADIO SCIENCE

PROGRAM AND ABSTRACTS

1976 Annual Meeting

October 11-15

Held Jointly with

ANTENNAS AND PROPAGATION SOCIETY

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS

Amherst, Massachusetts

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DESCRIPTION OF

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The International Union of Radio Science is one of 17 world scientific unions organized under the International Council of Scientific Unions (ICSU). It is commonly designated as URSI (from its French name, Union Radio Scientifique Internationale). Its aims are (1) to promote the scientific study of radio communications, (2) to aid and organize radio research requiring cooperation on an international scale and to encourage the discussion and publication of the results, (3) to facilitate agreement upon common methods of measurement and the standardization of measuring instruments, and (4) to simulate and to coordinate studies of the scientific aspects of telecommunications using electromagnetic waves, guided and unguided. The International Union itself is an organizational framework to aid in promoting these objectives. The actual technical work is largely done by the National Committees in the various countries.

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The International Union, as of the XVIII General Assembly held in Lima, Peru, August 1975, has nine bodies called Commissions for centralizing studies in the principal technical fields. The names of the Commissions and the chairmen follow.

A. Electromagnetic Metrology
Altschuler (USA)

B. Fields and Waves
van Bladel (Belgium)

C. Signals and Systems
Picinbono (France)

D. Physical Electronics
Smolinski (Poland)

E. Interference Environment
Likhter (USSR)

F. Wave Phenomena in Nonionized Media
Eklund (Sweden)

G. Ionospheric Radio
King (United Kingdom)

H. Waves in Plasmas
Gendrin (France)

J. Radio Astronomy
Westerhout (USA)

Every three years, the International Union holds a meeting called the General Assembly. The next General Assembly, the XIX, will be held in Helsinki, Finland in August 1978. The Secretariat prepares and distributes the Proceedings of these General Assemblies. The International Union arranges international symposia on specific subjects pertaining to the work of one Commission or to several Commissions. The International Union also cooperates with other Unions in international symposia on subjects of joint interest.

Radio is unique among the fields of scientific work in having a specific adaptability to large-scale international research programs, for many of the phenomena that must be studied are worldwide in extent and yet are in a measure subject to control by experimenters. Exploration of space and the extension of scientific observations to the space environment is dependent on radio for its communication link and at the same time expands the scope of radio research. One of its branches, radio astronomy, involves cosmos-wide phenomena. URSI has in all this a distinct field of usefulness in furnishing a meeting ground for the numerous workers in the manifold aspects of radio research; its meetings and committee activities furnish valuable means of promoting research through exchange of ideas.

Commissions A and B - Session 1A

Tuesday, October 12 0900 - 1215
AUDITORY AND OTHER SENSORY EFFECTS
Chairman: E.L. Hunt, Walter Reed Army Institute of Research

1. LOW FREQUENCY HEARING AND SEEING: D.J. Adrian, Megatek Corp., San Diego, CA

Auditory and visual (phosphenes) effects generated by transcranial stimulation with low frequency electric currents are described. These effects occur at frequencies in the Navy ELF communication band but the currents used correspond to fields which are orders of magnitude larger than planned. Frequency response characteristics for both effects were measured. The sensory channels were found to behave much like frequency selective filters but with a number of important nonlinearities. Several types of stimulus currents were used including sinewave, periodic bursts of sinewave and two simultaneous sinewaves of differing frequency. Habituation to both the phosphene and auditory sensation were noted. These effects and combination frequency effects received emphasis because of potential implications for the understanding of sensory processes.

The minimum current threshold for the phosphene and auditory effect occurs at 20-25 Hz and 60-90 Hz respectively. The effects were also generated by the application of two simultaneous sinewaves well above the cutoff frequency when the difference frequency was near the minimum threshold frequency.

A decrease in sensory "noise" was noted following some experiments. Possible application of this effect as a therapy for tinnitus ("ringing in ears") is briefly discussed.

2. MICROWAVE HEARING: THE RESPONSE OF SINGLE AUDITORY NEURONS IN THE CAT TO PULSED MICROWAVE RADIATION: R.M. Lebovitz and Ronald L. Seaman, Dept. of Physiology, Univ. of Texas Health Science Center at Dallas, TX

Inferences regarding "microwave hearing" have been based upon the reports of human observers, animal behavioral experiments, and the recording of auditory field potentials. Here we report on our recent studies of the response of single auditory neurons in the cat to pulsed microwave radiation (MWR) at 915 MHz. The response to acoustic click stimuli of primary auditory fibers and of cell bodies in brain stem cochlear nuclei were recorded via NaCl filled glass micropipettes. The effect of pulsed MWR on the neuronal discharge properties was then similarly determined. Threshold effects were observed at absorbed energies of 5 μJ/g per pulse; the response was independent on the MWR pulse parameters and independent of the average imposed MWR power density (less than 1 mW/cm^2). Of the more than 200 neurons studied, most demonstrated a similar response to acoustic clicks as to pulsed MWR stimuli, enabling us to define the acoustic equivalent of the latter. Units most sensitive to acoustic frequencies below about 3 KHz were more likely to be responsive to microwave pulses than were units with higher best frequencies. Our results refine and partially support the suggestion that microwave hearing is mediated by a thermoelastic absorption of the microwave pulse.

3. CHARACTERISTICS OF MICROWAVE-INDUCED COCHLEAR MICROPHONICS: Chung-Kwang Chou, Arthur W. Guy, University of Washington School of Medicine, Seattle, WA and Robert Galambos, University of California, San Diego, CA

With proper recording techniques, cochlear microphonics (CM) have been recorded from guinea pigs and cats during irradiation by 918 and 2450 MHz pulsed microwaves. Both horn applicators and a cylindrical waveguide exposure system were used to radiate the animals. As the body weight of the guinea pigs varied from 0.5 to 1.0 kg, the frequency of microwave-induced CM decreased from 50 to 42 kHz. Similarly, for cats with body weights of 0.9 to 3 kg, the frequency of microwave-induced CM decreased from 38 to 29 kHz. In addition, as the body weight of the test animals were increased, the number of cycles of CM oscillation varied from 11 to 7 cycles in guinea pigs and 10 to 4 cycles in cats. The characteristics of the microwave-induced CM clearly depend on the size of the animal head, i.e., the smaller the head, the higher the frequency of CM, and the thicker the skull, the less the oscillation of CM. For each animal, the same frequency and duration of CM were induced at both 918 and 2450 MHz with either horn applicator or the waveguide exposure system. The measured parameters were also independent of electrical field orientation with respect to body axis. The thresholds of evoked response (CM or N_1 nerve response) were 10 mJ/kg maximum in adult cats, 2.5 mJ/kg in kittens, and 7.5 mJ/kg average in adult guinea pigs. The above results indicate that the microwave auditory effect is mechanical in nature.

4. MICROWAVE CONTROL OF BEHAVIOR: AN AUDITORY PHENOMENON: R.B. Johnson, R.H. Lovely and A.W. Guy, Univ. of Washington School of Medicine, Seattle, WA and Robert Galambos, Univ. of California, San Diego, CA

Rats learned to make a food reinforced "nose-poke" response while held in a plexiglass restrainer and subsequently were irradiated during alternating 5-min. periods with 918 MHz pulsed microwaves. Three animals were trained to respond only during irradiation and three trained to respond during non-irradiation. Six additional animals were similarly trained with alternating periods of acoustic stimulation. All twelve animals acquired the discrimination at comparable rates, learning to inhibit responding during inappropriate stimulus conditions. These results will be discussed in terms of the motivational properties of pulsed microwave irradiation and its effect on inhibitory processes. During continued training, the performance of some animals from these experiments gradually deteriorated. Auditory-evoked potentials could not be recorded from these animals at the stimulus intensities employed. Examination revealed profound middle ear infections rendering these animals effectively deaf. However, these animals demonstrated continued ability to perform when extremely intense acoustic stimulation or visual stimulation was provided. Six animals were adapted to perform the discrimination using acoustic stimulation as well as 918 MHz and 2450 MHz pulsed microwaves on a variable interval schedule of stimulus presentation. Comparisons were obtained for each animal between behavioral and auditory-potential thresholds for each form of stimulation. These comparisons support the conclusion that performance on the discrimination task requires adequate auditory stimulation, whether from acoustic or microwave origins. Finally, cochlear microphonic recordings from pulsed microwave irradiated rats, in addition to behavioral and physiological threshold comparisons in a "microwave avoidance" task, will be presented.

5. HOLOGRAPHIC EVALUATION OF HYPOTHESIZED RF HEARING MECHANISMS: A.H. Frey and E. Coren, Randomline, Inc., Huntingdon Valley, PA

It has been shown that pulse modulated EM energy at UHF is perceived by an illuminated person as a sound. The mechanism for the perception is unknown. One hypothesis that has been offered is conversion of the electromagnetic energy to acoustic energy within skin or bone by thermal expansion. The resulting acoustic energy, it is hypothesized, is then conducted via bone to the cochlea. If this hypothesis is valid, then skull motion should be discernable with a sufficiently sensitive technique.

We have used techniques involving holography to determine if the skull shown acoustic waves when exposed to pulse modulated EM energy. The holographic technique is extraordinarily sensitive, being able to resolve motion whose amplitude is less than the wavelength of light. The results of these studies will be presented and the implications discussed.

6. PREDICTED FREQUENCY AND THRESHOLD OF MICROWAVE-INDUCED AUDITORY SENSATION: J.C. Lin, Wayne State Univ., Detroit, MI

When a human subject is exposed to pulsed microwave radiation, an audible sound occurs which appears to originate from within or immediately behind the head. Laboratory studies have also indicated that evoked auditory activities may be recorded from cats, chinchillas and guinea pigs. Using a spherical model of the head, this paper analyzes a process by which microwave energy causes the observed effect. The problem is formulated in terms of thermoelasticity theory in which the absorbed microwave energy represents the volume heat source which depends on both space and time. The inhomogeneous thermoelastic motion equation is solved for the acoustic wave parameters under both stress-free and constrained surface conditions using boundary value technique and Duhamel's theorem. Numerical results show that the predicted frequencies of vibration and threshold pressure amplitude agree reasonably well with experimental findings over a wide range of incident microwave characteristics. The good agreement demonstrates the validity of the thermoelastic stress-production mechanism for microwave-induced hearing in man.

Commissions A and B - Session 1B

Tuesday, October 12 0900 - 1215
PROMPT BEHAVIORAL EFFECTS
Chairman: J.A. D'Andrea, University of Utah

1. PERCEPTION AND RESPONSE TO PULSED MICROWAVE RADIATION BY RATS: D.L. Hjersen and R.D. Phillips, Battelle-Northwest, Richland, WA, and R.H. Lovely, Univ. of Washington, Seattle, WA

A number of investigators have demonstrated that humans and experimental animals perceive pulse modulated microwave energy at low power densities. Frey and Feld found that rats exposed to 1.2 GHz microwaves (0.6 mW/cm^2, 30 μs pulses @ 100/s) spent more time in the shielded half of a two compartment shuttle-box than in the unshielded half. We obtained similar results using 2.88 GHz microwaves (10 mW/cm^2, 2.3 μs pulses @ 100/s). Additional experiments were undertaken to more precisely define the behavioral parameters and implications of these findings.

A series of experiments were conducted using a conditioned avoidance paradigm. Rats did not avoid or escape 2.88 GHz microwaves (10 mW/cm^2, 2.3 μs pulses @ 100/s) when a given 10 s warning cue prior to the onset of exposure. In another experiment, a conditioned taste aversion paradigm was used where a saccharin flavor was paired with pulsed microwave irradiation (same microwave parameters as above). Rats did not form an aversion to the saccharin flavor.

2. PAVLOVIAN CONDITIONING OF MICROWAVE-INDUCED HYPERTHERMIA: R.I. Bermant, Univ. of Kansas, D.R. Justesen, Kansas Univ. School of Medicine and Kansas City Veterans Adm. Hospital.

Rats are being subjected to a trace-conditioning procedure in which an auditory signal (conditional stimulus = CS) precedes by ≥ 30 sec. and then overlaps a shorter period (≤ 5 sec.) of microwave radiation at 2450 MHz in a multi-mode cavity. The radiation serves as the Unconditional Stimulus (US) and is sufficiently intense to produce a two to three degree rise (°C) in colonic temperature. Repeated pairings of CS and US have resulted in small increments (∿ 0.2°C) of colonic temperature but whether these increments are true Conditional Response (CRs) or are an artifact of sensitization or pseudo-conditioning will not be known until completion of control experiments. The data at hand reconfirm earlier observations in our laboratories that microwave radiation can elicit a rise of body temperature of endogenous origin, presumably through activation of sympathetic pathways via sensory stimulation.

3. TEMPERATURE DEPENDENCE OF MICROWAVE AVOIDANCE: J.C. Monahan and H.S. Ho, Bureau of Radiological Health, FDA, USPHS, HEW, Rockville, MD

Previous research has established that exposure to microwave radiation above a critical level is aversive to an organism. Microwaves caused the animal (mouse) to actively avoid the radiation by decreasing the percent absorption of the incident energy. The purpose of this investigation was to quantify the effect of ambient temperature on avoidance behavior induced by 2450 MHz CW radiation. Subjects were CF1 male mice weighing 30-34 g. They were irradiated in an environmentally controlled waveguide assembly at temperatures of 20, 24, 30 or 35°C and

a relative humidity of 50 ± 1.5 percent. Incident power levels ranged from 0.04 W to 4 W resulting in average absorbed dose rates of 0.06 to 55 mW/g. In those groups which exhibited avoidance behavior, the percent absorption decreased after the initial five minutes and remained lower for the duration of the exposure. The threshold incident power level at which avoidance behavior was observed decreased with an increase in the environmental temperature. This data suggests that the subjects were capable of detecting average absorbed dose rates of as little as 0.5 mW/g. Furthermore, this level of irradiation, while producing no core temperature increase was aversive and caused the animal to actively avoid the microwave radiation when the environmental temperature was 35°C.

Commission B - Session 1

Tuesday, October 12 0900 - 1215
TRANSMISSION LINES AND PROPAGATION
Chairman: K.F. Casey, Kansas State University

1. CLASSICAL MAPPINGS FOR MODELING SYMMETRIC TWO-WIRE SHIELDED CABLES: W.S. Ament, Code 5404, Naval Research Laboratory, Washington, DC

The low-frequency behavior of a symmetric two-wire shielded cable is determined by (1) the 'even' capacitance (per unit length) F_e of the two interior wires A, B at common potential v_i relative to the outer conductor C at potential v_o, (2) the 'odd' capacitance F_o of A relative to B, A and B having respective potentials v_a, $v_b = -v_a$, C floating, at potential $v_c = 0$ by the assumed symmetry.

For the 'even' case a parameterized cable cross-section and potential distribution $v(x,y)$ are easily modeled in a $s = x + iy$ plane through adding appropriate poles and zeroes to function $f(z) = 1 - z^2$ in the simplest mapping $u + iv = w(z) = -i\log(f(z))$. Here the equipotential surfaces $v = v_o < 0 < v_i$ represent the surfaces of C and of A,B; the pole- and zero-strengths in $f(z)$ represent the charges on A.B.C. The 'even' case provides one saddle-point $z = s$ of $v(x,y)$, where $dw/dz = 0$ and the potential is say $v = v_s$; s lies in the triply-connected z-plane dielectric-filled region D bounded by A.B.C. Theorem: F_e and $(v_i - v_s)/(v_i - v_o)$ determine F_o regardless of the details of the symmetric configuration. Proof: map D onto an r-plane exterior to three slits $B \sim (-1,-p)$, $C \sim (-q,q)$, and $A \sim (p,1)$; then map the upper-half U of the r-plane onto the interior of a w-plane rectangle with C lying along iv_o and with A,B lying along iv_i; a slit dividing A from B extends down to iv_s. F_e is essentially the width/height ratio of this rectangle, which with V_s is determined by p,q--or conversely. In the odd-case mapping of U onto a rectangle with A at iv_a, B at $-iv_a$, C folded back on itself along $v = 0$, the width-height ratio F_o is also set by p,q and therefore by F_e, V_s.

No published semblance of this classical-appearing theorem has been seen at time of submission. The mappings, and hence the relations among F_e, F_o and V_s, are via elliptic integrals. These integrals bear interesting resemblances with those for potentials of ellipsoids in three dimensions.

2. A GENERAL MULTI-CONDUCTOR TRANSMISSION LINE MODEL: F.M. Yesche, Science Applications, Inc., Berkeley, CA

The analysis of a large, complex system (such as an aircraft) which is excited by lightening or a nuclear electromagnetic pulse (EMP) is often simplified by decomposing the overall problem into a number of sub-problems, each of which can be solved independently. The total solution to the primary problem is then found by combining appropriately the sub-problem solutions.

A critical link in this approach is in determining how electromagnetic energy is distributed within the confines of a large system. This problem, referred to as "Internal Interaction," is usually treated by choosing a number of pertinent transmission lines within the system and solving the appropriate transmission line equations for the energy propagation. Such transmission line models are usually single conductors with simple loads.

A more sophisticated model consists of a general, multiconductor transmission line, with various branches, loops, generalized loads and distributed sources. This paper discusses the current effort to develop such a generalized multiconductor model. The formulation of the problem and numerical results will be presented.

3. ELECTROMAGNETIC FIELD DISTRIBUTION OF THE TEM MODE IN A SYMMETRICAL TWO-PARALLEL-PLATE TRANSMISSION LINE: C.E. Baum, D.V. Giri and R.D. Gonzalez, Air Force Weapons Laboratory, EL, Kirtland AFB, NM

This work is essentially a parametric study of the principal TEM fields of a symmetrical-two-parallel plate transmission line and has its relevance in the design and analysis of this class of EMP simulators. We consider the electromagnetic field distribution of the TEM mode, derive some analytical properties and plot the field magnitudes and components parametrically. This has been accomplished by using a special complex variable procedure which exploits the fact that the scalar potentials and fields (from the conformal transformation and its derivative, respectively) are analytic functions of the complex coordinates. The field distribution is seen to reduce to the results of earlier works which considered a few special paths in the transverse plane. It is believed that a clear understanding of the TEM field is very useful in interpreting and comparing with the higher order mode fields.

The two-dimensional complex field approach applies to various cross sectional shapes of cylindrical TEM transmission line structures. The present example illustrates how it is used to give formulas for the complex field. Similar formulas are possible for other transmission lines which have conformal transformations for the complex potential in terms of special functions.

4. HIGHER-ORDER MODES OF A RECTANGULAR-COAXIAL-STRIP TRANSMISSION LINE: J.C. Tippet and D.C. Chang, Univ. of Colorado, Boulder, CO

Knowledge of the higher-order modes in a structure consisting of a parallel strip line located inside a rectangular waveguide is useful in the design of the NBS TEM cell, a device which was developed for emissions and susceptibility testing of electronic circuits. In this paper, we find analytical expressions for both the spatial distribution and the cut-off frequencies of higher-order TE and TM modes. In particular, for the TE modes we derive an integral equation for the field in the gap regions between the center strip and outer conducting walls. For the TM modes, we derive an integro-differential equation. Applying the quasi-static approximation to the kernels of these two equations, we find analytical solutions using the singular integral equation method. The cut-off frequency of the first highest order mode has been measured experimentally for several TEM cells having different dimensions; the measured values differ only a few percent from the theoretical predictions.

5. ELECTROMAGNETIC SURFACE WAVE PROPAGATION OVER A BONDED WIRE MESH: D.A. Hill and J.R. Wait, Institute for Telecommunication Sciences, Boulder, CO

The electromagnetic surface wave that can propagate over a square mesh of intersecting parallel wires is considered. A doubly infinite set of homogeneous linear equations is derived for the currents on the wires. A mode equation for the propagation constant is derived by truncating the set of equations and setting the determinant equal to zero. The convergence of this process is improved by applying junction conditions on the current and charge.

For small mesh spacings, the numerical results agree with an approximate analytical solution obtained by the method of average boundary conditions. For this same case, the propagation constant is found to be independent of the azimuthal direction of propagation, and the mesh can be described by an effective transfer inductance. It is also shown that the mesh has properties similar to a thin plasma sheet.

6. GUIDED WAVES ON NONUNIFORM ACTIVE SURFACES: R.J. King, University of Wisconson Madison, WI, and S.H. Cho, Univ. of Colorado, Boulder, CO

EM wave propagation over and radiation from nonuniform active surface impedance planes are studied by numerical methods. The integral equation formulation for the magnetic field of a magnetic line source is obtained using the compensation theorem. The surface impedance is assumed to lie in the left half of the complex plane and to vary arbitrarily in the direction of propagation. This permits three types of waves depending upon the argument of the surface impedance, ϕ:

(a) $\pi/2<\phi<3\pi/4$; slow (nonradiating) and growing waves
(b) $3\pi/4<\phi<\pi$; fast (radiating) and growing waves
(c) $\pi<\phi<5\pi/4$; fast (radiating) and decaying waves.

Guidelines are developed for prescribing realistic surface impedance profiles to achieve specified radiation characteristics or alternatively, field distributions above and on the surface. Numerical examples are given for a variety of profiles having finite lengths. It is shown how wave amplification can effectively be used to control the beam direction, shape and side lobe level.

Actual synthesis of such active surfaces is an open question. Suggestions are given for their practical realization and potential applications.

7. WAVE PACKET PROPAGATION ANALYSIS WITH COMPLEX SPACE-TIME RAYS: K.A. Connor, Rensselaer Polytechnic Institute, Troy, NY

The properties of an electromagnetic pulsed beam propagating in a lossy, dispersive environment are considered. A theory developed for homogeneous, stationary, and isotropic media [Connor and Felsen, Proc. IEEE, 62, 1586 (1974)] utilizing direct complex space-time ray techniques and corresponding spectral integral formulations, solved by the saddle point method, is applied to a variety of loss and/or dispersion dominated regimes. Effects due to medium properties or the inhomogeneous character of the waves have been characterized by various authors in terms of a great variety of propagation velocities that differ somewhat from those that

are obtained from complex space-time ray analysis [e.g. Anderson, Askne, and Lisak, Proc. IEEE, 63, 715 (1975); Birger and Vainshtein, Sov. Phys. Tech. Phys., 18, 1405 (1974)]. Comparisons show advantages to the latter concept in terms of physical insight and generality of solution. In particular, effects due to strong dispersion or loss can be identified in the first term in the asymptotic solution and error bounds clearly established from the second term. Graphical techniques, utilizing plane wave dispersion surfaces to infer the variation of w and k along certain trajectories, are applied in nonstationary and inhomogeneous media as an example of the effectiveness of this approach.

8. PLANE WAVES IN HOMOGENEOUS TIME-VARYING MEDIA: SPACE HARMONICS ANALYSIS: J.M. Harris, COMSAT Laboratories, Clarksburg, MD

The method of space harmonics analysis is applied to electromagnetic wave propagation in homogeneous time-varying dispersive and nondispersive media. The results of the furmulation are time-only dependent Helmholtz equations whose solutions are synthesized using field continuity conditions. To illustrate the usefulness of the method, plane waves in suddenly changed media are studied and results compared with those previously obtained using other techniques (Laplace transform, Invariant imbedding, etc.). The method is then applied, using coupled waves theory, to obtain plane wave solutions in an electron density-modulated or pumped plasma. Analytical results for the time-periodic-plasma give conditions necessary for sustained exponentially growing waves and natural mode wave oscillations along with explicit gain expressions for the parametric interactions. Emphasis throughout the paper is placed upon a complete description of the scalar fields in terms of wave split, amplitude, frequency conversion, power flow and energy density relations.

9. ANTENNA SPATIAL FILTERING OF WAVES SCATTERED BY TURBULENCE: R.E. Collins, Case Western Reserve Univ., Cleveland, OH

The classical theory of antenna spatial filtering is based on the use of the far zone radiation pattern of the antenna. This theory does not give the correct results for the spatial filtering properties of an antenna for turbulence scattering which occurs in the near zone region, a region which can extend outwards from the antenna a considerable distance in the case of large aperture antennas. In this paper a new theory is developed that correctly accounts for the spatial filtering properties of the antenna in both the far and near zones. The new approach is based on reciprocity and describes the antenna received power in terms of the interaction of the antenna radiated field with the random currents induced in the turbulent media by the incident radiation. The new approach generalizes the results given earlier by Wheelon (Proc. IEEE, March 1972).

A further useful aspect of the new approach is that it gives the received power to a given order of accuracy from a knowledge of the induced random currents in the turbulent media to an order of accuracy one less than needed in the classical approach. For example, the Born results are obtained without the necessity of first finding the field scattered by the dielectric fluctuations when a wave is incident on the turbulent medium.

Commission F - Session 1

Tuesday, October 12 0900 - 1215
REMOTE SENSING
Chairman: A.W. Straiton, The University of Texas at Austin

1. PASSIVE REMOTE SENSING OF CLOUD AND RAINFALL: L. Tsang, J.A. Kong and D.H. Staelin, M.I.T., Cambridge, MA, and E. Njoku and J.W. Waters, California Institute of Technology, Pasadena, CA

Microwave radiometry has been used for passive remote sensing of the earth and the atmosphere. The effects of atmospheric liquid water on radiometric measurements are interesting for at least two reasons. Firstly, properties of cloud and rainfall layers such as their water content and drop size distribution may be inferred. This information is useful for meteorological purposes. Secondly, absorption, emission, and scattering of intervening cloud and rainfall layers may have a significant effect on radiometric measurements of the earth surface from aircraft and satellites.

In this report, we study the scattering effects on microwave thermal emission from a layer of cloud or rain consisting of spherical particles. Both numerical and analytical approaches are used. It is found that scattering induces brightening for optically thin layers and vice versa for optically thick layers. As a function of observation angle brightening occurs near nadir while darkening occurs at large angles in the case of small optical thickness. For large optical thickness, darkening occurs at all angles because of backscattering effects. For all optical thickness, the brightness temperature is higher with vertical polarizations than with horizontal polarizations. Results obtained from analytical formulas under single scattering assumptions are also compared and illustrated.

2. PASSIVE REMOTE SENSING IN THE PRESENCE OF RAINFALL AT FREQUENCIES BETWEEN 100 and 200 GHz: G. Schaerer, NASA Goddard Space Flight Center, Greenbelt, MD

The radiative properties of various different rainfall models with Marshal-Palmer dropsize distribution have been investigated theoretically. The radiative transfer equation has been solved in an iterative way, taking into account all orders of Mie-scattering and assuming a horizontally stratified atmosphere. The atmospheric absorption properties in the frequency range considered here are mainly determined by the strong oxygen line complex around 60 GHz, the single oxygen line at 119 GHz and the water vapor line at 183 GHz. Passive sensing from space is distributed by precipitation only within the windows between these lines. Because of the strong backscattering of raindrips, the brightness temperature over water decreases above a certain rain rate and reaches saturation at rain rates exceeding 20 mm/hr. A darkening of more than 15 K may occur in the frequency ranges 99-114 and 123-158 GHz for cold rain, with a rain layer thickness reaching to the freezing level. The maximum darkening over water is reached between 130 and 140 GHz, depending somewhat on the surface model used and is less than 30 K. This darkening effect is reduced however for rain not extending to the freezing level and may even be reversed.

3. REMOTE SENSING OF THE EARTH'S ATMOSPHERE BY THE USE OF THE RADIATION FROM OXYGEN AND OZONE: A. Afrashteh and A.W. Straiton, The University of Texas at Austin, TX

This paper presents calculated antenna temperatures which would be observed on a satellite scanning the earth at frequencies near oxygen and ozone absorption lines.

For the oxygen calculations, the standard atmosphere was used to provide a model for the distribution, temperature and pressure of oxygen as a function of elevation. The radiation and absorption were calculated for each height above the earth's surface for frequencies including the millimeter wavelength resonance lines. The radiation from each parcel of air as attenuated by the intervening atmosphere was integrated along lines from a satellite toward the earth. Various angles from the nadir were considered as well as various elevations of the satellite. The effect of antenna beamwidth was also examined. The opaqueness of the atmosphere removed the necessity of considering the radiation from the earth's surface.

Similar calculations were made for frequencies around the ozone absorption line at 110.836 GHz. The model used for ozone was a composite of various reported measurements. Radiation from the earth's surface and from the residuals of the water vapor absorption lines were taken into consideration.

Variations of the antenna temperature with changes in ozone concentration and with the height of the maximum attenuation were determined.

4. THE CORRELATION OF ACTIVE AND PASSIVE MICROWAVE OUTPUTS FOR THE SKYLAB S-193 SENSOR: K. Krishen, Lockheed Electronics Co., Inc., Houston, TX

This paper presents the results of the correlation analysis of the Skylab S-193 13.9 GHz Radiometer/Scatterometer data. Computer analysis of the S-193 data shows more than 50 percent of the radiometer and scatterometer data are uncorrelated. The correlation coefficients computed for the data gathered over various ground scenes indicates the desirability of using both active and passive sensors for the determination of various Earth phenomana.

5. MODELING A VEGETATION CANOPY AT MICROWAVE FREQUENCIES AS A WATER CLOUD: E.P.W. Attema and F.T. Ulaby, Univ. of Kansas Center for Research, Inc., Lawrence, KA

Because the microwave dielectric constant of dry vegetative matter is much smaller (by an order of magnitude or more) than the dielectric constant of water, and because a vegetation canopy is usually composed of more than 99% air by volume, it is proposed that the canopy can be modeled as a water cloud whose droplets are held in place by the vegetative matter. Such a model was developed assuming that the canopy "cloud" contains identical water droplets randomly distributed within the canopy. By integrating the scattering and attenuation cross section contributions of N droplets per unit volume, the scattering coefficient can be related to the water content per unit volume W (g/cm^3) of the canopy. The validity of the model was borne out by the strong dependence observed by measured scattering coefficient data of corn on W. The scattering data were acquired over a four month period at several angles of incidence (0°-70°) and frequencies (8-18 GHz)

for HH and VV polarizations. At angles higher than 40°, the correlation coefficient between the scattering coefficient σ°(dB) and W (dB) is higher than 0.8 at all frequencies in the 8-18 GHz region. The maximum value of the correlation coefficient (0.962) was observed at 17 GHz, 50° angle of incidence, VV polarization.

6. CROP CLASSIFICATION USING MULTIDIMENSIONAL RADAR MEASUREMENTS: F.T. Ulaby and T.F. Bush, Univ. of Kansas Center for Research, Inc., Lawrence, KS

Critical to the successful implementation of a cropland management scheme is the primary task of accurately identifying and estimating the acreages of crop types under cultivation within a given region of interest. Because radar is independent of solar illumination and nearly weather independent it has become a very viable candidate as a sensor for aiding in the task of cropland management. Making use of multi-date data collected by an 8-18 GHz, multipolarized radar spectrometer, systematic studies of radar's capabilities as a tool for remotely classifying crop types have been made. To date, these studies indicate that of the data's spectral, polarization and temporal dimensions, the temporal dimension is of the greatest importance. For example, operating at 14.2 GHz, VV polarization, the percent of correct classification of five different crops was observed to improve from about 60% with single date data to over 95% when four sets of data spread over a one-month growing period were combined. Moreover, by adding HH polarization data, 95% correct classification can be achieved by only three sets of data. This paper will present detailed results pertaining to the information content in the spectral, temporal and polarization dimensions of the scattering coefficient of crops.

7. COMPARISON OF L-BAND AND C-BAND RADAR PERFORMANCE FOR SOIL MOISTURE DETERMINATION: P.P. Batlivala, F.T. Ulaby and C. Dobson, Univ. of Kansas Center for Research, Inc., Lawrence, KS

One of the design questions for the Shuttle Imaging Radar pertains to the choice of the optimum radar frequency for remotely monitoring soil moisture content. Specifically, two frequency bands are under consideration: L-band and C-band. To determine the accuracy of soil moisture estimation with radar, a truck mounted mobile 1-8 GHz radar spectrometer mounted atop a 20 meter boom was used to collect data from a wide variety of bare and vegetated soils. Corresponding ground truth, which included soil moisture data at various depths, surface roughness profiles and vegetation data, were collected concurrently with the acquisition of the active data. Surface roughness, vegetation type, stage of growth, among others, are confusing parameters which introduce errors in the estimation of soil moisture. Apart from the obvious sources of errors listed above, slope of the target, variation of the response of vegetated souls as a function of time of day and row orientation of crops have also been observed to influence the radar return. The data have however shown that these errors can be minimized with the correct choice of sensor parameters. This paper will discuss the effects of these target parameters at L- and C-bands and evaluate the corresponding errors.

8. THE MEASUREMENT OF OIL SPILL VOLUME BY A PASSIVE MICROWAVE IMAGER: B.E. Troy, Jr. and J.P. Hollinger, Naval Research Laboratory, Washington, DC

For several years, the Naval Research Laboratory and the U.S. Coast Guard have conducted a joint program toward development of an airborne, passive microwave system for quick-response measurement of the volume of marine oil spills. The most recent experimental test in this program occurred in September 1975 during a controlled oil spill off the Virginia coast. Observations for the determination of oil slick thickness and volume were taken by a dual-frequency (22/31 GHz) microwave imager mounted on a NASA C-54 aircraft. The microwave images of the oil spill confirm earlier results that most of the oil is concentrated in a small region of approximately one millimeter thickness, surrounded by the larger remaining portion of the visible slick with negligible thickness. The use of the imager represents a significant improvement in data-taking technique compared to earlier tests, and will allow real-time oil volume measurement with an on-board computer.

Commission G - Session 1

Tuesday, October 12 0900 - 1215
M.F. AND H.F. PROPAGATION
Chairman: John Kelso

1. IONOSPHERIC RAY TRACING--BACKSCATTER IONOGRAM SYNTHESIS: B. Langworthy and T. Barrett, Parke Mathematical Laboratories, Inc., Carlisle, MA

Ionogram synthesis is presented as a system of computer programs including the Jones' ray-tracing program. A description is given of program packages, and their functions, for generating electron-density distributions from simple prescriptions in geographic or accurate geomagnetic coordinates, for extracting sequentially computed results to produce amplitude-modulated or leading-edge ionograms, and for computing signal power loss including ray spreading, backscatter cross section, ionospheric absorption and antenna gains.

The computer packages include provisions for accommodation of fine structures in the computed ionograms.

2. IONOSPHERIC RAY TRACING--COMPUTED BACKSCATTER IONOGRAM CHARACTERISTICS: M.S. Wong, Electromagnetic Sciences Div. (RADC/ETE), Hanscom AFB, MA

Jones' ray-tracing program and integrated subroutines by Langworthy and Barrett are being used to compute swept-frequency ionograms, for backscatter by ground and field-aligned ionization, in the presence of sharp horizontal boundaries in electron-density distributions. Prominent characteristics, minimum group-path traces, ray-density variations, and absorption of off-great-circle deviation along ray paths are presented for various alterations on major features of initial electron distributions.

An arbitrary distribution is encoded, and successively varied, with a piecewise representation that is easy for the user and free from unintended, fluctuating deviations at spatial points away from the set of given data points. This is imperative for inference, starting with an observed backscatter ionogram, of electron-distribution features by means of iterative ionogram computations.

3. COMPUTATIONAL STUDY OF LONG-RANGE HIGH-FREQUENCY IONOSPHERIC DUCTING: K. Toman, Hanscom AFB, MA, and D.C. Miller, Arcon Corp., Wakefield, MA

The propagation of high-frequency (HF) signals over long distances by way of ionospheric channels is studied by computing ray trajectories in numerically specified ionospheres without magnetic field. Horizontal ionization gradients are introduced to provide favorable conditions for the injection of rays from the ground into elevated ionospheric ducts. Electron density height distributions with and without ionization valleys are considered. The ducting efficiency, expressed in terms of the product of frequency- and launch elevation-angle interval for trapped rays, is controlled by negative horizontal ionization gradients for successful injection of rays and by the shape of the electron density height profile and its change with distance. Long-range ionospheric ducting of HF rays does not require but is facilitated by the continued presence of an ionization valley in the plane of the ray trajectory.

4. ADAPTIVE IONOSPHERIC MODELING TECHNIQUES FOR LONG RANGE TARGET LOCATION: T.I.S. Boak, III, A.H. Katz, and D.B. Odom, Raytheon Co., Sudbury, MA

The results of a Remote Beacon Location Study are described. This study is the most recent in the series of experiments designed to define, evaluate and improve the Raytheon-developed radar analysis technique which addresses the interpretation of high frequency long range ($\sim$ 3000 km) radar data in terms of very accurate estimates of target location. This experiment represents a significant step in that order of magnitude over past studies. The increased range resolution (nominally 1.5 km) allowed (in addition to demonstrating the ionospheric modeling procedures) a precise determination of the slant range to a target of known position, thus providing an estimate of the limits of the ionospheric modeling capability to achieve accurate ground range estimates.

The experiment was conducted during August 1975 using RADC's Ava/Dexter FM/CW radar and an SRI beacon located at Los Lunas, New Mexico to simultaneously collect both beacon and ionospheric sounding data.

5. REAL TIME ELECTRON DENSITY PROFILES: A.K. Paul, NOAA Environmental Research Laboratories, Boulder, CO

Modern digital ionosondes offer the opportunity for real time data processing. A simplified N(h) method was developed in which the numerical integration for the calculation of the matrix coefficients was replaced by a modified version of the mean value theorem. The resulting program is very simple and should easily fit on a minicomputer of a digital ionosonde. Tests on a large computer have shown that there is no significant loss on accuracy and the method may well be used as a general method at observatories where only small computers are available.

6. MULTI-PARAMETER IONOGRAMS: K. Bibl and B.W. Reinisch, University of Lowell, MA

Many features in standard ionograms have been described merely phenomenologically while the physical processes behind these features are poorly understood. Two such phenomena are the range and frequency spreads seen on many equatorial and high altitude ionograms. The reason for the lack of good physical models is the limited information content of the conventional ionograms, that only represent virtual echo height as function of frequency.

A new digital ionosonde (Digisonde 128PS) is described that measures within the ionogram for each of up to 384 height (range) bins the following signal parameters: amplitude, Doppler shift, angle of arrival and wave polarization, i.e. ordinary or extraordinary mode. By fast digital preprocessing the data output is arranged as 128 nine-bit bites for each transmitting frequency. Either 6 or 5 bits are used as amplitude information while the remaining 3 or 4 bits specify the signal parameters and the range window. Thirty different programs allow automatic or manual selection of parameter resolution.

For very precise incidence angle and Doppler measurements at selected frequencies and heights (ranges) the ionosonde operates in the so-called drift mode.

7. F-LAYER CONTRIBUTION TO THE MF NIGHT-TIME SKY WAVE PROPAGATION IN THE SHORT DISTANCE: J.W. Ra and K.Y. Hwang, Korea Advanced Institute of Science, Seoul, Korea

In the range of short distance near and within the skip zone, contributions from the propagation fields through the ionospheric F-layer may not be neglected but it becomes dominant contribution. This may be utilized in the calculation of the interference effect due to closely loated broadcasting stations. Sky wave contribution in the band of medium frequency and its propagation curves have mostly been studied experimentally. Theoretical work on this contribution appeared to be concerned mainly with the long distance prediction (more than 1,200 Km), for which ionospheric E-layer contribution appears to be sufficient for the prediction of the propagating fields in the night-time hours. The role of the F-layer contribution to the night-time medium frequency sky wave field is calculated numerically by modifying Jones' ray tracing program, where various necessary physical assumptions are made on the transmitting and receiving circumstances. The numerical calculations of the field strength are compared with the experimental data (annual averages of the medium values) measured in Japan for 8 broadcasting stations. Results accounting for F-layer contribution closely predict the measured values within the measurement error range (standard deviation), which is about 6 dB.

8. MEDIUM FREQUENCY SKYWAVE PROPAGATION IN NORTH AMERICA: J.C.H.Wang, Federal Communications Commission, Washington, DC

Analyses of extensive FCC field strength measurements have been presented at USNC/URSI previously. Various skywave field strength prediction methods were discussed and compared. This paper presents results of further observations of FCC data. Findings derived from the study of two previously unanalyzed low-latitude paths will also be presented. Influence of ground conductivity on ionospheric propagation will be investigated. Other factors such as frequency, solar activity and antenna gain will also be discussed as well as the field strength prediction method proposed by C.C.I.R. Interim Working Party 6/4. Its usefulness in North America will also be examined.

Commission J - Session 1

Tuesdau, October 12 0900 - 1215
COMMUNICATION WITH EXTRATERRESTRIAL INTELLIGENCE I
Chairman: F. Drake, Cornell University

1. OZMA II - A SEARCH FOR EXTRATERRESTRIAL LIFE: P. Palmer, Univ. of Chicago and B. Zuckerman, Univ. of Maryland

2. A SEARCH FOR RADIO SIGNALS FROM NEARBY GALAXIES: F.D. Drake and C. Sagan, Cornell Univ.

The 1,000-foot radio telescope of the Arecibo Observatory has been used to search for radio signals from the galaxies M33, M31, M49, Leo I and Leo II. Radio frequencies near 1420, 1667, and 2380 MHz were used with a bandwidth of 1 kilohertz and integration times typically of 60 seconds. A 1,008 channel data processor was utilized. No evidence of extraterrestrial radio signals has yet been found.

3. TECHNICAL CONSIDERATIONS IN SEARCH STRATEGIES: C.L. Seeger, Ames Research Center, NASA

4. PARAMETRIC STUDY OF INTERSTELLAR SEARCH SYSTEMS: R.P. Basler, G.L. Johnson and R.R. Vondrak, Stanford Research Institute, Menlo Park, CA

An evaluation has been made of the comparative cost of microwave receiving systems designed to search for signals from extraterrestrial intelligence. Specific design concepts were analyzed in parametric fashion to determine whether the optimum antenna system location is on earth, in space, or on the moon. A number of parameters were evaluated, including the hypothesized number of randomly distributed transmitting civilizations, the number of stars that must be searched to give any desired probability of receiving a signal, the required antenna collecting area, the necessary search time, the maximum search range, and the overall cost. The results of this analysis suggest that (1) search systems based on the moon are not likely to be cost competitive until an intensive level of space activity has been achieved, (2) if the search need be extended only a few hundred light years from the earth a Cyclops-type or Arecibo-type array on earth may be most cost effective, (3) for a search that has to extend out to 500 light years or more there may be a substantial cost and search-time advantage in using a large spherical reflector in space with multiple feeds, (4) protection from man-made radio frequency interference (RFI) will be required whether the antennas are sited in space or on earth, and in space this protection could be provided by an RFI shield, and (5) overall cost can range from a few hundred million dollars to tens of billions of dollars depending on the parameter values assumed.

5. THE RATIONALE FOR THE WATER HOLE: B.M. Oliver

A band of frequencies extending from 1400 to 1700 MHz and embracing the hydrogen and hydroxyl spectral lines has been dubbed the "water hole" and is considered to be a prime band for the search for extraterrestrial intelligence (SETI). This paper gives the physical and psychological basis for this belief.

6. POTENTIAL RADIO ASTRONOMY BENEFITS FROM CYCLOPS AND LESSER SETI SYSTEMS: J. Cuzzi, Ames Research Center, NASA

Commissions A and B - Session 2A

Tuesday, October 1400 - 1715
CNS EFFECTS
Chairman: L.E. Larsen, Walter Reed Army Institute

1. EFFECTS OF LOW POWER DENSITY MICROWAVES ON MACROMOLECULAR CONSTITUENTS OF THE BRAIN OF RATS: G.N. Catravas, J. Takenaga, J.B. Katz and J.R. Abbott, Defense Nuclear Agency, Bethesda, MD

Experiments have been conducted to determine the biochemical changes which occur in discrete regions of the brain of rats exposed to low power density microwave radiation. Groups of rats were exposed to microwaves (CW) of 2450 mHz frequency and 15 mW/cm^2 eight hours per day for three weeks. During exposure, the animals were confined in styrofoam cages, the inner walls of which were coated with quinine to prevent the rats from chewing through the walls of the cages. The microwave-induced changes in the PGE_1-stimulated brain adenyl cyclase and serotonergic systems were investigated in this series of experiments. Preliminary results indicate an increased sensitivity of brain adenyl cyclase to PGE_1. Marginal changes (increase) in the activity of tryptophan hydroxylase and levels of serotonin in the hypothalamic-thalamic region were also observed.

2. MICROWAVE EFFECTS ON THE BLOOD-BRAIN BARRIER OF HAMSTERS: E.N. Albert, L. Grau and J. Kerns, George Washington Univ. Medical Center, Washington, DC

The chemical milieu surrounding neurons is thought to be maintained within narrow limits by physicochemical means between blood vessels, brain tissue, and cerebrospinal fluid. Since microwaves have been reported to alter behavior, neuronal structure, and chemical effluxes, it appears reasonable to explore the effects of microwaves on the morphological aspects of the blood-brain barrier.

In the experimental approach, Chinese hamsters were exposed to C. W. microwave energy at 2450 MHz for 1-2 hours at 10, 50, and 70 mW/cm^2 power densities. The exposed and sham-irradiated animals were anesthetized and injected with various electron dense tracers, fixed by perfusion, and prepared for gross, light, and electron microscopic examination.

As expected, a positive reaction was present in the area postrema, pineal body, pituitary gland, supraoptic crest, and choroid plexus at the gross and light microscopic levels in sham-irradiated animals exposed to 50 and 70 mW/cm^2. However, brains of irradiated animals displayed a positive reaction in the cerebral and cerebellar cortices, medulla, thalamus, and hypothalamus as well as the above mentioned areas. Brains of exposed animals had lesions that varied in location and intensity. Closer observations with the electron microscope showed the tracer material present in the extracellular space of the neuropil. Furthermore, tracers appeared to have crossed capillary walls via the endothelial intercellular clefts and by increased pinocytotic activity.

Preliminary observations on animals exposed to 10 mW/cm^2 appear to be consistent with those animals exposed to 50 and 70 mW/cm^2.

3. AUDIOGENIC SEIZURE SENSITIVITY OF MICE AFTER REPEATED EXPOSURES TO 2.88 GHz PULSED MICROWAVES: R.D. Phillips, D.L. Hjersen and R.L. Sheldon, Battelle-Northwest, Richland, WA

Female mice (SJL/J strain) were exposed two hours daily to 2.88 GHz pulsed microwaves (2.3 μs pulse width, 100 pulses/s) in an anechoic chamber at an average power density of 10 mW/cm^2. Sensitivity to audiogenic-induced seizures was determined at 1 and 2 weeks after daily exposures (5 days/week) by subjecting the animals to white noise (110-114 dB) and measuring the latencies to running fits and full tonic-clonic seizures.

All mice were primed at 21 days of age by subjecting them to 110-114 dB of white noise for 60 s. The mice were then pretested at 28 days of age to score seizure sensitivity for distribution of animals into control and experimental groups on the basis of equivalent means and variencies in seizure latencies.

The latency to a full tonic-clonic seizure was significantly increased ($p < 0.05$) in exposed mice compared to controls after one week of exposure. The animals were retested after an additional week of exposure and treated mice continued to have longer latencies than controls ($p < 0.01$.). Latencies to running fits were not affected by microwave exposure for one or two weeks.

The results of a parallel investigation using CW microwaves, currently in progress, will be given.

4. ELECTROMAGNETIC ENERGY EXPOSURE EFFECTS ON MOTOR COORDINATION OR BALANCE: A.H. Frey and S. Gendelman, Randomline, Inc., Huntingdon Valley, PA

The effect of pulse-modulated electromagnetic energy on motor coordination or balance was evaluated. A horizontal rod was set to rotate at an increasing rate of speed until a predetermined speed was reached. The subjects, sprague-dawley rats, were divided into two troups: sham exposed and EM energy exposed. The EM energy exposure occurred during their time on the rotating rod. In a series of experiments, different EM energy parameters were used. The animals were exposed individually on the rotating rod until such time as they fell off. The time scores of the animals on the rod were recorded for evaluation. The results of this evaluation will be presented.

Commission A and B - Session 2B

Tuesday, October 12 1400 - 1715
IMMUNOLOGIC AND HEMATOPOIETIC EFFECTS
Chairman: C. Romero-Sierra, Queen's University, Canada

1. MICROWAVES (2450 MHz) STIMULATE MATURATION OF B LYMPHOID CELLS IN SPLEENS OF EXPOSED MICE: W. Wiktor-Jedrzejczak, A. Ahmed, P. Czerski, W.M. Leach, and K.W. Sell, Naval Medical Research Inst. and Bureau of Radiological Health, FDA, Bethesda, MD

CBA/J male adult mice were exposed to 2450 MHz microwaves (amplitude modulated 12 Hz) at a forward power 0.6 watts for 30 min. in an environmentally controlled waveguide facility. The absorbed dose rate was computed from measurements of forward, reflected, and transmitted power and was about 14 mW/g body weight of the animal for each exposure. The experiments were carried out with two groups of mice. One group received a single exposure for 30 min., the other group a total of three exposures of 30 min. each at three day intervals. Sham exposed animals served as controls.

A single exposure to microwaves in such conditions produced a significant increase in the frequency of a subpopulation of B lymphoid cells bearing a receptor for complement (CR^+). Triple exposures not only enhanced this effect but also significantly increased the total frequency of Ig+B cells in spleens of exposed mice. The effect was most pronounced seven days after exposure and was independent of cell proliferation since the total number of spleen cells and the incorporation of ^{3}H-TdR (DNA-precursor), ^{3}H-Uridine (RNA-precursor) and ^{3}H-Leucine (protein precursor) by spleen bone marrow, and peripheral blood lymphoid cells of the exposed mice remained unchanged. This effect could not be related to the arrest of further maturation of B cells in CR^+ stage, since seven days after a single exposure the number of cells spontaneously forming IgM antibody also increased as evaluated by the plaque assay. Moreover, the functional immune capacity of these mice was evaluated by the response of their spleen cells in vitro to B cell-specific mitogens: dextran sulphate lipopolysaccharide, poly I.C., and PPD-turberculin. While there was no significant increase in their ability to respond to dextran sulphate (which stimulates neonatal B cells), there was a significant increase in their ability to respond to the other B cell mitogens used.

The proportion of T lymphoid cells (theta-positive) remained unaltered similarly as their functional capacity as evaluated by response of spleen cells in vitro to the T cell specific mitogens-phytohemagglutinin and concanavalin A and to allogeneic stimulator cells in mixed lymphocyte cultures.

2. THE EFFECT OF MICROWAVES (2450 MHz) ON THE RESPONSE OF MICE TO T LYMPHOID CELL DEPENDENT AND T LYMPHOID CELL INDEPENDENT ANTIGENS: PRELIMINARY RESULTS: W. Wiktor-Jedrzejczak, A. Ahmed, P. Czerski, W.M. Leach and K.W. Sell, Naval Medical Research Institute and Bureau of Radiological Health, FDA, Bethesda, MD

Groups of CBA/J male adult mice were injected on day "0" with 0.5 ml of saline, or 0.2 ml of T lymphoid cell dependent antigen (i.e. requiring the cooperation of T cells for the production of antibody) - sheep red blood cells (SRBC) or 100 µg of

synthetic T cell independent antigen (i.e. B cells produce antibody without cooperation with T cells) - DNP-lysine-Ficoll. On days 1, 2 and 3 the experimental groups consisting of four animals each were exposed to 2450 MHz microwaves. Controls consisted of mice which were sham-exposed. Exposures were performed in an environmentally controlled waveguide facility with a forward power of 0.6 watts to the average absorbed dose rate about 12 mW/g body weight for each exposure. On day 4 mice were sacrificed and their spleen cells were assayed for antibody by the modification of the direct plaque assay of Jerne. Cells from SRBC immunized animals were assayed using SRBC as indicator cells, while cells from DNP-lys-Ficoll immunized mice were plaqued against SRBC coated with appropriate antigenic determinant - trinitrobenzene sulfonic acid. Cells from saline injected animals were assayed against both these indicators.

While the number of IgM antibody secreting cells increased in non-immunized (saline) microwave-exposed mice as compared to non-immunized sham animals, the ability to form specific antibody against both T-dependent and T-independent antigen decreased in microwave-exposed animals. The difference was, however, statistically significant only in the case of their response to the T-independent antigen.

These results suggest that while microwaves stimulate non-specific reactivity of B lymphoid cells, they simultaneously decrease the number of antigen reactive cells specific for both thymus dependent and independent antigens. These exposure conditions of microwaves in vivo seem to be weakly immunosuppressive. Further studies on the mechanism of this reaction are currently in progress.

3. LYMPHOCYTE TRANSFORMATION INDUCED BY MICROWAVE RADIATION: A.T. Huang, M.E. Engle and J.A. Elder, Duke University Medical Center

Effects of microwave radiation at power densities below 30 mW/cm^2 have been examined in blood lymphocytes from Chinese hamsters. Animals were irradiated for 15 minutes on five consecutive days at 2450 MHz (CW) with power densities from 5 to 30 mW/cm^2 and at 9000 MHz (pulse) with density 10 mW/cm^2. Absorbed dose measurements were determined by twin-well calorimetry. One hour after irradiation, blood lymphocytes were obtained from orbital hemorrhage. Cells were cultured for one day if unstimulated or for three days if stimulated with phytohemagglutinin (PHA) to induce mitosis. After termination, lymphocytes were processed for morphological and cytogenetic analyses with a brief colchicine treatment to arrest cells in metaphase.

Microwave radiation caused a dose-related (5-30 mW/cm^2) increase in blastic transformation* of unstimulated lymphocytes. However, frequency of cell division from PHA-stimulation decreased in irradiated samples. Both effects were evident at 5 mW/cm^2. Autoradiography of cells labelled with [^{3}H]-thymidine and [^{3}H]-uridine suggests that the increased blastic transformation is associated with an enhancement of RNA synthesis, probably due to changes in chromatin structure. There was no evidence of radiation-related DNA repair. Cytogenic analysis of the irradiated samples showed no significant chromosomal aberration within these power densities.

*Increase in nuclear size by three fold in area.

4. EFFECTS OF PULSED MICROWAVES ON THE HEMATOPOIETIC SYSTEM OF MICE: H.A. Ragan and R.D. Phillips, Battelle-Northwest Laboratories, Richland, WA

Female mice were exposed ~ 8 hours daily for 10 days to 2.88 GHz pulsed microwaves (2.3 μS pulses at 100/S) in an anechoic chamber at an average power density of 5 mW/cm^2. Female littermates were sham-exposed and served as controls. All mice were killed 92 hours after the last exposure.

No statistically significant effects were observed on red cell parameters, total white cell counts, or the leukocyte differential counts. Platelet counts were lower ($P < 0.05$) in exposed mice. This was compatible with the relative paucity of megakaryocytes in bone marrow and spleen. Cellularity of femoral bone marrow was higher ($P < 0.001$) in the exposed group. Cytologic examination revealed a decrease in megakaryocytes, but a slight increase in the M/E ratio of exposed mice. More non-heme iron was present in the marrow from exposed mice, suggesting an interference with iron metabolism. Splenic erythropoietic and leukopoietic activity were greater and megakaryocytopoiesis was less in exposed than control mice.

Microwave exposure did not influence serum protein concentrations or the protein electrophoretic patterns. Serum triglyceride levels were higher ($P < 0.05$) in the microwave exposed group.

Hematologic changes observed in these mice will be compared to a group currently being exposed to CW microwaves.

5. AN ELECTRON MICROSGOPIC AND HEMATOLOGIC INVESTIGATION OF RATS CHRONICALLY EXPOSED TO LOW-INTENSITY 2.45 GHz MICROWAVE RADIATION: W.G. Switzer, Trinity Univ., San Antonio, TX, and D.S. Mitchell, Southwest Research Institute, San Antonio, TX

In an investigation of the biological effects of chronic exposure to low-intensity microwave (MW) radiation, an attempt was made to discover permanent changes in the fine structure of the cerebral cortex which could be associated with MW-induced behavioral changes (increased locomotor activity and disrupted operant discriminative conditioning performance) observed in the same group of subject.

Fifteen mature female Sprague-Dawley rats were exposed to 2.45 GHz continuous-wave MWs at an equivalent plane-wave power density of 5 mW/cm^2 for five hours a day, five days a week, for 22 weeks in a multimode chamber designed and calibrated for this purpose. Six to twelve weeks after cessation of radiation, irradiated and sham-irradiated control animals were perfused with a variation of Karnovsky's fixative and cerebral cortex tissues examined with an Hitachi HS-8 electron microscope. No changes in ultrastructure that could definitely be attributed to the prior action of MWs were observed.

Hematologic analyses revealed a significant increase in erythrocytes in irradiated subjects as compared to sham-irradiated control animals. No other statistically significant differences in hematologic parameters were observed. Daily core temperature sampling indicated that no whole-body heating took place in irradiated subjects.

Commission B - Session 2

Tuesday, October 12 1400 - 1715
NUMERICAL SOLUTION OF SCATTERING PROBLEMS
Chairman: R.J. Lytle, Lawrence Livermore Laboratory

1. AN IMPROVED METHOD FOR FINITE DIFFERENCE SOLUTION OF MAXWELL'S EQUATIONS: Y.P. Liu, Northrup Corp., Hawthorne, CA

Heretofore, the use of finite difference methods to solve Maxwell's equations in differential form has been limited by the requirement for a large spatial domain surrounding the scatterer. The calculations must be carried out to an artificially distant boundary to avoid erroneous reflected contributions to the numerical results. The requirement for a large spatial domain in the calculation limits the class of problems that can be solved within practical constraints of computer time and storage.

This paper presents a technique which successfully eliminates the necessity for the distant boundary. The method is based on an analytical introduction of Huygens' principle into the numerical procedure. It results in a formally correct and practical termination of the wave tracing procedure at a boundary always less than a wavelength distant from the scatterer.

An example is presented which shows an 80% reduction of the number of cells required to specify the problem. This can reduce computation time by an order of magnitude.

2. ELECTROMAGNETIC SCATTERING BY COLUMNAR SHEATH ICE CRYSTALS AND OTHER DIELECTRIC CYLINDERS: H. Weil and T.B.A. Senior, Univ. of Michigan, Ann Arbor, MI

Integral equations are developed and solved numerically for the currents induced by plane electromagnetic waves incident on thin walled cylinders of arbitrary cross-sections and complex refractive index. The method is based on replacement of the cylinder by an electromagnetically equivalent membrane of the same shape and with an appropriate thickness dependent surface impedance. The numerical procedures are economical for cylinders whose perimeters are less than about 15 wavelengths. The currents are used to compute absorption and bistatic scattering cross-sections over a wide range of infra-red wavelengths for hollow cylinders of hexagonal cross-section which simulate columnar sheath ice crystals, as well as for circular cylinders of similar size and refractive index. Accuracy of the method has been checked by comparison of its results for the hollow circular cylinders with those obtained by an expansion of the fields in a Mie-type series. The computed cross-sections are quite sensitive to the polarization of the incident wave, and for the hexagonal cylinders, to its direction as well; i.e. whether incident at 90° or 60° to a face of the hexagon. Also, because of geometric effects, peaks in the absorption spectra do not coincide directly with maxima in the loss tangent spectrum of the dielectric.

3. NEAR-FIELD ENERGY FLOW AND RADIATION: F.J. Deadrick and E.K. Miller, Lawrence Livermore Laboratory, CA

The radiation of electromagnetic energy is a concept of central importance in EM theory. From a mathematical viewpoint it is a phenomenon which is readily explained. In a physical context however, our understanding of radiation is not as firmly established primarily because of our inability to interpret mathematical formulas in physical visualizable terms. It is particularly difficult to do so in the near-field, in the vicinity of the radiating sources. Thus we have little more than an imprecise qualitative image of radiation from, and energy flow around, even a simple electric dipole.

It is our intent in this paper, by presenting some computed near-field results for a dipole (e.g. electric and magnetic field intensities, Poynting's vector), to provide some additional insight concerning the radiation process. The fields are obtained for time-harmonic excitation, but are shown as a function of time to dynamically demonstrate the spatial ebb and flow of the fields in the region around the dipole. By this means the distinction between the near and radiation fields is made clearer and the shedding of energy by the dipole can be observed. Depiction of the dynamic field behavior through the use of an integral hologram is found to be especially instructive, as will be demonstrated.

4. TIME-DOMAIN MODELING OF NON-LINEAR LOADS: J.A. Landt, Los Alamos Scientific Laboratory, NM, and F.J. Deadrick and E.K. Miller, Lawrence Livermore Laboratory, CA

The behavior of an antenna or scatterer when loaded with a non-linear impedance can be greatly modified from that which is observed under linear conditions. In some cases, the non-linearity can cause detrimental effects such as the intermodulation products which arise due to the non-linear mixing of two frequencies. A non-linearity may on the other hand be exploited in a beneficial way, for example to reduce late time ringing on a pulse excited antenna.

A procedure for treating general non-linear loads is described and illustrated by its application to three specific types of non-linearities in this paper. The treatment is developed within the framework of the wire approximation to the electric-field integral equation, and as such is applicable to the large class of objects that can be modeled by wires. Non-linear load types that are considered include those with piecewise linear voltage-current curves (one or more diodes for example) a load having a time varying impedance (which permits modulating the fields scattered from it) and a general non-linear load represented by specified voltage-current functions. Other procedures that have been worked out for handling non-linearly loaded structures are briefly summarized also.

5. DETERMINATION OF CURRENT ON A WIRE WHICH PASSES THROUGH A HOLE IN A PLANAR SCREEN: D.B. Siedel, Univ. of Arizona and C.M. Butler, Univ. of Mississippi

This paper addresses the problem of determining the current on a wire which passes through a small curcular hole in a planar, conducting screen and which is excited by a slice generator. The wire is perpendicular to the screen and its axis passes through the center of the hole. Integro-differential equations, accounting for the coupling between the wire and (annular) aperture/screen, are developed and solved numerically. Data showing the influence of the presence of the screen are presented,

and results pertinent to the practical problem of calculation of current on a wire which passes through a conducting wall, e.g. bulkhead, compartment partition, are discussed.

6. EQUIVALENCE OF WIRE MESHES TO A SOLID SURFACE: D.E. Young, Boeing Aerospace Co.

Thin wire moment computer codes have been used to solve for surface fields or scattered fields of solid structures by subdividing the solid surface into an interconnection of wire segments. Comparisons of calculations with measured radar cross sections have indicated that a wire segment length to radius ratio of 20 gives good results.

The segment length to radius ratio of a wire mesh used to simulate a solid surface is determined analytically in this paper. The approach is to equate the impedance terms of the wire grid moment solution to the corresponding impedance terms of a solid patch electric field moment solution. The impedance terms have a contribution from the current which is primarily inductive and a contribution from the divergence of current or charge which is primarily capacitive. The square wire mesh impedances are equal to the square patch impedances when the mesh segment length to radius ratio is 20.14 for the charge term and 5.8 for the current term. For electrically short segments the charge term dominates over the current term. The wire mesh equivalent (using the 20.14 and 5.8 ratios) is applied to a thick cylinder to illustrate the dipole and loop current modes.

7. EXPERIMENTAL RESULTS ON THE JUNCTION PROBLEM FOR THIN WIRES: B.M. Duff and S. Singarayar, Univ. of Mississippi

Structures composed of thin wires form an important class of problems in electromagnetic scattering and antennas. The solution of these problems by numerical techniques is now common. Most techniques which employ thin wire approximations are, however, not able to treat the actual variation of current and charge within the local region of a junction of wires. In the absence of an exact treatment of the junction, it is necessary to impose junction conditions on the current and charge (or derivative of current). The Kirchoff current law provides the necessary continuity of current at electrically small junctions. The appropriate condition on the charge has been a subject of considerable discussion. The problem in formulation of this condition arises when the wires forming the junction are of unequal radii. An experimental program to provide data for the definition of the charge condition has been conducted. The measurements have concentrated primarily on the stepped-radius monopole as a simple example of an unequal radii junction. Early results from this program have been previously reported by the authors. Questions concerning the response of the probes used had, however, prevented a final determination of the junction condition. New results are now available including a careful study of the probe response. These measurements support the junction condition

$$\psi_1 q_1 = \psi_2 q_2 = \cdots = \psi_n q_n$$

where

q_i = the linear density of charge on the wire of radius a_i

$\psi_i = 2[\ell n(2/\beta a_i) - 0.5772]$

as proposed by Wu and King. In addition to the stepped-radius monopole data is presented for a thin wire cross with unequal radii members.

8. A GTD-MM ANALYSIS OF THE RADIATION FROM SLOTS IN A PERFECTLY-CONDUCTING CYLINDER WITH A SURFACE IMPEDANCE LOADING: P.H. Pathak and J. Huang, Ohio State Univ. ElectroScience Laboratory, Columbus, OH

An integral equation (IE) which can be solved by a combination of geometrical theory of diffraction (GTD) and method of moments (MM) is obtained for the electric surface current density which is induced on a smooth, perfectly-conducting convex cylinder with a surface impedance type loading, when it is illuminated by an electromagnetic plane wave. The source term in the IE represents the current density induced on the same surface in the absence of impedance loading (i.e. on the unperturbed surface) when it is illuminated by the original plane wave; whereas, the kernel of the IE represents the current density on the unperturbed surface dur to a magnetic line source on the surface. The source term and the kernel in the IE are easily calculated via GTD [1]. The unknown current exists only over the impedance section, and it is solved via the MM procedure. Thus, one is able to treat electrically large cylinders far more efficiently than by conventional MM techniques in which the unknown current must be evaluated over the entire surface. Once this unknown current is evaluated, it readily furnishes the radiation pattern of a slot in the surface via reciprocity. Numerical results will be presented to show the effects of variable impedance loading, and shape of the cylinder on the patterns. It is noted that the scattered field is also readily available from a knowledge of the induced current. Furthermore, this approach can be applied to polygonal cylinders via a different GTD solution.

9. A SPECTRAL DOMAIN APPROACH TO HIGH FREQUENCY SCATTERING BY POLYGONAL CYLINDERS: W.L. Ko and R. Mittra, Univ. of Illinois

The problem of high frequency scattering from polygonal cylinders is typically analyzed using asymptotic methods based on the Geometrical Theory of Diffraction (GTD) and its modifications. Recently, a novel approach to this problem has been reported by Burnside et al., who employed the moment method in conjunction with GTD to derive an improved solution to this problem. In this paper we discuss a new approach to this problem, using a technique that is based on a representation of the scattered field in terms of the spectrum of the induced surface current on the scatterer, rather than as ray fields emanating from it. Such a representation lends itself to a combination of asymptotic techniques and the integral equation formulation, leading, in turn, to a procedure for systematic improvement of the asymptotic solution. The combination is conveniently carried out in the spectral domain since the Fourier transform of the surface current is directly related to the scattered field; a good approximation for the latter is usually available from one of the several high frequency asumptotic solutions. A unique feature of the method, which is typically unavailable in high frequency methods, is that it provides a convenient check for the satisfaction of the boundary condition on the surface of the scatterer. The application of the method is illustrated by considering the case of a rectangular cylinder, the results for which can be conveniently compared with those derived by the conventional moment method or the hybrid technique referred to earlier.

Commission C - Session 1

Tuesday, October 12 1400 - 1715
SIGNALING AND PROCESSING
Chairman: R. Price, Sperry Research Center

1. CROSS POLARIZATION COMPENSATION WITH FERRITE ROTATORS: A. Azizi and F.E. Gardiol, Chaire d'Electromagnetisme et d'Hyperfrequences, Lausanne, Switzerland

The performance of frequency reuse systems utilizing both polarizations can be strongly impaired by depolarization caused by atmospheric effects and antenna imperfections. An automatic compensating system was proposed by T.S. Chu, making use of mechanical rotating joints, phaseshifters and attenuators. The actual implementation of such a mechanical assembly would present difficulties due to the presence of moving and rotating parts. Its response would be too slow to allow continuous compensation of atmospheric effects.

Ferrite and semiconductor devices in circular waveguide can replace mechanical components: without any moving part and electronically controlled, they would provide maintenance-free operation with response times of the order of micro-seconds. Three ferrite structures providing polarization rotation are considered. A new latching rotator appears to yield the most promising approach.

A computer program for the simulation of the complete system was written to determine its response and the effects of frequency-dependent phaseshift and attenuation. Deviations of the order of one degree can degrade considerably the cross-polar discrimination down to the 20 dB level. The adjustment of the compensating system is therefore quite critical, its use may well be limited to narrow-band communications systems.

2. MULTIPLE BEAM ANTENNAS FOR SATELLITE COMMUNICATIONS: S. Das, Federal Communications Commission, Washington, DC

Considerable amount of work has been reported on the development of multiple beam antennas and their application to satellite communications. Three broad categories of multiple beam antennas have been studies: (1) lenses, (2) phased arrays and (3) reflectors. Ricardi and Dion have done pioneering work in analyzing and successfully developing zoned lens type spacecraft antennas. Wesley and Tomita have studied, and Lu and co-workers are testing Bootlace lens type spacecraft antennas. Different types of phased array antennas for spacecraft have been developed and studied by Kummer and others. McGahan analyzed and developed a limited scan antenna comprised of a microwave lens and a phased array feed. Formation of multiple beams with (1) two reflectors, (2) spherical reflectors and (3) off-set reflectors have been reported. McNee and co-workers investigated a combination of an off-set reflector with a spherical lens for producing multiple beams. An unattended multiple beam earth terminal has been developed by Ryde, Kreutel and Smith. Murphy has discussed the application of multiple beams for a maritime satellite system. These antennas could be used for fixed- and broadcasting-satellite services.

3. ANALYSIS OF SIGNALS FROM A CROSS-HOLE PROBING SYSTEM: D.L. Lager, R.J. Lytle, J.G. Huebel, Lawrence Livermore Laboratory, CA

The data analysis for LLL's cross-hole EM geophysical probing technique is made possible by assuming the physics are adequately described by ray optics. These assumptions allow the governing equations to be written as a linear system which can be solved by the iterative Algebraic Reconstruction Techniques (ART). The ART algorithm is the most familiar of the techniques.

This paper describes two major improvements to the analysis, one to improve the physics while maintaining a linear system and the other to improve the convergence of the solution of the system. Previous work was based on the assumption that straight line paths linked the transmitters and receivers. Ray tracing has been introduced to determine the curved paths linking the transmitters and receivers. After the ray paths have been traced the system of equations is redefined and the ART algorithm used to obtain the new solution.

The convergence of the solution of the system of equations has been improved by the development of a variation on the ART algorithm which converges to the least squares solution. This frees ART from the difficulty that the solution is dependent on which row of the system is selected as the last.

4. TRANSMISSION OF CHIRP PULSES VIA MULTIPATH HF IONOSPHERIC CHANNELS: A. Malaga and R.E. McIntosh, University of Massachusetts

In a previous paper, the compression of chirp pulses (i.e. pulses whose instantaneous frequency is linearly swept) reflecting from the Ionosphere was considered. In this paper, the transmission of such pulses via multipath HF ionospheric communication channels is treated. The model used for the ionosphere consists of two layers whose ionization profile various parabolically in the vertical direction. The multipath spread of the channel, T_M, imposes a constraint on the duration of hte transmitted pulse. If the energy received at any instant of time is to be due to a single transmitted pulse, then the duration of the transmitted pulse T, must be chosen so that $T >> T_M$ for any time of the day. As the delay characteristics (vs. frequency) of each transmission path of the channel differ from each other, the frequency sweep of the chirp pulse can be matched to only one path. However, it is found that if the center frequency of the chirp pulse is chosen properly, the total received signal consists of two moderately compressed pulses (20 - 30 dB) and one undistorted pulse. Hence, more of the received energy is concentrated in a shorter interval of time than when pulse compression is not used.

5. PERFORMANCE RESULTS OF A DECISION-FEEDBACK EQUALIZER FOR SERIAL DATA TRANSMISSION THROUGH TROPOSPHERIC SCATTER MEDIA: L. Ehrman and P. Monsen, Signatron, Inc., Lexington, MA

A digital data modem which can operate at 1.5, 3.1, 6.3, 9.4, or 12.6 Mbps has been developed under the Megabit Digital Troposcatter Subsystem program. The modem is designed to operate over Defense Communications System troposcatter links. An adaptive decision-feedback equalizer is used in the demodulator to eliminate inter-

symbol interference, combine diversity channels, and augment the existing diversity configuration with multipath or implicit diversity. This paper presents the results of a field test of the MDTS modem at the RADC troposcatter test facility during the winter of 1976. The field test results under the generally weak signal and strong multipath conditions which were present during the winter tests were excellent at all data rates. The modem operated successfully when the multipath was spread more than one symbol interval; field test performance results are consistent with theory and simulator performance tests; and the channel multipath is utilized to realize an implicit diversity advantage. The field tests establish the capability of the MDTS modem to efficiently communicate digital data over DCS troposcatter links at data rates up to 12.6 Mbps.

6. A PREDICTION METHOD FOR "GENERALIZED" TIME AVAILABILITY IN WIDEBAND DIGITAL TROPOSCATTER COMMUNICATION TO INCLUDE VARIATIONS IN MULTIPATH DISPERSION: S. Wenglin

The prediction of communication performance on a troposcatter link generally considers the statistical variation of only the signal strength. The multipath dispersion is treated as a constant or only its average or maximum effect is considered. This in the past has been due to the limiting effect of the coherence bandwidth upon the transmission bandwidth, with lack of perfect coherence across the transmission band introducing a performance penalty. However, there is presently a trend toward using adaptive digital modems for transmission bandwidths which may deliberately exceed the coherence bandwidth of the tropo link in order to improve performance. The statistical variation of multipath dispersion as well as signal level should then be considered in predicting communication performance. A performance prediction method is described for digital tropo communication which combines existing signal strength prediction methods with a simple model of the variation of multipath dispersion (based on the meager data currently available). The performance of the digital modem is conveniently characterized by the required signal strength as a function of multipath spread for a desired maximum average bit error rate. The joint probability density function of signal strength and multipath spread may then be integrated over that region for which the desired maximum bit error rate is obtained. This results in a "generalized" time availability representing the percentage of hours for which both average signal strength and average multipath spread are such that the desired performance is achieved. The method is extended to include calculation of generalized time availability with a fixed but arbitrary service probability.

7. MINIMIZED FOUR-PLANE PROCESSORS: F.P. Carlson, University of Washington, Seattle

Considering a Fourier transform analog processor as a minimized two-plane processor and a convolution/correlation analog processor as a minimized three-plane processor, one can examine minimized four-plane processors as a basic processing element. Using the Rayleigh-Sommerfeld propagation integral equation, the four-plane processor kernel is the first processor kernel in the hierarchy of m-plane processors that is integral in form. The two-plane and three-plane processing kernels are simple, explicit, and non-integral forms, quite amenable to realization and interpretation. A generalized four-plane kernel is not so easily recognizable in its general form. However, several examples can be described and realized. A general example that

is realizable in a four-plane system is the Woodward ambiguity function, used for range and doppler signal analysis. Another example is an oblique to rectangular plane image erecting system. These and other examples will be described and illustrated.

8. SPECTRAL MOMENT ESTIMATION FROM CORRELATED PULSE PAIRS: D.S. Zrnic', National Severe Storms Laboratory, Norman, OK

Estimates statistics of the first two power spectrum moments from the pulse pair covariance are analyzed. The input signal is assumed to be colored Gaussian and the noise, white Gaussian. Perturbation formulas for the standard deviation of both mean frequency and spectrum width are applied to a Gaussian shaped power spectrum, and so is a perturbation formula for the bias in the width estimate. Mean frequency has an almost Gaussian probability density with tails above the normal curve.

First spectrum moment estimation from interlaced pulse pairs is presented. Throughout this study, estimators from independent, spaced and contiguous pulse pairs are compared to provide a continuum of statistics from equispaced tightly-correlated to statistically independent pulse pairs.

Commission F - Session 2

Tuesday, October 12 1400 - 1715
NEW SATELLITE BEACON PROPAGATION EXPERIMENTS ABOVE 10 GHz
Chairman: D.C. Cox, Bell Laboratories

1. TESTING RAIN ATTENUATION METHODS AT 28 GHz USING RADAR DATA AND FADE MEASUREMENTS ASSOCIATED WITH THE COMSTAR BEACON: J. Goldhirsh, Johns Hopkins Univ., Laurel, MD

An experiment is described to evaluate methods for determining the rain attenuation at 28 GHz along an earth-satellite path using radar. An S-band weather radar at Wallops Island, Virginia, directs its beam axis parallel to that of a nearby receiving antenna whose system measures the COMSTAR beacon signal at 28 GHz. Average rain reflectivity levels, $Z[(mm)^6/m^3]$ are determined as a function of time along the radar beam at adjacent range bins whose resolution is 150 m. These reflectivity factor levels are injected into the formulation, $k = aZ^b$ where k[dB/km] is the attenuation coefficient and a and b are empirical constants dependent upon the drop size distribution. The distributions of Marshall-Palmer, Joss et al., as well as those measured at Wallops Island with an electromechanical disdrometer system are considered (APL distribution). Summing the individual attenuation contributions along the path, the total fade depth is calculated and compared with the directly measured level for the same time. The capabilities of determining individual attenuation events as well as long term attenuation statistics are examined.

As part of the method for establishing the rain attenuation using radar, periodically obtained RHI's in the plane of the earth-satellite path are examined and the type of rain is classified as either convective or non-convective. Where a significant melting layer exists (non-convective), its influence on the attenuation is taken into account.

2. PRELIMINARY RESULTS FROM THE CRAWFORD HILL 19 GHz COMSTAR BEACON PROPAGATION EXPERIMENT: D.C. Cox and H.W. Arnold, Bell Laboratories, Holmdel, NJ

The AT&T Company COMSTAR communications satellites carry beacons transmitting at 19.04 and 28.56 GHz. The 19 GHz beacon is switched between two orthogonal linear polarizations at a 1 KHz rate, and has an average EIRP of greater than + 50 dBm per polarization over most of the continental U.S.

A 19 GHz receiving system is in operation at Crawford Hill, New Jersey, for measurement of earth-satellite propagation phenomena. This receiver has a 48-50 dB signal-to-noise ratio in clear air when operating against the COMSTAR I beacon. Polarization switching and four receiver channels allow observation of direct and cross-polarized signal components in two orthogonal polarizations. The receiving system will be described and preliminary measurements of rain-induced attenuation, cross-polarization, and differential attenuation will be presented.

3. COMSTAR 28/19 GHz BEACON PROPAGATION EXPERIMENT AT COMSAT LABS: G. Hyde, COMSAT Labs, Clarksburg, MD

COMSAT Laboratories is collecting propagation data at its Clarksburg, Maryland facility using the 28/19 GHz COMSTAR Beacon transmissions from the COMSTAR I satellite. The beacon signals are received using a precision 5 meter antenna facility and a COMSAT-Labs built beacon receiver. The quantities measured include the level of the five transmitted signals, i.e. the 19.04 GHz vertically and horizontally polarized signals, and the 28.56 GHz carrier and its two side-tones at 28.56 ± 264.4 GHz. Additionally the amplitudes of the two cross-polarized 19.04 GHz components are measured. Finally the phase between the two side-tones and the carrier frequency is measured.

Reception of data began June 25, 1976. This presentation will cover the features of the propagation receive facility outlined above, data received through the ensuing summer of 1976 and a preliminary quick-look analysis of the data.

4. COMSTAR BEACON RECEPTION AT REMOTE, UNATTENDED SITES: G.A. Zimmerman, Bell Telephone Laboratories, Holmdel, NJ

Early efforts directed toward estimation of rain attenuation statistics along earth-space paths have been based on suntracker and radiometer measurements. Use of radiomaters is particularly attractive, in that they are simple, and choice of receiving coordinates is arbitrary. On the other hand, radiometer measurements are limited to essentially a 10 dB dynamic range, hence estimates of outage statistics for greater ranges have been made by extrapolation from lower frequencies, and/or from the statistics obtaining at lower attenuations. Direct measurement of fade characteristics at 18 and 28 GHz over a 30 dB range is desired to confirm these projections. This will be accomplished as a portion of the program of measurement of the COMSTAR Beacons.

Reliable reception of the beacon signals, which vary in absolute level between -120 and -150 dBm, requires the ability to automatically acquire the signal, track it through deep fades, and, in the instance of temporary loss of signal, to acquire essentially without delay. In addition to variations in received amplitude, the signal frequency varies due to the periodic heating and cooling of the satellite brought about by the diurnal shielding of the electronics by the satellite body. The methods used to realize the Beacon receivers, the background for the experiment, and some preliminary results will be discussed. Where feasible this experiment will be related to both earlier and ongoing radiometer experiments.

5. RAIN DEPOLARIZATION AND ATTENUATION MEASUREMENTS AT 11.7 GHz ON THE CTS SPACECRAFT DOWNLINK: P.H. Wiley, W.L. Stutzman, E.A. Manus, R.E. Marshall, C.W. Bostian, S.B. Holt, Jr., and S.R. Kauffman, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA

The authors are investigating rain depolarization and attenuation on an 11.7 GHz downlink path from the CTS spacecraft. The satellite transmits right circular

polarization and a ground receiver continuously monitors the right circular and left circular components of the received signal. These are recorded concurrently with the ground rainfall rate, wind velocity, and temperature.

Data are presented which show the amplitude and relative phase behavior of the co-polarized and cross-polarized signals during several storms. The dependence of attenuation and the cross polarization ratio (CPR) on rain rate is examined and the measured data are compared with theoretical predictions. Extrapolation to linear polarization is considered. The clear-weather behavior of the received signals is described.

6. MEASUREMENTS OF PRECIPITATION ATTENUATION AND DEPOLARIZATION USING THE 12 GHz TRANSMISSIONS FOR CTS: W.L. Nowland, Bell-Northern Research, Ottawa, Canada and J.I. Strickland, Communications Research Centre, Ottawa, Canada

The launch of CTS in January 1976 has provided research institutions in Canada and the U.S. with the unique opportunity of being able to measure, within their respective climatic environments, the precipitation induced attenuation and depolarization of electromagnetic waves along satellite paths at 11.7 GHz. A receiving terminal comprising a 12 foot parabolic reflector, a high efficiency dual linearly polarized feed, a dual channel narrowband phase-locked receiver, and a computer controlled data acquisition system has been established at the Communications Research Centre in Ottawa. Measurements are being made of signal strength and RF phase variation of the horizontal and vertical components of the circularly polarized 11.7 GHz CTS beacon transmission. The receiving terminal will also be used to perform periodically, throughout the 2 year satellite lifetime, identical measurements on linearly polarized CW transmissions in the low power transmit band (11.843-11.928 GHz) from the CTS transponder. In this presentation, a brief description of the receiving terminal together with the results of preliminary measurements of precipitation attenuation and depolarization will be given.

7. A MEASUREMENT OF RAIN ATTENUATION AND DEPOLARIZATION OF THE 12 GHz COMMUNICATIONS TECHNOLOGY SATELLITE (CTS) BEACON SIGNAL - SOME EARLY RESULTS: A.J. Rustako, Jr. Bell Laboratories, Holmdel, NJ

Rain attenuation and depolarization of a 12 GHz C-W satellite beacon signal are being measured at a receiver site in Holmdel, J.N. The beacon signal is provided by the Communications Technology Satellite (CTS) from a geosynchronous orbit at a nominal longitude of 116°W. The receiving antenna is a 20 ft. aperture horn reflector fitted with a dual sense circular polarized feed. Continuous monitoring of the satellite beacon is provided by use of an antenna tracking system controlled by predicted pointing data. The path slant angle for the Holmdel location is about 27° providing roughly a 14 to 20 km path through rain clouds. A two branch receiving system provides a 35 dB measuring range for the direct clockwise polarized signal and a 55 dB measuring range for the reverse sense depolarized signal. The residual reverse sense signal level in clear air is 32 dB below the direct signal level. Data has been recorded since April 1976.

7. ATTENUATION AND CROSS-POLARIZATION FROM THE 12 GHz CTS BEACON: W.J. Vogel and A.W. Straiton, The Univ. of Texas at Austin

To fully utilize satellite spectral capacity it has been proposed to transmit simultaneously over two distinct channels which cover the same frequency band but have orthogonal polarizations. If these are not the characteristic polarizations of the propagation medium leakage of energy from one channel to the other causes cross talk and may restrict the full use of the communication channel during rain storms or periods of atmospheric instability.

Described is an experiment in which the attenuation and cross-polarization isolation of a circularly polarized wave at 11.7 GHz (transmitted from the synchronous CTS satellite) have been monitored continuously from 12 June 1976. The receiver uses a turn-stile junction to achieve better than 40 dB clear air isolation between channels. The cross-polarized channel is slaved to the co-polarized phase locked receiver which has a better than 20 dB fade margin in 100 Hz noise bandwidth.

The objective of the experiment is to obtain continuous data on the attenuation and cross-polarization for circular polarization due to the atmosphere at 11.7 GHz. Besides relating cross-polarization to attenuation the fraction of time that either will exceed a given level will be determined for Austin, TX.

Data obtained up to October, 1976 will be presented.

8. CTS 11.7 GHz PROPAGATION EXPERIMENT - PRELIMINARY RESULTS: D.B. Hodge, R.C. Taylor, and D.M. Theobold, The Ohio State Univ. ElectroScience Lab, Columbus

A four-element coplanar fixed antenna array whose outputs are coherently combined (self-phased) provides automatic spatial and frequency tracking of the CTS 11.7 GHz circularly polarized c.w. beacon. The system demonstrates the feasibility of employing a self-phased array as a relatively economical method of unattended fixed point tracking of a geosynchronous satellite. Amplitude data from each element and from the array sum channel are available for attenuation and amplitude scintillation measurements. Differential phase between element pairs is also determined, providing angle-of-arrival information. All data from the receiving system is recorded digitally and the system is being operated on a 24-hour basis. Preliminary examples of data will be presented.

Commission J - Session 2

Tuesday, October 12 1400 - 1715
COMMUNICATION WITH EXTRATERRESTRIAL INTELLIGENCE II
Chairman: F. Drake, Cornell University

1. AN OBSERVATIONAL PROGRAM TO SEARCH FOR SETI SIGNALS: S. Gulkis and R. Edelson JPL

2. WALSH WAVES FOR COMMUNICATION WITH EXTRATERRESTRIAL INTELLIGENCE: R.S. Dixon Ohio State University

Sinusoidal functions are traditionally used, and are well suited for working with analog (continuous) signals. In contrast, Walsh functions are well suited for working with digital (two-valued) signals. Since extraterrestrial communications may be binary in form, Walsh waves (radiated Walsh funtions) are worth considering in this context. They have the useful property that their Doppler shift can be detected at the receiver, unlike sinusoidal waves. Walsh signals can be used as carriers for all types of modulation. They are simpler to use, since mixing them produces only one sideband, and their digital filters require only addition and subtraction, rather than multiplication.

3. NATURAL LIMITATIONS ON MINIMUM BANDWIDTH IN INTERSTELLAR RADIO PROPAGATION: G. Helou, NAIC

4. A NEW METHOD FOR GALACTIC COMMUNICATION AT VERY HIGH POWER LEVELS: T. Gold, Cornell University, Ithaca, NY

A new method of signalling across galactic spaces is discussed, that provides the possibility of power levels vastly higher than can be obtained by conventional means. It is a method we could employ to transmit signals that could be received without difficulty at distances of kiloparsecs. This implies also that we should search for signals generated elsewhere by such a technique.

Joint APS/URSI Session

Wednesday, October 13 0900 - 1215
INVITED PAPERS
Chairman: R.L. Fante, Rome Air Development Center

1. THE RADIO SEARCH FOR EXTRATERRESTRIAL INTELLIGENT LIFE: F.D. Drake, Cornell Univ., Ithaca, NY

The searches made for extraterrestrial intelligent radio signals at the NRAO, NAIC, Ohio State University, and Algonquin Radio Observatory will be described. Through these and other searches some million combinations of stars in our own galaxy and radio frequencies have been tested for intelligent signals. In some cases signals only 1/1000 of our strongest signals could have been detected. In addition to these searches, some 10^{11} stars in other galaxies have been tested for the presence of much stronger signals. No evidence for any signal has yet been found. However, this is not surprising, since the number of star and radio frequency combinations which must be tested before there is a high probability of success is many orders of magnitude greater than the number of combinations so far tested.

This situation has led to the development of designs for far more powerful systems to search for signals. The most developed of these designs is Project Cyclops, which has been included as a later step in a phased program of research in SETI being proposed within NASA. This program will be described.

2. ELECTROMAGNETIC TRANSIENT UNDERGROUND RADAR (ETUR) FOR GEOPHYSICAL EXPLORATION: L. Peters, Jr., The Ohio State Univ., Columbus, OH

In simplest terms, ETUR is a conventional radar without the carrier. A narrow pulse is transmitted into the ground and a pulse scattered from any asymmetrical target (w.r.t. the antenna axis of symmetry) is observed on an electrically isolated receiving antenna. The pulse width is sufficiently narrow so that the transmitted pulse magnitude has become negligible when the scattered pulse arrives at the antenna terminals. These and other essential features of the ETUR system will be discussed. By careful design, these two mechanisms, the short pulse width and the antenna isolation provide a reasonably clear range window. This allows the reflected pulse to be observed in real time on the oscilloscope display. Experimental results will be presented in terms of this reflected pulse. These include the reflected pulses obtained from infinite metal and plastic pipe, finite length pipes and other fractured rock zones, tunnels and coal mines. A commercial version of ETUR using a trade name Terrascan for the detection of buried pipes should be available at the time this paper is presented.

Computations indicate that the concept can be made to work at substantial depths (on the order of kilometers) by using a) longer antennas and b) wider pulses with lower frequency content and a higher but still practical voltage level. Some of the limitations pertinent to these greater depths will be discussed.

In addition to detection of the targets already discussed, ETUR should prove useful in a variety of applications including underground water and water leaks, location of abandoned mines, detection of natural resources, sink holes, and archeological

surveys, etc. The state-of-the-art of some of these applications will be discussed.

A major problem for remote sensing systems is identifying the cause of the signal being sensed. For ETUR, there is a need for identifying the scatterer. While the spectrum of the reflected pulse does not contain all of the high frequency energy of the transmitted pulse (and thus the received reflected pulse is much wider than the transmitted pulse), it does contain a very broad spectrum. It is expected that some of the free space target identification techniques can be used once the appropriate signatures of buried targets have been generated. Research activities in this direction will be discussed very briefly.

3. OIL EXPLORATION VIA SUBSURFACE ELECTROMAGNETIC TECHNIQUES: M.E. Cram

Each year thousands of boreholes are drilled into the Earth. Electromagnetic, Acoustic, Radiation, and other devices are suspended in these holes to record data pertaining to the physical composition of the subsurface formations. These data will, hopefully, help us to locate oil, gas, coal, minerals, and water. In the search for oil and gas, wells have been drilled to depths of nearly six miles. Temperatures in excess of 500°F and pressures above 20,000 psi, although not experienced every day, are becoming more common. In addition to these subsurface methods, several surface methods are employed in geophysical applications.

This paper concentrates on describing the Electromagnetic techniques that have been found useful in the quest for new energy sources, the location of mineral deposits and even potable water. Techniques for measuring naturally occuring electromagnetic phenomena such as Spontaneous Potential and Telluric currents are described. Measurements using man-generated electromagnetic fields are also discussed. These include descriptions of the Schlumberger and Wenner electrode arrays, laterologs, normals, focussed electrode arrays, induction devices, nuclear magnetic resonance methods, and electromagnetic propagation techniques. Examples of results from several of the techniques are presented. Methods of interpretation of the data, in conjunction with data from the aforementioned acoustic and radiation devices are also described.

4. BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES: A REVIEW OF CURRENT RESEARCH: W.A.G. Voss, Canada

The reasons for, and the differences between non-ionizing radiation "standards" across the world are first discussed, together with the methods used to measure power density. The reported nervous system and behavioral effects of electromagnetic waves, many of which occur at low field strengths, and over a wide range of frequencies, are then summarized. Coordinated work at both the macro and microscopic levels - from animal behavior to the study of intra and extra-cellular ionic movements - is being undertaken. A cohesive theory may now be emerging on effects induced at the bio-electronic level. Methods for studying field interaction with neural tissue, enhanced tissue healing, possibly through leucocyte depression, effects on small organisms as well as behavioral changes from long term exposure, require the specification of precise and repeatable field conditions, over a wide range of frequencies, pulse rates and environmental factors. In this context the

question of actual field strengths and energy deposition (or absorption) vs incident power density presents measurement problems. The paper emphasizes the need for verifying existing work and replacing some vague speculations with reliable data from multi-disciplinary research.

5. REAL TIME COMPENSATION OF OPTICAL WAVEFRONT DISTORTION: J.W. Hardy, Itek Corp., Lexington, MA

The propagation of light at visible wavelengths through the earth's atmosphere is seriously perturbed by refractive index variations in the medium due to turbulent mixing of air of different densities. This effect provides one of the major limitations to ground based astronomy; under average conditions of turbulence the limiting resolution or "seeing" is in the region of 2 arc seconds which is more than an order of magnitude worse than the diffraction limit of a 1-meter telescope aperture at visible wavelengths.

Real time compensation for atmospheric wavefront distortion has recently been achieved using two specially developed components; 1) an a.c. interferometer capable of measuring optical path distortion over a two dimensional receiving aperture of any size at kilohertz rates, using the light from a reference source such as a laser or bright star; 2) a deformable mirror whose optical surface can be selectively deformed at kilohertz rates in order to compensate for the measured wavefront distortion. These two components, together with a parallel analog computer, are arranged in a closed-loop feedback system that corrects the incident wavefront distortion in real time, thereby producing near diffraction-limited performance.

The components used in the experimental system are described, together with some experimental results.

Commissions A and B - Session 3A

Wednesday, October 13 1400 - 1715
DOSIMETRY
Chairman: H.S. Ho, Bureau of Radiological Health, FDA

1. COMPARISON OF THE AVERAGE SPECIFIC ABSORBED POWER IN THE ELLIPSOIDAL CONDUCTOR AND DIELECTRIC MODELS OF HUMANS AND MONKEYS AT RADIO FREQUENCIES: H. Massoudi, C.H. Durney, and C.C. Johnson, Univ. of Utah, Salt Lake City

The perturbation theory has been previously used to find the first-order internal electric field, the power distribution, and the peak and average specific absorbed power in prolate spheroidal and ellipsoidal models of man and experimental animals irradiated by an electromagnetic plane wave when the wavelength is long compared to the dimensions of the body using what we call the "conductor" model of man. In the conductor model, the conductivity is written explicitly in the curl $\underline{H}$ equation as: $\nabla \times \underline{H} = \sigma \underline{E} + j\omega\varepsilon \underline{E}$. In what we call the "dielectric" model, the conductivity is contained implicitly in the complex permittivity, so that the curl $\underline{H}$ equation is $\nabla \times \underline{H} = j\omega\varepsilon \underline{E}$. The two models give different results for first-order fields because the equations are expanded in a power series in $k(k = \omega\sqrt{\mu\varepsilon})$, and in the conductor model σ enters in to the zero order equations, but in the dielectric model it does not. Because of the nature of the zero-order equations, the expressions obtained from the conductor model are not valid as $\sigma \to 0$. We have found that the conductor model is valid only if $\varepsilon_2 >> \varepsilon_1$, ε_1 and ε_2 being the real and imaginary parts of the complex dielectric constant of the models, respectively. Consequently, some caution must be exercised in applying the results of the perturbation theory based on the conductor model. In this paper, the results of the perturbation theory applied to a lossy dielectric ellipsoidal model are described. The average specific absorbed power in dielectric ellipsoidal models of man and rhesus monkey are calculated and compared with those of the conductor models for the six standard polarizations. The average specific absorbed power in the two models is found to be the same if the conduction current in the body is much larger than the displacement current. Although the conductor model is inaccurate for low values of conductivity, the equations are simpler than the ones for the dielectric model, and hence the conductor model is advantageous when it is valid.

In the modeling procedures it has been found necessary to use tissue conductivity values below the range of validity of the conductor model, thus the dielectric model is essential for accurate theoretical modeling.

2. INTERNAL EM FIELD AND ABSORBED POWER DENSITY IN HUMAN TORSOS INDUCED BY 1 TO 500 MHz EM WAVES: B.S. Guru and K.M. Chen, Michigan State Univ., East Lansing

In the study of biological effects induced by EM waves and in medical applications utilizing EM radiation, it is important and desirable to know the internal EM field and power density induced by an EM field inside a human torso.

This paper presents numerical results on the internal EM field and absorbed power density inside a human torso induced by EM waves of frequencies ranging from 1 to 500 MHz and of both vertical and horizontal polarizations. The induced fields inside the torso are dependent on the frequency and the torso geometry. Resonance phenomena at particular frequencies are discussed. Theoretical results are obtained based on the tensor integral equation method and some of the theoretical predictions are compared with existing experimental results.

3. MICROWAVE DOSIMETRY VIA ELECTRIC FIELD MAPPING WITHIN FULL-SIZE AND SCALED PHANTOM MODELS: P. Herchenroeder and A.Y. Cheung, Univ. of Maryland, and M. Swicord and H. Bassen, Bureau of Radiological Health, FDA, Rockville, MD

Electric field strengths and patterns induced by plane wave irradiation within various tissue structures were examined using a calibrated, non-perturbing, isotropic electric field probe. The probe was implanted inside simulated tissue phantoms of various shapes and sizes. To establish the reliability of the probe for implantation measurement, we compared the values of the electric field detected by the probe inside plane wave irradiated phantoms of simple geometry (planar slabs and spheres) with theoretical predictions at 915 MHz and 2450 MHz. Under all conditions, the magnitude and relative pattern of electric field distributions agree closely with existing theoretical predictions. Using the same probe, absolute electric field intensity at various locations were made within half-sized and quarter-sized human phantoms (with properly adjusted electrical properties); developed for simulated total body exposure studies at 915 MHz and 2450 MHz; using 2450 MHz and 10,000 MHz, respectively. Thermographic techniques similar to those of Guy were used in conjunction. One-dimensional and two-dimensional E-field distributions throughout the body were mapped using data generated from continuous single-axis probe-scans and sectional thermographic presentation at various locations. The simultaneous use of the E-field probe, together with thermography, give a complete, detailed, quantitative evaluation of induced internal electromagnetic field under various exposure conditions.

4. BIOLOGICAL PHANTOM MATERIALS FOR SIMULATING MAN AT DIFFERENT FREQUENCIES: O.P. Gandhi and K. Sedigh, Univ. of Utah, Salt Lake City

The paper gives compositions of biological phantom materials for simulating man over the frequency range 13-570 MHz (including the important resonance regions of 33 and 65 MHz). These materials have been developed to fill eight proportionately scaled man-shaped cavities of height 7.6-40.6 cm for dosimetric measurements at 300, 400, 600, 915, 985, and 2450 MHz. Complex permittivity (ε_c) measurements at the irradiation frequencies were made using a modified version of the coaxial line method used previously by Guy. Models reduced by β in all dimensions allow simulation of man at frequencies given by (experimentation frequency)/β, provided materials with ε_c at (lower) simulated frequencies are used. Whole-body "average" values of ε_c at simulated frequencies were first calculated on the basis of 65 percent muscle and tissues of high water content and 35 percent fat, bone, and tissues of low water content from extrapolated values for these tissues from Johnson and Guy's article. Several compositions of salt, polyethylene powder, Superstuff, and water were first measured for ε_c's at the six experimental frequencies. Interpolated compositions were then measured and modified, if necessary, for desired permittivities.

To simulate man at still higher frequencies, compositions are being developed for average electrical properties to the depth of penetration for individual parts of the body. Also, dosimetric measurements will be compared for correct and incorrect phantom materials.

5. EXPERIMENTAL HEATING PATTERNS IN BI-LAYERED BIOLOGICAL TISSUE CIRCULAR APERTURE SOURCES: J.E. Wallace and A.W. Guy, Univ. of Washington, Seattle

Three circularly cylindrical waveguide apertures have been developed for the purpose of heating biological tissues. Each applicator is dielectrically loaded to maintain a small aperture diameter and still permit propagation of the TE_{11} mode at 918 MHz. The applicator diameters are: 8.9 cm (ϵ_r = 6.0), 11.1 cm (ϵ_r = 4.0), and 11.1 cm (ringed dielectric configuration). Also a circularly symmetrical heating distribution in the tissue. Testing of the applicators was performed on a planar bi-layered (fat and muscle) phantom model which simulates human tissue. Each applicator was tuned to minimize applicator VSWR. The heating patterns induced in the tissue were then measured using an established thermographic technique. Very briefly, this technique uses a high power microwave source (500 W) to heat the tissue for a short period of time (10 to 20 sec.). The desired tissue surface is then scanned with an infrared sensitive camera. The significant parameters which were measured are: ratio of peak heating in the fat to peak heating in the muscle; peak specific absorption rate (SAR) in both fat and muscle tissue; uniformity of heating at a given depth into the tissue; and depth of penetration of energy into the muscle tissue. Each applicator was compared to a 13 x 13 cm square bifurcated aperture which is currently used clinically for diathermy purposes. This applicator also operates at 918 MHz.

Commissions A and B - Session 3B

Wednesday, October 13 1400 - 1715
DOSIMETRY
Chairman: J.C. Mitchell, USAF School of Aviation Medicine

1. ELECTROMAGNETIC POWER DEPOSITION IN MAN AND ANIMALS WITH AND WITHOUT GROUND AND REFLECTOR EFFECTS: O.P. Gandhi, E.L. Hunt and J. D'Andrea, Univ. of Utah, Salt Lake City and Walter Reed Army Inst. of Research, Washington, DC

For free space irradiation, whole body absorption densities are given for humans for the three polarizations for frequency region 0.5 to 8.7 times the $\bar{E}||\hat{L}$ resonance frequency f_r (65 x (1.75/height in meters) MHz). For $\bar{E}||\hat{L}$ postresonance region the relative absorption cross section (S parameter) reduces as f_r/f from the peak value of 4.2. The S parameter asymptotically approaches the "optical" value (1-power reflection coefficient) or about 0.5 for $f \geq 8.5\ f_r$. The whole body absorption curves for the three orientations coalesce for $f > 4\ f_r$.

For feet touching ground a resonance frequency of 32.5 x (1.75/height in meters) with a peak S value of 8.4 is observed. Experimental results are given for power deposition in man models and rats in the presence of reflectors of flat and 90°-corner varieties. Whole body absorptions 5-20 times that at resonance values were observed for spacings to the reflecting surfaces accurately predicted from antenna theory.

Projected energy deposition rates for man and animals subjected to incident fields of 10 mW/cm^2 are given with and without ground and reflector effects. Resonance values as high as 3000-6000 watts for adult humans are predicted. The times to convulsion of 100 and 400 gm rats for incident field intensities of 5-20 mW/cm^2 confirm some of the highest projections in the presence of reflecting surfaces.

2. WHOLE BODY DOSIMETRY OF SMALL ANIMALS: THE EFFECT OF WEIGHT AND EXPOSURE GEOMETRY: J.B. Kinn, EPA, Research Triangle Park, NC

Whole body energy absorption of 2450 MHz radiation was measured in rats over a weight range of 9-440 grams and in mice ranging from 30-50 grams. Simultaneous exposures of numbers of animals in various configurations were made in a free field condition in an anechoic chamber. Measurements of whole body absorption were made with twin-cell calorimeters. Preliminary results indicate that the range of energy absorption may vary by a factor of 2-7 within specific weight groups. The implication of this spread on the choice of incident power levels to be used in dose-effect studies will be discussed. Comparison of the measured dose to theoretical values produced by a spherical shell model show considerable variations of the observed from the predicted. Specific relationships of absorbed dose to power density and size will be presented.

3. DRUG-INDUCED ECTOTHERMIA IN SMALL MAMMALS: THE QUEST FOR A BIOLOGICAL DOSIMETER: D.L. Putthoff, D.R. Justesen, D.M. Levinson, L.B. Ward, Univ. of Kansas School of Medicine and Kansas City Veterans Adm. Hospital

In a passive state, the small, hirsute mammal is an elegant conservator of thermal energy. Further, the rapidity with which the circulatory system can disperse and equilibrate thermal energy would render the living animal a useful whole-body calorimeter but for the complicating factors of physiological and behavioral thermoregulation. Moderate thermal loading of the intact mammal by, say, microwave radiation, will bring a host of responses into play by which excess of energy is actively dissipated. If, however, a chemical "lesion" could be introduced that rendered the mammal ectothermic--"cold-blooded"--then one could parlay pre- and post-radiation temperatures of the living animal into estimates of quantities of absorbed energy. Such a preparation would be extremely useful in studies in the free field where an empirical fit between measures of incident and absorbed energy is the objective.

We report here extensive studies of two compounds, sodium salicylate and cortisone acetate, and their effects upon colonic or rectal temperatures of mice, rats, guinea pigs, and rabbits of both sexes and of pigmented and albino strains. While the salicylate produces a marked hypothermal response in mice and rats, it is less effective in guinea pigs and rabbits and is otherwise variable with respect to strain. Cortisone appears to produce a more uniform hypothermal response; studies of mice and rats reveal that increments of colonic temperature from short periods of moderately thermalizing microwave radiation yield estimates of energy dosing that are accurate within $\pm$ 10%.

4. USE OF HEATING AND COOLING CURVES TO MEASURE MICROWAVE ENERGY ABSORPTION IN BIOLOGICAL SAMPLES: J.W. Allis, C.F. Blackman, M.L. Fromme and S.G. Benane, EPA, Research Triangle Park, NC

Analysis of heating and cooling curves can provide an accurate and reliable measure of the rate of microwave energy absorption for many biological systems. We wish to demonstrate a method of analysis which is superior to those already appearing in the literature. The method uses the entire heating or cooling curve to measure rate of energy absorption rather than relying on the estimation of the initial slope. The cooling constant and temperature rise of the sample due to irradiation can be obtained directly from either a heating or a cooling curve. The method does not require the determination of the heating curve constant which contains the absorption cross-section of the sample. The latter constant is not necessary for calculation of the rate of energy absorption. Data will be presented demonstrating the use of the method for far field exposure of samples contained in tissue culture flasks and petri dishes as well as for exposure of a sample at the end of a waveguide transmission line.

Commission A - Session 1

Wednesday, October 13 1400 - 1715
ANTENNA MEASUREMENTS
Chairman: G. Birnbaum

1. SELF-CALIBRATION OF ANTENNAS BY AN EXTRAPOLATION TECHNIQUE: C.F. Stubenrauch, National Bureau of Standards, Boulder, CO

A method for determining gain of a linearly polarized antenna which does not require the use of either a calibrated gain standard or a three antenna measurement is discussed. Based on the extrapolation technique, developed by Wacker at NBS, which permits calculation of far-field gain from measurements obtained at distances less than D^2/λ, the self-calibration method is a practical way of measuring gain using only the antenna and its image. It is shown that the functional form of the reflection coefficient for an antenna illuminating an infinite ground plane is a double infinite series in inverse powers of the height of the antenna above the ground plane. Measurement of the reflection coefficient as a function of height then allows the determination of coefficients of the series by a curve fitting technique. One of these coefficients is directly related to the gain of the antenna. Experimental technique will be discussed and results presented and compared to measurements made using more conventional methods.

2. POLARIZATION MEASUREMENT TECHNIQUES FOR LARGE APERTURE EARTH STATION ANTENNAS: W. English, COMSAT Labs, Clarksburg, MD

The introduction of frequency reuse on orthogonal polarizations to conserve spectrum in commercial communications satellite systems has established the need for precision polarization measurement techniques for large aperture earth station antennas. These satellite systems require low levels of antenna polarization coupling. Polarization isolation performance requirements of 30-40 dB are typical.

A comparative evaluation of several polarization measurement techniques that have been implemented is presented. These techniques utilize either satellite or boresight flux sources. The practicality of using randomly polarized stellar sources for the measurement of large aperture earth station antenna polarization is also considered.

Diagnostic polarization measurement procedures that identify both the type and location of depolarization sources are discussed. Depolarization can result from differential phase delay, differential amplitude attenuation or VSWR effects within the antenna system. Differences that exist between circularly polarized and linearly polarized systems are noted. Several alternative representations of antenna system polarization responses are utilized to simplify measurement data reduction.

The results of recent polarization measurement programs for large aperture earth station antennas are summarized.

3. EMBEDDED BARE AND INSULATED ANTENNAS: R.W.P. King, Harvard Univ., Cambridge, MA

A quantitative study is made of the receiving qualities of antennas embedded a short distance below the surface of a dissipative material in terms of the complex transfer function and the properties of the antenna. Types of antennas investigated include bare and insulated dipoles as single elements and in two-element broadside arrays. The eccentrically insulated dipole is also studies. Actual voltages across practical load impedances are determined when the antennas are embedded specifically at depths of 0.1, 0.5 and 1.0 cm in hide or skin. Comparable results apply also to muscle. It is shown that the frequency for maximum voltage across the load with skin as the material is 700 MHz and that resonant bare dipoles have a practical length. However, the higher directivity of insulated dipoles provide comparable voltages with the same antennas and loads at 3 GHz.

Commission A - Session 2

Wednesday, October 13 1400 - 1715
DIELECTRIC MEASUREMENTS
Chairman: G. Birnbaum

1. L-BAND MEASUREMENTS OF THE DIELECTRIC PROPERTIES OF SALINE SOIL USING A POWER TRANSFER TECHNIQUE: F.T. Ulaby and E.P.W. Attema, Univ. of Kansas Center for Research, Inc., Lawrence, KS

Data are presented on complex permittivity of soil samples as a function of moisture content and salinity. The measurements were made in the 1-2 GHz range using the power transfer technique discussed above.by Carver. Since the free space method appeared to be impractical in this particular frequency range, a TEM-waveguide cell has been used.

The actual microwave measurement requires a sample size of approximately 50 cc and can be made manually in less than one minute using commercially available instrumentation for insertion loss measurements. The paper describes how the complex dielectric constant is calculated using the insertion loss of the cell at one single frequency for low, medium and high loss samples and examines the effects of the various sources of error on measurement accuracy. Based on the measured data, an empirical mixing formula incorporating moisture content and salinity is proposed.

2. DIELECTRIC SHEET POWER SPECTRAL RESPONSE AND SWEPT-FREQUENCY MEASUREMENT APPLICATIONS: K.R. Carver, New Mexico State Univ., Las Cruces

The power density of a plane wave incident obliquely on a large homogeneous lossy dielectric sheet will be reduced upon transmission by initial and higher order polarization-dependent reflection losses as well as by internal conversion to heat. The ratio of transmitted to incident power densities can be expressed in a simple closed form which depends uniquely on the incident angle, polarization, electrical thickness and the complex dielectric constant. In this paper, the spectral transmission response is discussed for a dielectric sheet of fixed thickness and of complex dielectric constant. Several practical measurement applications arise from this analysis. For example, the complex dielectric constant of a dielectric sheet can be obtained from an examination of its normal incidence swept frequency power response; phase information is unnecessary. This leads to a practical, accurate and efficient means for measuring soil dielectric constants, such as are required in microwave remote sensing. The sweep bandwidth required depends in a simple manner on the median frequency electrical thickness and dielectric constant. This swept-frequency technique can be used at frequencies below L-band with closed TEM air transmission lines, although it is necessary that both source and detector be very well matched. At higher frequencies, free-space transmission between collimated horns or reflectors may be used, with the dielectric placed in the transmission path.

3. MEASUREMENT OF THE DIELECTRIC CONSTANT AND CONDUCTIVITY OF BIOLOGICAL MATERIALS BY MICROWAVE CAVITY PERTURBATION METHOD: C.H. Ma and D. Deaton, Univ. of Mississippi

The electrical properties of blood and solid biological materials were determined from the measurements of the resonant frequency and Q of the resonance curve of microwave cavities with and without samples inside the cavities. Unlike the commonly used transmission line and waveguide methods in which the accuracy and repeatibility are critically dependent upon the accurate measurement of the sample dimensions, the smoothness of the sample surfaces, slicing and packing techniques, et., it is found that the accuracy of the cavity perturbation method relies only upon the accuracy of mass measurement of the sample, if the sample is small compared to the cavity and is placed in the region with approximately uniform field. Circularly cylindrical cavities with sample filled glass tube as a central rod were used in the experiments. Initially, measurements to verify the accuracy of the technique were performed, resulting in accurate determination of the dielectric constant and conductivity in dielectric materials of known properties. The electrical properties of bloods and various solid biological materials were determined and the properties of the white blood cells were measured as a function of temperature. The results are summarized in the plots of the electrical properties of the biological materials with temperature and quantities of the samples as parameters and good repeatibility is observed throughout the range of investigation.

4. MICROWAVE INTERROGATION OF DIELECTRIC TARGETS (I) BY SCATTERING PARAMETERS: L.E. Larsen and J.H. Jacobi, Walter Reed Army Institute of Research, Washington, DC

Incident microwave radiation may be used to interrogate the physical structure and RF electrical properties of dielectric objects. It would appear to be possible that such radiation could be used to image biological targets on the basis of these properties which are not available to X-ray, ultrasonic or nucleonic interrogation. Indeed, the properties used to form a microwave image may be uniquely relevent to the structure and function of biological systems.

Single and multiple dielectric discontinuities of various geometries and magnitudes were investigated in a medium of dionized water. Mechanical scanning permitted the investigation of spatial resolution and aperture effects.

The scattering parameters measured were the amplitude and phase of S_{11} and S_{21} for a phase locked 3243 MHz source. These were studied as functions of space for the various dielectric discontinuities presented. Dielectrically loaded, matched antennas were incorporated into a digitally controlled scanner which was interfaced to an automatic network analyzer (HP 8243A). The resulting complex functions of space were further processed to create a real valued function of space for intensity presentation of the data. The real valued spatial series were also inverse filtered by digital methods to compensate for antenna patterns.

Use of this system allowed the detection of single and multiple dielectric discontinuities of dimensions well below one wavelength in water. The results were sensitive to aperture size, wavelength, and antenna separation.

5. MICROWAVE INTERROGATION OF DIELECTRIC TARGETS, (II) BY TIME DELAY SPECTRUM:
J.H. Jacobi and L.E. Larsen, Walter Reed Army Inst. of Research, Washington, DC

Dielectric materials have the property that the velocity of propagation of electromagnetic energy in the material is a function of the dielectric constant of the medium. This property may be exploited to permit mapping of dielectric inhomogeneities in a target according to the time delays present in the signal which passed through the target. A method is described whereby time and transmitted frequency are related with a linear chirp. The received signal is mixed with a reference signal which does not pass through the target. Time delays due to changes in velocity of propagation, path length effects due to diffraction, and calibration effects appear as frequency shifts in the mixer output. A sweep oscillator is chirped from 2.0 to 4.0 GHz, and the mixer output is processed by generalized harmonic analysis.

The method is capable of resolving a change inpath length which is equivalent to 40 picoseconds of propagation time. Time delay spectra were collected as functions of space by mechanical scanning through various dielectric discontinuities in a medium of deionized water. It was possible to detect targets with dimensions less than one wavelength in water for the highest frequency transmitted.

COMMISSION B - Session 3

Wednesday, October 13 1400 - 1715
ELECTROMAGNETISM
Chairman: P.L.E. Uslenghi, University of Illinois

1. TRANSIENT DIFFRACTION BY A SEMI-INFINITE CONE: K.K. Chan and L.B. Felsen, Polytechnic Institute of New York

The time-dependent response due to a point source in the presence of a semi-infinite cone is expressed in terms of a "quasi-optic" integral representation of the time harmonic Green's function, which leads to a new form of the time dependent solution. The result, which contains an integral, can be reduced further if we restrict ourselves to the evaluation of the scattered field by a small-angle cone, with the source located on the cone axis. As will be shown, solutions for all observation times are obtained in remarkably simple closed forms involving only elementary functions provided that the observation point lies in a region that excludes the rays reflected from the cone surface according to the laws of geometrical optics. This region of applicability accommodates important applications, in particular, the on-axis back-scattered fields. To confirm the validity of the closed form results, the early-time and long-time behavior of the transient field are evaluated as special cases and compared, respectively, with solutions obtained independently by different approaches. Both the scalar Dirichlet and Neumann problems, and the vector dipole problems (leading to the dyadic Green's functions), can be treated in this manner.

2. SPHERICAL HYBRID MODES IN A CONICAL DIELECTRIC WAVEGUIDE: M.S. Narasimhan, Indian Institute of Technology, Madras, INDIA

Based on the earlier work (Narasimhan 1973, 1974), an accurate time-harmonic EM field solution in terms of spherical hybrid modes valid inside (region 1; $0 \leq \theta \leq \alpha_0$) and outside (region 2; $\alpha_0 < \theta \leq \pi$) a loss-free dielectric cone of relative permittivity ε_r, half-flare angle α_0 and flare-length kr_0 is presented in this paper. The spherical wave functions (associated with the HE_{mn} mode) employed in the analysis pertaining to regions 1 and 2 are similar with the only difference that in region 2 conical functions of the first kind of order 'm' and index -0.5 +jp are employed instead of associated Legendre functions of the first kind of order 'm' and index 's' used in region 1. Considering a long dielectric cone, which implies a far-field approximation ($kr_0 >> 1$), and applying the appropriate boundary conditions, the aperture field over the dielectric and outside the dielectric cone are obtained with a knowledge of the amplitudes of the vector potentials in regions 1 and 2 and the eigenvalues 's' and 'p' which are determined using an efficient numerical technique used earlier by the present author. Long dielectric cones of different flare angles (α_0 = 5° to 30°) and permittivities (ε_r = 1.05, 2.00) were constructed for the HE_{11} and TM_{01} modes of operation and their radiation patterns were measured at the X-band. Measured patterns showed very good agreement with calculated patterns based on the analysis presented and the aperture integration technique.

3. BACKSCATTER FROM NON-CIRCULAR CONES AND FRUSTUMS: K.M. Mitzner, Northrop Corp., Hawthorne, CA

Physical Theory of Diffraction (PTD) is used to calculate the far-field backscatter of a plane wave from the frustum of a non-circular cone. A principle feature of the approach is the use of a canonical result for physical optics scattering from a narrow finite-length element of cone surface. This leads to a finite and accurate value for the backscatter at incidence normal to the conical surface or to a cone generator whose end-points are scattering centers.

When multiply-scattered and surface-bound waves can be neglected, the scattering can be described as the sum of contributions from the base and top edges. Because the two edges are geometrically similar, the solution can be reduced to evaluation of a line integral around the base edge only. This integral can usually be evaluated by standardized asymptotic techniques, either uniform or non-uniform, or by simple and accurate numerical methods. Under appropriate conditions, the PTD solution reduces to the standard Geometrical Theory of Diffraction (GTD) solution.

The corresponding calculation for a cone involves a line integral, which describes the scattering from the base edge and the physical optics scattering from the tip, plus a contribution from the fringe wave current at the tip. The line integral alone gives an accurate result over a broad range of incidence angles.

4. FUNDAMENTAL SOLUTIONS FOR THE PENETRABLE WEDGE: R.J. Pogorzelski, Univ. of Mississippi

The behavior of electromagnetic fields in the presnece of a dielectric wedge has been recently studied by postulating that the fields can be represented by power series in increasing powers of the distance from the edge having angularly varying coefficients. It is well known that by studying the relationship between the leading terms of the power series and involing an energy boundedness condition, one may determine the character of the field singularity at the edge. In this paper, explicit formulas are derived for all of the coefficients in the power series thus providing an infinite set of power series solutions of the Helmholtz equation in the penetrable wedge geometry. Some aspects of the utility and properties of this set of functions are discussed. Superpositions of these functions which satisfy a radiation boundary condition in the far zone remain to be found before the problem can be considered completely solved.

5. AN EXPRESSION FOR THE UNIFORM EDGE DIFFRACTION COEFFICIENT WHEN THERE IS A CAUSTIC ON THE SHADOW BOUNDARY: P.H. Pathak and R.G. Kouyoumjian, The Ohio State Univ., Columbus

In this paper the uniform edge diffraction coefficient of Kouyoumjian and Pathak is extended to treat the presence of a caustic on the shadow boundary (SB) or reflection boundary (RB). A transition function $F(X)$, which contains a Fresnel integral, appears in the expression for the diffraction coefficient, and its argument X depends upon the wavefront curvature of the incident (or reflected) and diffracted fields. If a caustic appears on the SB or RB, X may be positive or negative. There is no difficulty if $X > 0$; however, if $X < 0$, $F(X)$ has two branches. It is shown that the proper branch is determined by an analytic con-

tinuation of the result in Pathak's paper and that $F(X)$ for $X < 0$ is the complex conjugate of $F(|X|)$. The present analysis is extended to include the uniform slope diffraction coefficient of Kouyoumjian and Hwang. Universal curves of the edge diffraction, and the slope edge diffraction transition functions for $X < 0$ will be presented along with illustrative examples involving the plane wave illumination of two and three dimensional concave surfaces in which the caustic of the reflected rays intersects the RB between the edge and the field point, so that $X < 0$ in the far zone for these examples. The contributions from the edge excited rays on the illuminated and shadowed sides of the concave surfaces are included in the present treatment.

6. THE DIFFRACTION AT AN EDGE FORMED BY TWO UNIFORM IMPEDANCE SURFACES: Y. Hwang, Aeronutronic-Ford, Palo Alto, CA and R.G. Kouyoumjian, The Ohio State Univ.

The diffraction by a wedge with different impedance boundary conditions at its two surfaces is considered. In the case of a right-angle wedge a functional transformation is used to simplify the boundary conditions. The eigenfunction solutions for the transformed functions are obtained and replaced by integral representations, which are then evaluated asymptotically by the modified Pauli-Clemmow method of steepest descent. In the case of diffraction by a two-part plane surface, the Wiener-Hopf technique is applied. The resulting integral representations for the diffracted field, which occur from the inverse transformation, are also evaluated asymptotically by the modified Pauli-Clemmow method of steepest descent. It is seen that the functional transformation method for a right-angle wedge can be extended in an approximate way to obtain a useful solution for the wedge of arbitrary-angle, provided that one of the wedge surfaces satisfies a Dirichlet boundary condition. The solutions are interpreted ray-optically to obtain diffraction coefficients for the geometrical theory of diffraction. These diffraction coefficients are uniform in the sense that they are valid in the transition regions adjacent to shadow and reflection boundaries. Thus, although the geometrical optics field is discontinuous at these boundaries, the total field, which is the sum of the geometrical optics field and diffracted field, is continuous there. The utility of these new diffraction coefficients is demonstrated through their application to a number of examples.

7. FEYNMAN PATH INTEGRAL AND ELECTROMAGNETIC DIFFRACTION PROBLEMS: G.A. Deschamps and S.W. Lee, Univ. of Illinois, Urbana

Path integrals were introduced in 1924 by N. Wiener to represent solutions of the heat equation, and later in a different form by R.P. Feynman (1948) to express the propagator in quantum mechanics. In this latter application an action $S(\gamma)$ is defined for each path joining point y to point x in time t and the propagator is given by

$$K(x,y,t) = \int_{\Gamma} e^{ikS(\gamma)} d\gamma$$

where Γ is the set of all paths γ, sufficiently regular, and satisfying constraints imposed by boundary conditions. The differential $d\gamma$ and the integral itself must be properly defined as γ belong to a space of infinite dimension.

This paper will discuss the application of Feynman formalism to electromagnetic diffraction problems by interpreting $S(\gamma)$ as the optical length of γ. Although path integrals are of interest mostly as a conceptual tool that can be used in formulating quantum mechanics, they can also lead to practical solutions, at least when asymptotic results are desired. This will be illustrated by two examples: (1) the diffraction of a plane wave by a pair of half planes, (2) the evaluation of the field on the shadow boundary cast by n-staggered half planes. In this first example, a result obtained very simply agrees with the asymptotic result deduced from the exact solution.

8. ELECTROMAGNETIC COUPLING TO CABLES THROUGH WINDSHIELD IN AN AIRCRAFT: J.L. Lin and W.L. Curtis, Boeing Aerospace Co., Seattle, WA

The objective of this investigation is to study the electromagnetic field penetration from the exterior to the interior part of an airframe through apertures such as cockpit windshield. Since the cables located near the windshield post are very close to the cockpit windows (or apertures), practically, the fields at the location of the cable are approximately the same as those with apertures lying on an infinite conducting sheet so long as the aperture is small compared to the interior region and the Q of the interior region is not large. Thus, the geometry and the configuration of the problem as described permit us to apply the wire-mesh techniques coupled with Babinet's principle to find the fields in the interior region of the aircraft at the location of the cable. Thevenin equivalent voltage source of the cable is subsequently determined, using the reciprocity theorem.

Since the aircraft is of a finite conducting cylinder which will resonate at low frequency, the excitation of the windshield should be a function of the aircraft skin current and charge at low frequencies in contrast with the physical optics solution for a plane wave incident directly on the apertures at high frequencies. Consequently, the problem is divided into a low frequency and a high frequency model with an appropriate excitation for each individual models. At low frequencies, the quasi-static solution prevails and the penetration fields are obtained in terms of the dipole moments related to the tangential magnetic field intensity and normal electric field intensity that would exist at the center of the aperture if it were completely shorted. The high frequency solution, however, depends on a direct plane wave illumination on the apertures.

As a numerical example, a typical cable routing near the windshield in the cockpit area is chosen. A Thevenin equivalent circuit for the cable with voltage sources identified separately for the magnetic and electric couplings is given for all frequencies and for different aircraft orientations. The corresponding time domain solution is included.

9. TIME-DEPENDENT SGEMP ANALYSIS ON A PERFECTLY CONDUCTING SPHERE FOR TWO TYPES OF SOURCE CURRENTS: R. Stettner, Mission Research Corp., Santa Barbara, CA

The subject of System-Generated Electromagnetic Pulse (SGEMP) is the study of the interaction of electromagnetic fields, generated by spatial source currents, with objects. The objects are usually assumed to be perfectly conducting. The spatial source currents for formed from photoelectrons leaving the object itself.

We investigate the time dependence of skin currents on a perfectly conducting sphere for two types of axially symmetric source currents: (1) a continuous, time-dependent flow of electrons leaving perpendicular to the sphere, over a hemisphere, and moving with constant velocity; (2) electrons forming a time-dependent dipole layer on a hemisphere of the object.

The solution to Maxwell's equations, in space, is expanded in terms of Legendre polynomials and spherical Bessel functions. On the sphere, the time-dependent solution for the skin currents appears naturally in terms of the exterior modes. The interior modes do not appear in this formualtion. The portion of the skin current solution due to the higher frequency and more highly damped modes appears to be well approximated by the quasi-static solution.

Commission E - Session 1

Wednesday, October 13, 1400 - 1715
ATS-6 ELECTROMAGNETIC SURVEY
Chairman: E.A. Wolff, NASA Goddard Space Flight Center

1. ATS-6 ORBITAL MEASUREMENTS OF RFI IN THE 5.925-6.425 MHz BAND, PART ONE - EXPERIMENT DESIGN AND CONFIGURATION: V.F. Henry, NASA Goddard Space Flight Center, Greenbelt, MD

The frequency spectrum of 5.925 to 6.425 GHz is shared by fixed communications satellites and by terrestrial point-to-point microwave links. The C-Band RFI Measurement Experiment was designed to measure and evaluate the mutual interference between these systems. Utilizing the unique high-gain steerable antenna of the ATS-6 satellite, this experiment determines the power flux density at the geostationary orbit in terms of geographical and frequency distribution of terrestrial RFI sources. System performance enables the identification of RFI sources as small as 10 dBw EIRP with a frequency resolution of 10 KHz.

During the first year of measurements, RFI data were acquired for more than 50 U.S. sites including Alaska and Hawaii, and for the majority of proposed earth terminal sites for domestic satellite systems. A comprehensive database of RFI has been compiled for this 500 MHz segment of the C-Band spectrum. Experimental results have demonstrated the feasibility of using a geostationary satellite with a high-gain steerable antenna to survey the Earth for sources of potential RFI, and to define the electromagnetic noise enviornment of the synchronous orbit.

2. ATS-6 MEASUREMENTS OF RFI IN THE 5925 and 6425 MHz BAND, PART TWO - DATA ACQUISITION AND EVALUATION: E.J. Mueller, C.E. Willman, Westinghouse Electric Corp., and V.F. Henry, NASA Goddard Space Flight Center

This paper is based upon the ATS-6 Radio Frequency Interference Measurement Experiment (RFIME) conducted by the U.S. National Aeronautics and Space Administration, Goddard Space Flight Center, to demonstrate the feasibility of making large-scale RFI measurements from space and to provide a basis for further evaluation of the sharing between space telecommunications services employing geostationary satellites and terrestrial radio services.

More than 300 satellite hours of RFIME measurements were made between August 1974 and June 1975 employing the ATS-6 satellite positioned in geostationary orbit at 94°W longitude. Measurements were made with the spacecraft 9.1 meter antenna directed primarily at locations in the United States. Over 2500 complete frequency scans representing 125 million independent RFI measurements (10 KHz) segments) were recorded.

Results to date were consistent with that expected relative to the major metropolitan areas and the terrestrial 6 GHz microwave links that feed these areas. Most of this RFI was contained in common carrier "channel" assignments but there were also some as yet unidentified RFI signals detected. The majority of the detected RFI was 8-14 dBW EIRP earth referenced, with some sources exceeding 30 dBW.

3. ATS-6 ELECTROMAGNETIC ENVIRONMENT SURVEY OF L, S & VHF FREQUENCY BANDS, PART ONE - THEORY AND EXPERIMENT DESIGN: R. Taylor, NASA, Goddard Space Flight Center, and C. Willman and A. McCourt, Westinghouse Electric Corp.

The Electromagnetic Environment Survey (EES) Experiment was developed by the NASA Goddard Space Flight Center in order to gather orbital RFI data within the 146-154 MHz (VHF), 1630-1670 MHz (L-band), and 2230-2270 MHz (S-band) frequency regions. The experiment employed the use of the NASA ATS-6 satellite with its high gain 9.1 m steerable antenna and the Rosman, N.C. ATS receive station. Either of three selectable spacecraft receivers (L,S, or VHF) were available for RFI monitoring. The antenna feeds for these receivers were also selectable to provide either a L-band pencil beam (1.3°), a L-band fan beam (1° x 7.5°), a S-band pencil beam (1°), or a VHF earth coverage beam (15°). The acquired RFI data, in conjunction with C-band RFI data (5925-6425 MHz) acquired through a similar ATS-6 experiment, is intended to provide an empirical data base upon which technically sound decisions regarding mutual interference between satellites and terrestrial stations can be made. This paper briefly describes the EES experiment background, experiment configuration(s), data recording procedure, calibration technique, and system detection capabilities. A second paper titled Part Two "Aollication and Results" is also presented.

4. ATS-6 ELECTROMAGNETIC ENVIRONMENT SURVEY OF L, S & VHF FREQUENCY BANDS, PART TWO - APPLICATION AND RESULTS: R. Taylor, NASA, Goddard Space Flight Center, and C. Willman and A. McCourt, Westinghouse Electric Co.

The Electromagnetic Environment Survey (EES) Experiment was conducted 1 April - 10 June 1975 utilizing the geosynchronous ATS-6 satellite. The experiment recorded RFI data at 146-154 MHz (VHF), 1630-1670 MHz (L-band), and 2220-2270 MHz (S-band). Another paper titled EES Part One "Theory and Experiment Configuration" presents the experiment background and configuration. This paper briefly summarizes the application and results.

The earth disc as viewed from 94°W longitude was systematically surveyed utilizing the 9.1 meter antenna of ATS-6 at all three frequency bands. The acquired EES data was sequentially recorded in 10 kHz segments and later computer processed by signal-plus-noise to noise thresholding. RFI sources have been detected in all three frequency bands with measured e.i.r.p. of 26-61, 28-52, and 44-63 dNm at L, S, and VHF respectively. The incidence of RFI sources in the L- and S-band spectrum was found to be greatest when viewing major metropolitan areas and also along U.S. coastlines while VHF recordings all indicated extensive RFI. The results are cataloged in an EES data base which describes each detected RFI source by frequency, power level, and geographic location.

Commission E - Session 2

Wednesday, October 13 1400 - 1715
RADIO NOISE AND INTERFERENCE
Chairman: J.R. Herman, Radio Sciences Company

1. SHORT-TERM STABILITY OF NOISE AND INTERFERENCE IN THE 2-6 MHz FREQUENCY BAND: G. Meltz, A.H. Katz, T.I.S. Boak, III, and R.B. Marshall, Raytheon Co., and J.A. Mullen, Raytheon Co.

The short-term statistical characteristics of 2-6 MHz noise and interference have been investigated using diurnal observations obtained throughout two 48-hour intervals in July 1976. Data were collected at Dexter, N.E. (44.02N, 76.07W) using a wide aperture (2..6 ft.) linear array and a computer controlled receiver with an analysis bandwidth of 50 kHz. During each data collection period about 10 minutes in duration) a programmed sequence of frequency and time dwells was stepped across the band. The characteristics that will be discussed include the stability of the total noise power level (atmospheric plus RFI) in the full analysis band and in narrower 0.1-1 kHz frequency bands, the amplitude probability distribution within a stability interval, and the temporal stability of frequency excision to reduce RFI. Distributions of noise after excision will be compared with canonical distributions for various resolution bandwidths and excision thresholds.

2. CORRELATION OF SIMULTANEOUS INLAND AND MID-ATLANTIC MEASUREMENTS OF HF NOISE AND INTERFERENCE: J. Ames and J. Schlobohm, Stanford Research Inst., Menlo Park, CA, and G. Meltx, A.H. Katz and J.A. Mullen, Raytheon Co., Sudbury, MA

Simultaneous wideband observations of HF noise and interference obtained at Dexter, N.Y. (44.02°N, 76.07°W) and aboard a quiet gas-turbine powered ship crossing the North Atlantic have been compared to determine the difference in the statistical characteristics and channel occupancy at sea and ashore. Synchronized identical computer controlled receivers were used to sequentially sample the 2-6 MHz band with an analysis bandwidth of 50 kHz. Measurements were obtained throughout two 48-hour intervals in July 1976. A wide aperture (2116') linear array was used at the land-based site to steer a narrow beam at 75 degrees True. Omnidirectional antennas were used aboard the ship.

The conditional probability relating the clear and occupied spectral segments (frequency resolution of 117 Hz) at sea and ashore will be described as a function of frequency and time of day. Also comparisons between the Amplitude Probability Distributions for interference-free channels as well as differences in absolute noise level at both locations will be presented.

3. SOME RESULTS OF AN INVESTIGATION OF ELECTROMAGNETIC INTERFERENCE PROBLEMS IN CANADA: C.P. Tou and D.A. Ray, Nova Scotia Technical College, Halifax

Electromagnetic interference (EMI) can be far more damaging than many other forms of environmental pollution under certain circumstances. Thus, the EMI problem becomes of national and international concern. In view of the importance of EMI control, the Department of Communications of Canada has initiated a project for a thorough and comprehensive study of the EMI situation in Canada so as to provide effective measures to control existing and future EMI problems.

The paper reports some results of the investigation of EMI problems in Canada. The statistics of man-made EMI sources and their effects on communication and other systems are given to show the dominant EMI sources in urban and rural areas and the general trend of the growth of various types of EMI sources. In addition, the philosophy and the overall scheme of EMI control resulting from this study are discussed in some detail.

Sooner or later a nation will face the challenge of EMI problems and EMI respects no national boundaries, so understanding EMI problems and international cooperation are essential to national and international EMI control. It is believed that the results of this study should be of interest to those involved in the control of the interference environment.

4. REPORT ON THE ACTIVITIES OF THE IEEE TASK FORCE ON TECHNICAL BASIS FOR SELECTION OF INTERFERENCE LIMITS FROM ELECTRIC POWER LINES AND STATIONS: P.S. Maruvada, Hydro Quebec Institute of Research, Varennes

Limits have been established in the past for electromagnetic interference, generated by certain types of electrical and electronic equipment, by national regulatory agencies and also be international organizations such as CISPR. In recent years, increasing consideration has also been given in different countries to setting limits to interference from high voltage power lines and stations. It should be mentioned in this context that the Radio Noise and Corona (RN & C) Subcommittee, which is a part of the Transmission and Distribution Committee of the IEEE Power Engineering Society, has been involved over the past thirty years in standardizing the instrumentation and measurement techniques, collection of data and developing appropriate design guides for radio interference (RI) from high voltage power lines and stations. In continuation of its efforts in this field, therefore, the RN & C Subcommittee has created a Task Force to formulate, on the basis of existing knowledge, a technical basis for selection of interference limits from electric power lines and stations.

The main objectives of this Task Force are:

a) collection and assessment of all relevant information on the interference characteristics of power lines and stations, the characteristics of available signals, and the criteria for acceptable signal to noise ratios,

b) examination, on the basis of existing information, of the technical and economic impact of setting interference limits, and

c) formulating a technical basis for setting interference limits.

The Task Force has been created in the beginning of 1975 and is composed of members from utilities, industry, research organizations, universities, and regulatory agencies. This paper will report on the progress of the work of this Task Force.

Commission F - Session 3

Wednesday, October 13 1400 - 1715
SOME APPLICATIONS AND EFFECTS OF EM AND
ACOUSTIC WAVES IN THE EARTH ENVIRONMENT
Chairman: E. Gossard

1. ATMOSPHERIC MODIFICATIONS BY HIGH-POWER MICROWAVE BEAM AT 22.2 GHz (WATER VAPOR ABSORPTION LINE): M.D. Grossi and G. Colombo, Smithsonian Inst., Cambridge, MA

Recent studies by NASA have indicated the feasibility of orbiting up to synchronous heights a Space Solar Power Laboratory equipped with a solar cell array of approximately 50 Km^2 surface, with a 2.3 GHz transmitter of about 10 Gigzwatt output power and with an antenna beam (a fraction of a degree wide) that is steerable and can be oriented at will toward any region of the earth surface within line of sight. The power density in the antenna beam can reach levels of 100 to 1000 Watts/m^2 at the earth surface.

By retuning the transmitter to the frequency of the water vapor absorption line (22.2 GHz), it can be shown that a transfer of a substantial amount of energy from the high power microwave beam to the atmosphere takes place through processes of absorption by atmospheric water vapor, by clouds' water droplets and by rain droplets. This hearing of the moist and cloudy atmosphere, as well as the one occurring in the soil, have a potential of causing substantial atmospheric modifications. It can be shown in fact that this hearing of the atmosphere is capable of elevating the temperature of 2 Km^3 of air of 1°C/minute and of sublimating, also in one minute, 650 tons of ice crystals.

Various meteorological consequences of substance appear possible, such as the dissipation of fog layers, the prevention and modification of hail thunderstorms and the correction of situations of severe atmospheric pollution.

2. FLUID FLOW MAPPING USING ELECTROMAGNETIC PROBING: R.J. Lytle, D.L. Lager E.F. Laine and J.D. Salisbury, Lawrence Livermore Laboratory, CA

When one pumps a fluid into the ground, it is desirable to know exactly where the fluid flows to and its rate of advance. This is important in oil reservoir engineering, in situ coal gasification, and hydrology studies concerning underground storage of chemical wastes.

Determining where the fluid flows to and its rate of flow is presently limited to assumptions of uniform flow rates. This assumption can be erroneous in many situations. For example, the fluid may have a preferred direction of flow or may have a flow rate that is spatially dependent. Some means of monitoring where the fluid flows to and its rate of advance is needed. Electromagnetic waves can be used to determine this information. By injecting into a medium , fluid with electrical properties different than the fluid naturally present, high frequency electromagnetics may be used to determine the location and rate of advance of the injected fluid front. By placing a transmitter in the same drill hole into which the fluid is injected, and placing receivers in nearby drill holes, a three-dimensional fluid flow profile may be obtained by monitoring the time variation of the attenuation and phase shift between the transmitter and the receivers. Both the attenuation and phase shift contain significant and interpretable data. A simple data interpretation method is given credence by calculations for fluid

flow profiles with known solutions. Injecting a more saline solution, rather than a lower conductivity solution than is naturally present, appears to yield the more reliable information. Test-of-concept experiments in field situations have yielded results consistent with one's intuition.

3. A RADIO LOCATION SYSTEM TO WARN ARCTIC OIL DRILLING SHIPS OF SEA ICE HAZARDS: R.N. DeWitt, J.A. Green, H.G. Tornatore, Electro-Physics Labs, Columbia, MD

In order to warn ships engaged in marine oil drilling operations of drifting ice floes that may pose a hazard to them, a system has been devised to relay OMEGS navigation signals from transponders deployed on the ice floes. The OMEGA signals are telemetered hourly for a three-minute interval via medium frequency surface wave propagation. The system has been designed to provide positional accuracy of 6 centilanes (<1 km) over a range extending to 100 km. The necessity to propagate over paths with portions as long as 5 km covered by a 4 m thick layer of poorly conducting multi-year sea ice has dictated the use of a frequency of 2.5 MHz or less. At these low frequencies, the ice constitutes a thin dielectric layer, that in combination with the underlying conductive sea water, presents an "inductive" type of surface impedance.

4. USE OF A SYNTHETIC TIME-DOMAIN PULSE TO MEASURE THE DIELECTRIC CONSTANT OF GRAIN: F.R. Clague, National Bureau of Standards, Boulder, CO

A technique is described which determines the complex dielectric constant of grain as a function of frequency from approximately 100 MHz to 2 GHz. The time domain pulse is synthesized from weighted discrete frequency data using an Inverse FFT. This data, measured by an automatic network analyzer, is the scattering (S) parameters of the grain sample which is contained in a coaxial line. The time-domain response is windowed to remove unwanted clutter such as connector discontinuities and multiple reflections, then transformed back to the frequency domain and the desired dielectric parameters calculated.

Time domain techniques allow the response of the sample to be easily, although not necessarily completely isolated from the transducer imperfections that must also be accounted for in frequency domain measurements. This is particularly true for the expected extension of these techniques to an open system. The use of a band-limited synthesized pulse based on a phase locked frequency source reduces the inaccuracies caused by the jitter and drift of real pulse sources and sampling oscilloscopes. A synthesized pulse also allows any number of hypothetical pulse shapes to be easily tried. Thus, while the final system will have an actual pulse generator, the use of a synthesized pulse allows a determination of the "best" result that can be obtained in the time-domain. Sample results of the measurement technique will be presented.

5. ATMOSPHERIC PROBING USING ACOUSTIC PROPAGATION TECHNIQUES: P.A. Mandics and D.W. Beran, National Oceanic and Atmospheric Adm., Boulder, CO

The versatility of acoustic propagation techniques for remotely probing the planetary boundary layer has been demonstrated in two recent experiments. First, a monostatic, vertically-pointed echo sounder was installed on a ship for the

Global Atmospheric Research Program Atlantic Tropical Experiment (GATE). The data have provided new and unique information about the moist tropical marine boundary layer. Long periods of convective plume activity, without the usual diurnal cycle, were observed under fair-weather conditions. Disturbances such as cumulo-nimbus-generated downdrafts resulted in a more stable stratification with multiple, undulating inversions. Hummock-shaped acoustic returns were associated with low-level cumulus clouds.

The second experiment utilized a bistatic acoustic echo sounding arrangement to measure wind profiles up to 600 m height. An electronically-steered receiving antenna was used to track the transmitted pulse. The wind information contained in the Doppler frequency shift of the returns was derived digitally using a fast Fourier transform technique. System operation was verified by comparing winds determined by the echo sounder with those measured by a balloon-borne anemometer.

6. COUPLING OF ATMOSPHERIC WAVES TO MINOR CONSTITUENT ACOUSTIC WAVES: S.H. Gross and H. Eun, Polytechnic Institute of New York

Studies of traveling ionospheric disturbances have indicated that strong coupling of neutral atmospheric acoustic-gravity waves to ionization acoustic waves is possible under appropriate conditions. These waves may be involved in traveling ionospheric disturbances. It has also been found that resonant coupling to minor neutral constituent acoustic waves is possible and that such coupling is mass dependent, the relationship depending on the state of diffusion and the temperature gradient. These neutral waves may produce traveling neutral waves may produce traveling neutral disturbances that affect the distribution of species individually in the mesosphere and thermosphere. The nature of these waves, their mode of propagation, the mass cut-off effect and phase shifts will be described. Large phase shifts are possible for helium relative to argon and nitrogen. Such behavior was observed by Atmospheric Explorer C and may be indicative of the existence of these neutral species waves.

7. SIMULATION OF MULTIPATH FADING FOR NAVY'S MLS SYSTEM: H.S. Hayre, Univ. of Houston, TX

Since it is too expensive and time consuming to attempt to "mock up" the proposed Microwave Landing System (MLS) on a full scale basis, and furthermore computer simulation of the multipath problem is not completely possible, ultrasonic simulation offers a practical, inexpensive and quick alternative to the full scale tests. The exact naval system is wavelength scaled and the MLS frequency of 1.79 MHz thus resulting in a scale factor of 72. All the aircraft deck dimensions, as well as the aircraft models are 1/72 scale of the originals. All antenna beamwidths are appropriately reproduced so that areas/volumes illuminated by these are accurately duplicated in the laboratory. The scan is simulated by taking static data at various points in the scan, although later plans are underway for a time scan in the ultrasonic simulation. Some of the results obtained in the area of ocean and deck multipath are described. The results for the worst case of deck parked aircraft multipath is also included.

Commission G - Session 2

Wednesday, October 13 1400 - 1715
TRANSIONOSPHERIC PROPAGATION AND
IONOSPHERIC IRREGULARITIES
Chairman: T. Van Zandt

1. SIMULTANEOUS VHF SCINTILLATION AND 50 MHz RADAR STUDIES OF F-REGION EQUATORIAL IRREGULARITIES: S. Basu, J. Aarons, Hanscom AFB, MA, A. Bushby, R.W. Woodman, Instituto Geofisico Del Peru, Lima, and J.P. McClure and C. LaHoz, Univ. of Texas at Dallas

A detailed comparative study has been made of nighttime scintillations of 137 and 254 MHz transmissions from two synchronous satellites observed at Huancayo, Peru and 50 MHz Jicamarca radar backscatter from equatorial F-region irregularities. When only the bottomside F-region showed 3m irregularieies, weak to moderate VHF scintillations were observed. On nights when rising irregularity structures were found to extend to the F-peak and beyond, amplitude scintillations were severe ranging from 15 dB peak-to-peak to saturation on both 137 and 254 MHz. The amplitude of the return and the thickness of the F-layer irregularity region as seen on the radar are directly correlated with the depth of scintillation fading. Since the radar samples irregularities of size 3m and the VHF scintillations are responsive predominantly to irregularities of the order of kms to several hundred meters, these correlated measurements indicate the near simultaneous development of irregularity scale sizes over 2 to 3 orders of magnitude. This has important implications for irregularity spectra. A comparison of the onset times of topside irregularities as seen by the radar and saturated scintillations at a 4° eastward ionospheric location has, on specific nights studied, shown an earlier occurrence of severe scintillations to the east (in keeping with the sunset line travelling westwards) even though multiantenna radar measurements indicate eastward velocities. This gives information regarding temporal and spatial behavior of large-scale irregularity structures during their development phase. In the only instance when the Jicamarca radar operated until sunrise in the November-December, 1975 period it was found that isolated topside irregularity clouds were correlated with weak scintillations which are known to occur fairly often at this time. The origin of these irregularities near sunrise require much further investigation.

2. CORRELATED MEASUREMENTS OF VHF SCINTILLATION AND VHF RADAR BACKSCATTER FROM ELECTROJET IRREGULARITIES: S. Basu, Emmanuel College, Boston, MA, J. Aarons, Hanscom AFB, MA and B.B. Balsley, National Oceanic and Atmospheric Adm., Boulder, CO

The nature of electrojet irregularities responsible for daytime VHF scintillation has been studied from a set of measurements of scintillations at 41 and 140 MHz and radar backscatter carried out at Huancayo and Jicamarca respectively. The 50 MHz radar backscatter measurements have been used to probe the electrojet irregularities of 3m scale lengths and to identify the two types of electrojet irregularities, namely Type I generated by the two stream instability mechanism and Type II caused by the gradient drift instability mechanism. The scintillation observations at 41 and 140 MHz explore the irregularities of the order of 1 km to several hundred meters corresponding to the Fresnel dimension for these two frequencies at E region heights. The study shows that scintillations are observed on only those days when the radar is able to detect echoes indicating

thereby that the irregularities of kilometer and meter scale lengths co-exist. The times of onset and decay of scintillation are found to correspond closely with those of Type II irregularities which shows that the scale lengths of Type II irregularities extend to a value of about 1 km. During those periods when Type I irregularities are also detected by the radar, scintillations usually increase but continue even after the cessation of Type I activity. This increase is probably related to a strengthening of Type II echoes generally associated with the appearance of Type I. It may thus be concluded that Type II irregularities are responsible for daytime VHF scintillation. The electron density deviation and spectral index of electrojet irregularities with scale lengths ranging between a km to several hendred meters have been estimated from scintillation observations.

3. IONOSPHERIC SCINTILLATION MEASUREMENTS AT HONG KONG AND BAHRAIN: R. Taur, COMSAT Labs, Clarksburg, MD

The analysis and results of the scintillation data collected at Hong Kong and Bahrain Earth Stations from 1972-1974 are presented. Annual and worst month scintillation statistics are given. It was found that there are more weak scintillation activities on the eastern link of Hong Kong Earth Station than its western link. A sharp wedge-like irregular region in the ionosphere near the sunset line is proposed in order to explain the difference. The frequency dependence of ionospheric scintillations between 4 and 6 GHz has been re-examined. It appears that under very weak scattering conditions, the scintillation index (S_4) varies as λ^2. When scintillation becomes stronger, the variation falls between λ and λ^2.

The power spectrum of 4 GHz scintillation shows a roll-off slope of f^{-3}, the same as the results of measurements made in South America. When both tropospheric and ionospheric scintillations occur on a communication link, the slow fluctuations are contributed by the tropospheric turbulences and the ionospheric irregularities are responsible for the rapidly fluctuating components.

4. THREE COMPONENTS OBSERVED IN TRANSIONOSPHERIC SIGNALS: E.J. Fremouw, R.C. Livingston, and C.L. Rino, Stanford Research Inst., Menlo Park, CA

The complex envelope of signals transmitted through the ionosphere from phase-coherent beacons contains information pertaining to the study of both total electron content (TEC) and scintillation-producing irregularities. Traditionally, TEC has been studied in terms of relatively slow variations in dispersive phase and smaller scale irregularities have been investigated in terms of faster intensity scintillations. As expected, however, intensity scintillation is always accompanied by phase scintillation on similar time scales. Furthermore, analysis of two-frequency coherent signals from ATS-6 (geostationary) and the Transit (polar orbiting) satellites has revealed weak focusing and defocusing associated with dispersive-phase variations on times scales of a few minutes and a few seconds, respectively. Recent launch of a coherent beacon (DNA-002) having measurement signals at VHF, UHF, and L Band and a phase-reference signal at S Band permits detailed and unified investigation of the following three signal components: (1) that undergoing pure dispersive phase shift;

(2) that suffering refractive focusing and defocusing by large-scale ionospheric structure; and (3) that undergoing well-developed diffractive scatter. This paper will describe some recognizable characteristics of these three signal components, concentrating on the focus and scatter components, which together make up the composite scintillating signal.

5. CHARACTERISTICS OF VFH SCINTILLATION IN THE MULTIPLE SCATTER REGIME: S. Basu, Emmanuel College, Boston, MA and H.E. Whitney, Hanscom AFB, MA

The frequency dependence and power spectrum of scintillation in the multiple scatter regime have been studied by the use of 137 and 360 MHz data of intense ionospheric scintillation obtained at Huancayo, Peru. The frequency dependence of scintillation in the interval of 137 to 360 MHz is found to weaken progressively with increasing level of scintillation. The exponent for the frequency dependence is found to decrease from 1 to 0.1 as the S_4 index at 360 MHz increases from 0.2 to 0.8. This result implies that a frequency as high as 360 MHz may encounter saturated scintillation regime in the equatorial region. The Fourier power spectra of scintillations exhibit a nearly flat low frequency part extending over 0.01 to 0.1 Hz and a linear roll off between 0.1 to 1 Hz. The absence of Fresnel frequency modulation of the Fourier spectra even though the irregularities are anisotropic indicates that the observed scintillation arises from thick irregularity layers. This is also substantiated by the recent VHF radar backscatter observations of nighttime equatorial irregularities. Another result of interest is the monotonic decrease of the difference of autocorrelation intervals at 137 and 360 MHz from + 0.8 to - 0.5 as the S_4 index at 360 MHz increases from 0.2 to 0.8. This result implies that the scattered power develops finer scale lengths with increasing phase deviation.

6. PULSE PROPAGATION IN A DISPERSIVE AND RANDOM MEDIUM: K.C. Yeh, Univ. of Illinois, and C.C. Yang, National Taiwan Univ.

An electromagnetic pulse propagating through the ionosphere can be modified owing to dispersion as well as random scattering from irregularities. As a result, the pulse arrival time and the pulse width are altered. In this paper we show how such quantities can be computed and related to medium parameters. In this connection the two-frequency mutual intensity function studied in random medium propagation enters in the formualtion naturally. The results show that in the weak scatter limit the average arrival time of a pulse is affected mainly by dispersive effects while the pulse width is affected both by dispersion and random scattering. Possible applications to transionospheric propagation will be discussed.

7. IONOSPHERIC SCINTILLATION AT GHz FREQUENCIES AND ITS EFFECT ON THE SEASAT-A SYNTHETIC APERTURE RADAR: W.D. Brown, Sandia Labs, Albuquerque, NM

The effects of phase scintillation on the performance of the synthetic aperture radar (SAR) located on the SEASAT-A satellite are described. The phase scintillation is produced by scattering from electron density irregularities in the F-region of the ionosphere. Equations are derived which relate the performance

of the SAR to the power spectrum of the electron density irregularities. Two forms for the power spectrum were selected for comparison: (1) a power-law variation in the wave number with a constant three-dimensional index equal to four, and (2) a Gaussian variation. The outer scale length of the irregularities was varied from 150 to 3,500 meters and the mean square electron density fluctuation was simultaneously adjusted to keep the amplitude scintillation index constant at values which are consistent with the auroral region data of L.A. Maynard. The degradation of SAR performance increases with increasing outer scale length and is most dramatically manifested by the rapid increase in the integrated sidelobe ratio.

8. MIDLATITUDE IONOSPHERIC SCINTILLATION FADING OF MICROWAVE SIGNALS: W.E. Brown, III, G.G. Haroules, and W.I. Thompson, III, U.S. Dept. of Transportation, Cambridge, MA

Amplitude measurements of microwave (1550 MHz) signals from the NASA ATS-5 geostationary spacecraft were made during the period from December 1973 through July 1974. This amplitude data has been analyzed for diurnal, geomegnetic and seasonal variations as well as for a relation to the equatorward boundary of the high latitude scintillation region.

The uplink signal to the spacecraft, at a frequency of 1650 MHz, was transmitted from the DOT/TSC/Westford Propagation Facility in Westford, Massachusetts, U.S.A. (42°.6N; 71°.5W geographic). The uplink signal was frequency translated by the spacecraft's L-band transponder, in the narrow-band frequency translation mode, to a downlink frequency of 1550 MHz. The downlink signal was then received at the Westford facility on three independent receiving systems where its amplitude was recorded in both analog and digital form.

The three detected voltages from the vector voltmeters were digitized, preprocessed and recorded on magnetic tape for later computer processing. In each of the 2500 12-min. data samples the best channel was analyzed. In the case where the same channel was acceptable it was analyzed as long as it remained acceptable. The 12-min. data samples were statistically analyzed to determine mean values, root-mean-squares, probability density functions and probability distribution functions. The value of the 12-min. distribution function at the 90 percentile level was termed a "scintillation index".

The scintillation index values were associated with the corresponding planetary magnetic index values and the results indicated that higher values of magnetic activity are associated with the higher values of scintillation index.

Commissions A and B - Session 4A

Thursday, October 14 0900 - 1215
MICROWAVE MEASUREMENTS AND EXPOSURE SYSTEMS
Chairman: J.C. Lin, Wayne State University

1. INDUSTRIAL RF (6-40.68 MHz) PERSONNEL EXPOSURE PROBLEMS-INITIAL OBSERVATIONS: D.L. Conover, Robert A. Taft Labs, Cincinnati, OH

The performance characteristics of commercial and NBS radiofrequency (10-300 MHz) field-strength monitors are compared and the results of industrial radiofrequency (RF) personnel exposure measurements are presented. Monitor comparisons indicated that only one commercial monitor was usable from 13 to 40 MHz. A unique RF exposure synthesizer, developed for NIOSH by NBS, was used for monitor comparisons.

Results of 1,359 industrial RF power source measurements with the NBS field-strength monitors are described. Repetitive electric and magnetic-field-strength measurements, taken under the same exposure conditions, showed more variation in magnetic-field strength measurements. The degree of field-strength variation was reduced when the source operator was used as a reference frame for exposure measurements. Differences between field-strength readings taken at seven anatomical positions indicated the need for multiple readings to describe an individual's exposure. The dependence of field-strength readings on the distance from RF power sources revealed the presence of standing waves. At least 7-% of the sources emitted electric and magnetic-field strengths that exceeded the field-strength guides (200 V/m and 0.5 A/m, respectively) specified in the ANSI C95.1-1974 Personnel Exposure Standard for RF radiation.

2. RADIOFREQUENCY RADIATION LEVELS IN URBAN AREAS: D.E. Janes, R.A. Tell, T.W. Athey, and N.N. Hankin, EPA, Silver Spring, MD

In october 1975 the U.S. Environmental Protection Agency began measuring levels of radiofrequency radiation in urban areas as a part of its program to determine the need for environmental radiofrequency exposure standards.

Data on environmental levels have been obtained for Atlanta, Boston, Miami, Philadelphia, and parts of Washington, D.C. About 7% of the U.S. population live in these Standard Metropolitan Statistical Areas. Data are collected at 15 to 30 sites within each metropolitan area. Earlier investigations led to the working hypothesis that the principal sources of environmental radiofrequency radiation are the broadcast services. The frequency bands measured are the standard AM broadcast band (0.5-1.6 MHz), the VHF-television bands (54-88 and 174-216 MHz), the FM radio band (88-108 MHz), two land mobile bands (150 and 450 MHz) and the UHF-television band (470-890 MHz). Values of power density integrated over the frequency range from 55 to 900 MHz generally fall into the range between 0.001 and 1 $\mu W/cm^2$ with most values between 0.01 and 0.1 $\mu W/cm^2$. Values above 1 $\mu W/cm^2$ have been found and these exposure situations will be discussed. Representative spectra for each of the bands will also be presented and discussed.

3. A MICROWAVE EXPOSURE SYSTEM FOR PRIMATES: L.N. Heynick, P. Polson, A. Karp, Stanford Research Institute, Menlo Park, CA

A set of cavity/cage units developed for chronic irradiation of macaques and smaller animals at 2.45 GHz is described. Each cavity is a three-foot, multi-mode, mode-stirred cube excited by a 2M53 magnetron. Forward and reflected powers are measured by calibrated diode detectors in a bidirectional coupler between the magnetron and cavity. Power values are set by phase-angle selection and maintained constant by detector-output feedback to a thyristor control circuit. The cage is of low RF-loss-tangent materials. Calorimetry with saline-filled bottles and dolls was used to determine energy absorption values as related to net input power and time. Calorimetric measurements were taken with plane-wave irradiation in an anechoic chamber, to establish total absorbed power equivalence between the two irradiation methods. Scanning IR thermography was also performed at the University of Washington on macaque carcasses irradiated in the cavity/cage unit. Twelve units are currently in use at SRI for investigating behavioral effects on squirrel monkeys subjected to chronic irradiation.

4. RADIATORS FOR MICROWAVE BIOLOGICAL EFFECTS RESEARCH--WAVEGUIDE SLOT ARRAY WITH CONSTANT RADIATION INTENSITY: M.J. Hagmann and O.P. Gandhi, University of Utah Salt Lake City

Microwave biological studies with large targets or multiple targets require a large working area with near-constant exposure. At high microwave frequencies where high-power sources are not readily available, it is desirable to use a radiator providing a constant intensity beam so the working area may receive almost all of the total radiated power.

Several synthesis procedures have been used for design of a longitudinal shunt slot array having a pattern with nearly constant radiation intensity over the beamwidth and zero intensity outside. A beamwidth of 12.5° was chosen as being small enough for a radiated beam to approximate a plane wave yet give enough divergence for convenient chamber dimensions. Discontinuities in the desired pattern force the Fourier-synthesized pattern to have significant errors due to overshoot and ripple. Solutions developed on the basis of Fejer sums and Lanczos' σ factors gave patterns with objectionable rounding. A new procedure based on weighted least squares was developed for optimum characteristics.

The test design at 10.4 GHz uses 9 slots and has a calculated variation of $\pm$ 5 percent in radiation intensity over the 12.5° beamwidth with 80 percent of the total radiated power contained within the beamwidth. Experimental results on this antenna will be presented.

Commissions A and B - Session 4B

Thursday, October 14 0900 - 1215
INSTRUMENTATION - PROBES
Chairman: R.R. Bowman, National Bureau of Standards

1. OMNIDIRECTIONAL POWER DENSITY PROBES: T.M. Babij, Hubert Trzaska, Technical University of Wroclaw, Wroclaw, Poland

Up to the present time power density in the near field has often been measured with the use of directive, resonant antennas or short electric dipoles measuring in fact electric field. Both these methods have limited applicability. The measurements of the power density in the near field needs the use of a probe sensitive to the electric and magnetic field simultaneously, having definite sensitivity for the both components, flat frequency response and omnidirectional radiation pattern. For this purpose the authors use sensors with a number of loops, dipoles of unipoles. In most of them electric dipoles are formed by electrostatic screening of loops. The simplest sensor consists of two loops in each plane; electric field detector is connected between the screens of the loops. The probe with triple quadrant antenna consists of three perpendicular loops, screens of which made three quadrant antennas of common arms. To improve its radiation pattern for electric field an additional unipole was added. The unipole of the modified triple quadrant antenna makes another three quadrant antennas with the screens of the loops. Another probe consists of three loops, inside them are immersed three orthogonal dipoles. Each dipole is placed in the plane of different loop for minimize mutual couplings. This probe has three modifications. The first uses as electric dipoles two equal parts of the screen of each loop, the other uses only half of the screen and the third uses unscreened loop for electric field as well. The main problem here is to get sufficient sensitivity for magnetic field. All these probes are destined for frequencies below 300 MHz.

2. EVALUATION OF AN IMPLANTABLE ELECTRIC FIELD PROBE WITHIN FINITE, SIMULATED TISSUES: H. Bassen, P. Herchenroeder, A. Cheung, and S. Neuder, Bureau of Radiological Health, FDA, and University of Maryland

A miniature, isotropic, electric field probe has been experimentally used to map fields within small spheres of simulated muscle tissue 6.6 cm and 16 cm in diameter irradiated by plane waves at 450, 915, and 2450 MHz. Good agreement with theoretically predicted values were obtained with respect to absolute values and spatial distribution in both spheres. The probe, consisting of an orthogonal array of 2.5 mm dipoles with integral diode detectors, is highly independent of the media in which it is implanted, with respect to its absolute calibration. This is because of the well-documented principle of probe response independence from dielectric constant, unique to properly designed insulated dipoles. Thus, the probe may be calibrated in free space and used, without a large correction factor, in media with a high or low value of dielectric constant. The probe's independence of boundary-proximity effects results from the use of electrically small dipoles, together with subminiature, low capacitance diode detector chips. Preliminary results of in-vivo measurements in laboratory animals will be presented. Further miniaturization of the probe (using 1 mm dipoles) will be discussed and prototype performance will be presented.

3. A MICROWAVE COMPATABLE TEMPERATURE ELECTRODE: L.E. Larsen, R.A. Moore, J.H. Jacobi, and F. Halgas, Walter Reed Army Institute of Research and Westinghouse Electric Corporation

The microwave integrated circuit electrode reported by Larsen, Moore and Acevedo has been further developed to improve its performance: 1) it operates in significantly higher energy density fields (250 mW/cm^2 rather than 50 mW/cm^2, CW, 2450 MHz); 2) it employs an improved resistance measurement method via four terminals located at the transducer; 3) the transducer is now glass encapsulated for improved long-term stability; 4) a hyper-thin film transmission line is used for improved RF decoupling; 5) the electrode is fabricated with methods more suitable for quantity production.

The electrode employs the notion of electrothermal matching whereby the electrode segments which operate in air differ in their physical and electrical properties from those which operate in tissue. This concept requires that electrode and medium losses are comparable in order to prevent unnecessarily high source impedances and/or heat sinking from the tissue being measured. Thermographic methods were used to verify RF properties of the electrode and transmission line in simulated tissue and air.

4. FURTHER DEVELOPMENTS OF THE BIREFRINGENT CRYSTAL OPTICAL THERMOMETER: T.C. Cetas, D. Hefner, C. Snedaker, W. Swindell, Univ. of Arizona, Tucson

A fiber optic probe thermometer which uses a birefringent crystal as a sensor was described at the USNC/URSI meeting in Boulder, October 1975. That prototype has a useful range from 15 to 45°C with a resolution of 0.1°C. Drifts in the calibration equivalent to 0.3°C over 16 hr were associated with instabilities of the order of 1% in the light emitting diode and photodetector. The diameter of the sensor, 2 mm, was based on convenience for the assembly of probes to be used for feasibility tests. The thermometer is used regularly to measure heating in phantoms and animals heated by microwaves, shortwaves and radiofrequency current fields. A newer version eliminates the effects of drifting in the opto-electronic components through use of a beam splitter which provides an optical reference signal. Only a single optical fiber is needed to carry light to the sensor and back to the photdetector. Appropriate electronics amplify the signal from the two optical channels, compute their ratio, and provide analog and digital displays. Complete thermometric evaluation data on the new version will be presented as well as a possible means for making the thermometers more generally available.

Commission B - Session 4

Thursday, October 14 0900 - 1215
ANTENNAS AND ARRAYS
Chairman: A.A. Ksienski, Ohio State University

1. RADIATION FROM A WIDE ANGLE CONICAL HORN WITH A HOMOGENEOUS DIELECTRIC SPHERE IN FRONT OF ITS APERTURE: A.K. Kamal, R.A. Nair and S.C. Gupta, University of Roorkee, India

The effects of placing a homogeneous dielectric sphere in front of the aperture a wide angle conical horn are studied both theoretically and experimentally. The theoretical formulation of the radiation characteristics of the device is made on the basis of scattering of Electromagnetic waves by a dielectric sphere. Using the far field approximations, the transverse electric field over the horn aperture when operating in the HE_{mn} hybrid mode are used. This incident field induces a secondary fields having two parts viz. (i) the scattered field external to the dielectric sphere and (ii) the transmitted field internal to the sphere. The proper form of the potentials for the scattered fields are used. Now the radiation from the device is treated as a boundary value problem and solutions are obtained by scattering superpositions as presented in [1] for a case based on the Huygen's source model. An expression for the directivity of the antenna device in forward direction relative to an isotropic source is obtained after calculating the total power radiated. The forward directivity of this antenna system is obtained as,

$$D = \frac{\left| \sum_{n=1}^{\infty} \frac{2n+1}{2} (-1)^n (\alpha_n + \beta_n) \right|^2}{\sum_{n=1}^{\infty} \frac{2n+1}{2} (|\alpha_n|^2 + |\beta_n|^2)}$$

where,

$$\alpha_n = (1 + \frac{C_n}{a_n}), \quad \beta_n = (1 + \frac{b_n}{a_n})$$

and a_n, b_n, c_n are constants of scattered field potentials.

Experiments were performed with conical horn of half flare angle 26° and aperture diameter 11.75 cm, using paraffies wax ($\varepsilon_r = 2.25$) dielectric spheres of diameters 9cm, 6cms and 4 cm. The gain and pattern measurements were carried out at X-Band (f = 9.68 GHz). The E-plane radiation pattern for the system with 6 cm diameter sphere at a distance of 24 cm from the cone aperture is experimentally obtained and is compared with the theoretical results and are found in agreement.

2. BROADBAND MULTI-ELEMENT MONOPOLE ANTENNAS: G. Goubau, Comm/ADP Lab.

The antennas discussed in this paper are derived from a short monopole with a top capacity formed by a conductive plate. The vertical conductor is replaced by a number of conductors, and the capacitor plate is divided into an equal number of segments, one connected to each of the conductors. The resulting structure is an

assembly of closely coupled "sub-monopoles". The sub-monopoles are interconnected at the top by inductances. One or two of the sub-monopoles are connected to the input terminal of the antenna structure, while the others are grounded. Multi-element monopole antennas have small physical height and can be designed to have bandwidths which are a multiple of those of single monopoles with the same overall dimensions. Examples to be discussed are a structure of four sub-monopoles with a height of 4.3 cm having a bandwidth from 450-920 MHz, and a structure of three sub-monopoles with a height of 2.7 cm having a bandwidth from 550 to 1000 MHz. The radii of the capacitor plates in both cases are 6.15 cm.

3. ACTIVE ELEMENT PATTERN OF A RECTANGULAR WAVEGUIDE IN A PERIODIC PLANAR ARRAY: C.A. Chuang and C.C. Han, Aeronutronic Ford, Palo Alto, CA and S.W. Lee, Univ. of Illinois

For a periodic planar array of rectangular waveguides with an arbitrary lattice, a formula is derived to calculate the active element field pattern from the known solution when the array is excited cophasally.

From the study of phased array problems, it is known that the active element power pattern is related to the power transmission coefficient of a cophasal array by a factor $\cos\theta$, where θ is the polar angle measured from the array normal. This relation can be simply deduced from conservation of energy, as $\cos\theta$ accounts for the factor of projecting an element aperture in the observation direction θ. In certain applications, however, a more precise relation between active element field pattern and the solution of a cophasal array is needed because not only power but also phase and polarization information are essential. The latter relation is yet unknown, except for a special two-dimensional case. The objective of the present study is to derive a formula that relates the active element field pattern and the solution of a cophasal array under a most general condition.

The derived formula of the active element pattern is then used to design an array feed of an offset parabolic reflector for a specific application. In this application, a dual circularly polarized array of rectangular guides is used and the active element pattern of the elements of the array should have, within a prescribed conical region around the forward direction, a well-defined phase center, a sufficient amplitude taper, and a good axial ratio for both senses of circularly polarized excitations.

The design resulting from the newly developed formula gives an active element pattern which as a maximum voltage axial ratio of 1.2 and 3.4 dB amplitude taper within a 25° conical region and over a 10% frequency band.

A finite array of closely packed square waveguides has been constructed and the measured active element pattern is compared with the computed result.

4. ADMITTANCES AND FIELDS OF A PLANAR ARRAY: T.K. Liu, Science Applications, Inc., Berkeley, CA

An infinite planar array of wire antennas is under study. The infinitely long wires contain driving gaps at uniform intervals and the gaps are driven in a constant-amplitude, progressive-phase manner.

Taking the periodicity of the structure and the triggering sequence into consideration, the magnetic vector potential is obtained in the Fourier Transform domain. This potential can be re-expressed in the space-harmonic form. The quantities of interest, namely, the currents and the radiation fields are then derived from the expression for the vector potential.

The results show that with a proper triggering sequence, the array launches a wave whose main lobe is a TEM plane wave propagating in a desired direction. The main lobe is the only one present for frequencies such that the spacing between adjacent array elements are small compared with wavelengths. Grating lobes occur at higher frequencies, and their propagation directions are frequency dependent.

5. THE VALLEY FORGE DEFORMABLE, TRANSMIT-RECEIVE ARRAY: E.N. Powers, B.D. Steinberg and D. Carlson, University of Pennsylvania, Philadelphia

Valley Forge Research Center has a continuing research program in the area of large, thin, random, arbitrarily conformal, adaptively phased arrays. In principle, such arrays can yield high resolution, narrow beamwidth antenna patterns without the necessity of the expensive, mechanically and electrically well defined structures implied by classical array theory. Conformality implies that the array may be mounted on an arbitrary surface. This property was exploited to design a 20 foot, four element, deformable, transmit-receive array, an array which will continue to function at or close to its design capability even if the individual elements are moved away from their design positions through flexure due, for example, to wind loading, or the more violent deformation resulting from physical damage. The experimental array was constructed so that the individual elements could be moved arbitrarily in two dimensions up to a distance of one wavelength with respect to their initial positions, and the performance of this transmit-receive array was studied as the element positions were disturbed. This paper will compare the calculated performance and the measured results of these experiments.

6. EXPERIMENTAL SCANNING OF A 100 FOOT RANDOM ARRAY: C.N. Dorny, B.D. Steinberg, B.S. Meagher, Jr., University of Pennsylvania, Philadelphia

A thin, random, conformal, self-phasing array was constructed at Valley Forge Research Center in the summer of 1975. This array employed 16 self-standing array elements spread over a region 100 wavelengths in extent. The locations of the elements were chosen from a table of random numbers. The outputs from the individual elements were fed back to a central processing point. The construction and first results from this array were described at the 1975 USNC/URSI-IEEE Boulder meeting. Since that time, the collected data has been analyzed, a series of beamforming and scanning experiments have been performed, and comparisons made with the

theory of the performance of such arrays. This work has led to a more detailed understanding of the performance and operation of the thin, random, large, conformal, adaptively phased array. This paper will review the array experiment and present the new results of the data analysis.

7. ELEMENT PATTERNS FOR OPTIMALLY MATCHED FINITE ARRAYS: W.K. Kahn, George Washington University, D.C.

A technique is developed for predicting the element patterns which would result if any given array of antennas were appropriately matched in impedance by means of a lossless feed network designed for this purpose. When the requirement for match is most broadly interpreted, namely as match for all excitations, the form of our result can be anticipated from the conservation of energy. Generally, impedance match for all excitations does not constitute an appropriate objective. This distinction between match for all excitations and an appropriate partial match is essential in the application of this method to closely spaced arrays. For such arrays, the indiscriminate requirement of match for all excitations leads to difficulties in tuning and excitation (and in computation) akin to those associated with supergain. The excitations and element patterns derived using partial matching are not simply predicted by the conservation of energy.

The theory is illustrated through application to a uniform array of line sources and dipoles. Element patterns obtained with an appropriately matched array are compared with those from the infinite array model, the latter having been obtained previously by an independent technique.

8. NEW TECHNIQUES FOR BROADBAND ANTENNA MEASUREMENTS: J.D. Adams and W.R. Cooke, Georgia Institute of Technology, Atlanta

Current and projected radar and communication systems for many applications will require increased signal bandwidth to satisfy requirements for greater range resolution and accuracy (radar systems), and high data rates (communication systems). For some radar applications, pulse widths on the order of one-nanosecond, which corresponds to range resolutions of about 6 inches, are currently being considered. Generation, radiation, and reception of a nanosecond pulse will demand a signal bandwidth of at least 1 GHz. In communication applications, it has been predicted that within the next ten years we will see the realization of 2.5 GHz bandwidth communication systems in the 20 and 30 GHz regions.

Past techniques for broadband antenna measurements have been limited and inflexible. To alleviate this problem, Georgia Tech is developing innovative techniques for evaluation and analysis of relatively high gain microwave antennas over octave instantaneous signal bandwidths. Two new measurement techniques have been synthesized, and measurement systems based on these techniques have been designed. The first system uses amplitude only information while the second system uses both amplitude and phase information. Thus, the second system allows one to obtain, within the system's octave bandwidth limitation, all the possible information about a particular antenna.

The new amplitude-only antenna measurement system has been breadboarded abd utilized to measure antenna response at instantaneous bandwidths up to 1.5 GHz. Although this system determines and employs amplitude information only, it nevertheless represents an advancement over conventional measurements (which employ only CW signals) since it can provide instantaneous average spatial pattern information and average gain over up to an octave bandwidth.

9. COMPARISON OF MODELS FOR CALCULATING EFFECT OF RADOME DAMAGE ON MONOPULSE ANTENNA PATTERNS: R.J. Papa, RADC/ETEP, Hanscom AFB, MA

Several different aperture blocking models are used for calculating the far field radiation patterns of monopulse radar antennas covered by a damaged radome. The damaged portion of the radome (patch area) is characterized by a complex dielectric constant which differs from the unperturbed radome material. Several computer models are used to study boresight shifts in the monopulse difference patterns for various patch shapes, patch sizes and patch locations. The effect of the patch shape and location on the tracking signal is also investigated. First order diffraction effects are taken into account by using a plane wave spectrum-surface integration technique to calculate the far field pattern of antennas covered by a damaged radome of ogival shape. A computer model has been developed to study the effect on the boresight axis of a noise source in the near field of a partially blocked aperture corresponding to a monopulse antenna. The uncertainty in angular position of the boresight axis due to the noise source is studied as a function of the system parameters.

Commission B - Session 5

Thursday, October 14 0900 - 1215
GROUND EFFECTS ON ANTENNAS
Chairman: C.D. Taylor, Mississippi State University

1. THEORY OF THE INSULATED LINEAR ANTENNA IN A DISSIPATIVE MEDIUM: K.M. Lee, T.T. Wu and R.W.P. King, Harvard Univ., Cambridge, MA

The theoretical model of an insulated antenna in a general ambient medium is reviewed briefly. Attention is then directed to the solution of the integral equation for the current distribution in the antenna. The properties of the kernel are discussed in detail and approximate solutions for the complex wave number obtained. The evaluation of the kernel and other related numerical problems are discussed and a numerical method of computation is presented. A discussion of approximate solutions is included. A comparison of the theoretical results with measured data and numerical computations is made to check the applicable range of the theory.

2. THE HORIZONTAL WIRE ANTENNA OVER AN IMPERFECT CONDUCTOR: R.M. Sorbello and R.W.P. King, Harvard Univ., Cambridge, MA

When a wire antenna is placed horizontally in proximity to an imperfectly conducting half-space, the antenna properties may be vastly different from the isolated antenna case. The wave number for the current distribution on the antenna can be shown to depend on the electrical properties of the medium over which the antenna is placed and on the height at which the antenna is positioned. Measurements have been made to determine the wave numbers that exist on the antenna placed at heights ranging from $.01\lambda_0$ to $.25\lambda_0$ over a variety of media including fresh water, salt water and moist earth. These measurements are compared with theoretical predictions developed by King, Wu and Shen and the ranges of validity for this theory are discussed. For antennas of finite length special attention must be given to the transmission-line-type end effect associated with the nonuniformity in the transmission-line parameters at the end of the wire. This end effect has been determined experimentally for the above cases. The influence of this effect on the measured wave numbers is discussed along with the current and charge distributions and input admittance of the antenna.

3. FINITE CYLINDRICAL SCATTERER NEAR IMPERFECTLY CONDUCTING GROUND: D.H. Herndon Auburn University, AL

A Pocklington type integro-differential equation is formulated for the current induced on a finite length, cylindrical scatterer, near and parallel to a finitely conducting ground plane. Image theory is used where the current on the image is related to the current on the object by the ratio of the complex reflection coefficient for the appropriate angle of incidence and polarization involved. An expression for the circumferential variation of the axial current is derived using quasi-static image theory. This expression is then implemented in the equation for the induced currents. Through application of the method of moments the equations for the induced currents are reduced to a set of matrix equations which are inverted numerically, and uniform and non-uniform circumferential current distribution are compared.

4. RADIATION FROM A PARALLEL-PLATE, FLANGED WAVEGUIDE OVER A FINITELY-CONDUCTING GROUND: C.M. Butler, Univ. of Mississippi, and D.B. Seidel, G.L. Jackson, W.A. Johnson, and P.Y. Sako, Univ. of Arizona, Tucson

Aperture and radiated fields are calculated for the problem of a TEM-driven, parallel-plate, flanged waveguide which opens over a finitely-conducting ground (earth or sea). An integral equation, accounting fully for the presence of the lossy ground, is formulated for this aperture antenna problem and is solved numerically. Data illustrating input impedance, aperture fields, and radiated fields are presented for cases of interest, and the influence upon these quantities of the presence of the earth or sea is assessed.

5. MODAL EXCITATION AND PROPAGATION ALONG A GOUBAU LINE PARALLEL TO THE AIR-EARTH INTERFACE: D.C. Chang, E.F. Kuester and S.W. Maley, Univ. of Colorado

Wave propagation along thin-wire structures parallel to a lossy half-space is considered from a waveguide mode viewpoint. It is shown that the total current on the wire due to an aperture excitation can be uniquely decomposed into discrete and continuous modal currents, whose corresponding fields form an orthogonal set. Dependence of the discrete modal propagation constants of a Goubau line over the earth upon the parameters of the line are discussed, and for certain combinations of these parameters, the two discrete modes are shown to degenerate. This unusual behavior, absent at low frequencies, will complicate the application of these structures in practice. Some preliminary experimental results in support of the possible existence of two discrete modes will be given.

6. GEOPHYSICAL SUBSURFACE PROBING WITH HORIZONTAL ELECTRIC AND MAGNETIC DIPOLE ANTENNAS: J.A. Kong, D. Cheng, and L. Tsang, M.I.T.

Radiation patterns and interference plots are examined when a horizontal dipole antenna is used in geophysical subsurface probing. We consider media that are uniaxially anisotropic with optic axes perpendicular to the interface. Radiation patterns in the end-fire and the broadside directions are plotted for different uniaxial permittivities and permeabilities. The performance of horizontal electric and horizontal magnetic dipoles are compared. The results reveal that the use of a horizontal magnetic dipole is more effective in subsurface probing because its radiation pattern exhibits very sharp concentration of power at some particular angles. In the broadside direction the angle is at $\tan^{-1}(n^2a^2 - a)^{-1/2}$ where n is the refractive index of the medium and a is the ratio of the dielectric constant along the optic axis to that perpendicular to the optic axis. This concentration of power launched into the medium will be displayed as a function of distance when there is a subsurface layer. The sharp peaks occur at distances $2md(n^2a^2 - a)^{-1/2}$ where m is any integer and d is the depth of the subsurface. Compared with the results calculated for a horizontal electric dipole, we may conclude that the horizontal magnetic dipole provides a clearer indication of the depth of a subsurface for both isotropic and anisotropic media.

7. WIDEBAND INDUCTION SYSTEM CHARACTERIZATION OF AN UNDERGROUND COAL BURN CAVITY: E.A. Quincy, Univ. of Wyoming, and D.F. Moore, U.S. Energy R&D Adm., Laramie

A conducting cavity in an underground coal burn was remotely probed from the surface with a wideband electromagnetic induction system. The cavity, located near Hanna, Wyoming, was produced by underground gasification of a 30-foot thick subbituminous coal seam ranging in depth from 300 to 400 feet. The cavity filled with saline ground water after the burn. The wideband loop-loop system employed pseudo-noise and cross-correlation techniques to produce a transient time response in the field. Additional computer processing produced normalized 3-dimensional signature maps in both the time and frequency domains. These horizontal profiling maps, corresponding to a 100 Hz - 50 kHz passband, demonstrate that a significant anomaly is produced by the cavity as the system is moved across the site. Time domain maps show nearly a 6 to 1 change in relative peak-to-peak values whereas the frequency domain magnitude response changes as much as 36 to 1. Results were corroborated using another single-frequency system. These anomalies demonstrate the feasibility of employing induction systems to remotely characterize underground coal burn cavities filled with conducting fluid.

8. ELECTROMAGNETIC MODELING OF REFLECTIONS INSIDE A SUBSURFACE GASIFIED COAL SEAM: J.J. Holmes and C.A. Balanis, West Virginia University, Morgantown

To aid in the design of an electromagnetic system for the detection, monitoring, and mapping of the burn front of an underground coal gasification (UCG) process, an analytical model has been developed that will predict the magnitude of the electromagnetic field reflected from the gasified portion of the coal seam. The modeling scheme is representative of a transceiver embedded in a coal seam with its antenna directed toward the gasified section. The monitoring system transmits a radio wave that propagates along the coal seam, reflects off the coal-gasified section interface, and returns along the seam to the receiver located at or near the transmitter.

The coal and gasified section have been modeled electrically as lossy media, surrounded above and below by relatively high conducting overburden and underburden. Vertical and horizontal electric and magnetic dipole antennas have been investigated, utilizing a geometrical optics formulation which also takes into account the physical roughness of the coal-overburden (underburden) and coal-gasified section boundaries. Indications are that an electric or magnetic dipole antenna oriented to yield a vertically-polarized wave produces the strongest reflected fields. It is believed that the lack of phasing and the strong reflections off the boundaries, of the vertically-polarized wave, causes its favorable propagation characteristics.

9. NATURAL PROPAGATION OF ELECTROMAGNETIC WAVES IN TUNNELS: L. Deryck, Univ. de Liege

A complete experimental study in various tunnels, and for frequencies comprised between 1 MHz and 1,000 MHz is presented. The results obtained make possible a better understanding of the different propagation processes in underground galleries.

Experiments were made in a tunnel without any conductor and the conductivity of the underground was evaluated "in situ".

The analyses of the results show the existence of cut off frequency and enable us to distinguish three different fields of frequency, characterized by three different processes of propagation.

Under cut off frequency, waves propagate through the rock, in the same way as if there was no cavity. The attenuation increases with the square root of frequency and is depending on the conductivity of the underground.

In the neighborhood of cut off, just below it, attenuation is only determined by the shape and geometrical dimensions of the tunnel. It is independent of conductivity.

At frequencies above cut off, the experimental results are strongly correlated with the theoretical attenuation of the fundamental waveguide modes.

The checking of these conclusions was made in road tunnels of various shapes and dimensions. These results are also presented; they show the strong correlation between the propagation and the electrical properties of the walls of the tunnel.

Commission F - Session 4

Thursday, October 14 0900 - 1215
RADIO METEOROLOGY
Chairman: I. Katz, ~~Raytheon Co.~~

1. THE DEPENDENCE OF PATH DIVERSITY PERFORMANCE ON BASELINE SEPARATION DISTANCE AND ORIENTATION: D.B. Hodge, The Ohio State Univ., Columbus, OH.

The performance of earth-space path diversity systems in the Montreal, Quebec, area was simulated using 3 GHz radar backscatter data from the McGill Radar Weather Observatory. The radar data were calibrated directly in terms of path attenuation by means of two 13 GHz radiometers implemented by the Communications Research Centre within the field of view of the radar.

The baseline separation distances required to obtain 95% of the maximum achievable diversity gain ranged from 19 to 31 km depending on the path azimuth and elevation angles. These distances are somewhat larger than those reported earlier for diversity systems operating in Ohio and New Jersey. The diversity gain was found to depend only weakly on the orientation of the baseline with the optimum orientation nearly bisecting the angle bewteen the propagation path and the axis of predominant rain cell orientation.

2. A MODEL FOR MICROWAVE PROPAGATION ALONG AN EARTH-SATELLITE PATH: D.J. Fang and J. Jih

Recent studies of microwave transmission through a precipitation medium have contributed to clarify the mechanism of propagation and have also provided a framework for the interpretation of measurements at centimeter and millimeter wavelengths. However, the problem of utilizing the results of theoretical studies to establish engineering models and eventually to make reliable predictions of propagation characteristics on a specific satellite-earth microwave link remains to be resolved. The primary difficulties are related to the effect of elevation angle on propagation parameters, which is not known in detail, the precise evaluation of the raindrop canting effect, for which equations are not available, and the scaling of the propagation parameters, for which precise procedures are not established.

The present paper attempts to provide engineering solutions to these problems. A slant path model is developed for electromagnetic wave propagation at centimeter and millimeter wavelengths through rain. Considerations which taken into account the random canting effect of raindrops are provided. The scaling procedures for transferring propagation information from one polarization to another, one frequency to another, and one elevation angle to another are demonstrated step by step. (This paper is based upon work performed in COMSAT Laboratories under the sponsorship of the International Telecommunications Satellite Organization (INTELSAT). Views expressed in this paper are not necessarily those of INTELSAT.)

3. VALIDITY OF THE EXPONENTIAL DROP SIZE DISTRIBUTION ASSUMPTION IN DETERMINING RAIN RATE AND LIQUID WATER CONTENT USING DUAL WAVELENGTH RADARS: J. Goldhirsh, Johns Hopkins Univ., Laurel, MD.

The assumption is tested for using an equivalent exponential drop size distribution in a dual wavelength radar method to ascertain rain rate, R, and liquid water

content, M. The dual wavelength system utilizes the assumption that the drop size distribution has the form, $N_0 \exp(-\Lambda D)$, where N_0 and Λ are parameters determined from the radar measurements. The technique also employs the use of the attenuation coefficient, k[dB/km] as measured with a K_a band radar (f = 30 GHz) and the reflectivity factor, $Z[mm^6/m^3]$, as measured using an S-band radar (f = 3 GHz).

Through the analysis of 122 measured raindrop spectra, the validity of the assumed exponential drop size distribution is tested. Specifically, values of k at 30 GHz and Z are initially calculated from the measures spectra. These parameters are presumed to be the same as measured using a dual wavelength system. An equivalent exponential drop size distribution is calculated from which R and M are estimated. These are compared with the "true" precipitation parameters calculated using the measured spectra. The dual wavelength method gives percentage rms differences for rain rate, R, and liquid water content, M, to within 5% and 8%, respectively, when compared with the directly calculated quantities using the measured spectra.

4. THE ZEROING OF CROSS POLARIZATION FOR TRANSMISSIONS THROUGH A RAIN MEDIUM: G.C. McCormick and A. Hendry, National Research Council of Canada, Ontario.

In one of the simplest rain models all drops are taken to be equioriented oblate spheroids. The two linear polarizations which are transmitted unchanged through this medium are specified by a single real parameter, the drop canting angle. More complex models require the transmission of elliptical polarizations to achieve zero cross polarization; in general, two complex parameters (that is, four real parameters) are required for the specification of these two characteristic polarizations. The simpler models are seldom adequate for an exact presentation; thus, for example, inhomogeneous rain requires all four parameters.

Methods for measuring the three minor parameters, additional to the real part of the canting angle, are discussed. It is believed from preliminary observations that they do not have engineering significance.

A related question is whether the coherence of radiation is decreased by transmission through a rain medium. If such were the case, the resulting cross polarization could not be zeroed by an adjustment of the transmission polarization. Certain attempts to measure the degradation of coherence caused by rain have been negative. However, its detection may be possible by means of different or improved techniques.

5. SHORT DURATION RAINFALL RATES AND TERRESTRIAL RADIO LINK ATTENUATION ACROSS CANADA: B. Segal, Communications Research Centre, Ottawa, Canada, and D.B. Hodge, Ohio State Univ., Columbus, OH.

The probability of circuit degradation or outage due to liquid precipitation is an important consideration in the design of terrestrial microwave links. This paper presents some initial results of an intensive study of recorded rainfall observations. Precipitation records at some 45 meteorological stations covering all regions of Canada are being analyzed with approximately one minute resolution. A 10 year mean data base is being used to ensure the climatological validity of the results.

On the basis of a 'synthetic storm' model and employing short duration rainfall rates, predictions are made of attenuation over terrestrial paths. Variations in rainfall and attenuation rates as functions of various pertinent parameters will be presented for several locations. Some comparison with experimental observations will be made.

6. THE TROPOSPHERIC REFRACTIVE INDEX OVER CANADA: B. Segal, Communications Research Centre, Ottawa, Canada.

Various studies have been conducted of the refractivity at the surface of the earth and of the gradients in the lowest levels of the troposphere for different geographic areas. However, very few statistical data relating to the Canadian portion of the North American continent have been published. An effort is currently under way at C.R.C. to analyze 10 or more years' meteorological observations routinely recorded at some 70 locations in Canada and in the contiguous areas of the United States. For most of these locations, twice daily radiosonde observations and hourly surface readings are being studied. The seasonal characteristics of surface refractivity have been derived for different regions of the country. Cumulative distributions of refractivity gradients, calculated from the surface to heights between 50 and 1000 metres, will also be presented.

7. THE BASIS OF THE aR^b RELATION IN THE CALCULATION OF RAIN ATTENUATION: D.V. Rogers and R.L. Olsen, Communications Research Centre, Ottawa, Canada, and D.B. Hodge, The Ohio State Univ., Columbus, OH.

Because of its simplicity, the approximate relation $\alpha = aR^b$ between the specific attenuation α and the rainrate R is often used in the calculation of rain attenuation statistics. Values for the frequency-dependent parameters a and b are, however, available for only a limited number of frequencies. Some of these values, furthermore, were obtained experimentally, and may contain errors due to limitations in the experimental techniques employed. In this paper, the theoretical basis of the aR^b relation is discussed, and a comprehensive and self-consistent set of curves for a and b is presented for the frequency range 1-1000 GHz. Empirical equations for these curves, suitable for design applications, are also given. The a and b values were computed by applying logarithmic regression to Mie scattering calculations. The dropsize distributions of Laws and Parsons, Marshall and Palmer, and Joss, Thams, and Waldvogel were employed to provide values applicable to "widespread" and "convective" rain. Suggestions are made regarding the application of these results.

8. A MODEL FOR THE REFRACTIVE-INDEX STRUCTURE CONSTANT AT MICROWAVE FREQUENCIES: W.D. Brown, Sandia Laboratories, Albuquerque, NM.

A model for the refractive-index structure constant at microwave frequencies as a function of altitude, ground-level water-vapor pressure, ground-level temperature and a vertical integral of the windspeed, is presented. This model is based primarily on temperature fluctuation data. The predictions of the model are compared with data from star scintillation experiments, refractometer measurements,

radar backscattering and microwave propagation experiments, and the results of calculations by Tatarski. The model is used to study the effects of tropospheric turbulence on the performance of an air-borne synthetic aperture radar. The main effect is to increase the synthetic aperture sidelobe level.

Commission G - Session 3

Thursday, October 14 0900 - 1215
IONOSPHERIC STRUCTURE
Chairman: J. Evans, Lincoln Laboratories

1. AURORAL ABSORPTION AND HF COMMUNCIATIONS: V. Agy, U.S. Dept. of Commerce, Inst. for Telecommunication Sciences, Boulder, CO.

The purpose here is to list and to describe problems requiring solution so reasonable calculations can be made of the effect of auroral absorption on the performance of HF circuits. It is hoped, thereby, to attract attention of workers familiar with the phenomenon and the data to entice them to leave (temporarily) the rare atmosphere of their first interest to come down to earth to help the communicator.

The problems are of two kinds: (1) those associated with the probable data base -- assumed to be provided by riometer; and (2) those having to do with space and time distributions of the phenomenon itself.

Problems of the first kind are individually related either to the relative insensitivity of the riometer (e.g., a high effective threshold), or to the non-specific height at which observed attenuation occurs (e.g., the effect of sporadic E).

The scope of the second kind of problem is indicated by a few questions: How much auroral absorption is not directly associated with magnetospheric substorms? What are the seasonal and solar cycle variations in auroral absorption occurrence? How do auroral absorption occurrence and motion vary with longitude? Strangely, perhaps, these questions (and others) are still unanswered.

2. WORLD MAPS OF TEMPERATE ZONE SPORADIC E APPLICABLE TO PROPAGATION AT VHF: E.K. Smith, Inst. for Telecommunication Sciences, U.S. Dept. of Commerce, Boulder, CO.

CCIR Interim Working Party 6/8 (VHF propagation by sporadic E) chaired by K. Miya of Japan has produced a provisional method for the prediction of sporadic-E field strength at VHF. The Miya/Sasaki method (Radio Science 1. 99-108, 1966) is employed for deriving the VHF field strength if given the statistics of foEs. The vertical incidence sporadic-E data (foEs) is offered for three regions: Europe, North America, and Asia, and also for world maps of foEs > 7 MHz. These maps were prepared in Boulder, and their derivation is the primary subject of this paper. Whether or not the proposed method will be transmitted as an international standard will be decided at the Final Meeting of CCIR Study Group 6 in the Fall of 1977. Hence, it is timely to put the new aspects of the method before the scientific community for their consideration.

3. THE OBSERVED HEIGHT-DEPENDENCE OF TID PARAMETERS, M.G. Morgan, Darthmouth College, Hanover, NH; K.A. Ballard, White Sands Missile Range, NM; and C.H.J. Calderon, Jicamarca Radio Observatory, Lima, Peru.

Seven TID's, which were observed in 1969 with three ionosondes mutually 150 km apart in Northern New Hampshire and Vermont, are analyzed. Ionograms obtained

at each site every two minutes were reduced to true-height profiles of electron density. These were converted to iso-height contours of electron density at each station as a function of time. By cross-correlating the iso-height contours among the stations at successive heights it is found that the bearing of each TID is independent of height but that a sharp minimum exists in the speed of each. By auto-correlating the contours at the single stations, it is found that a sharp maximum in the amplitude of each TID exists at the height of the minimum speed. And by cross-correlating the contours between successive heights at the single stations it is found that a maximum in the wave tilt of each TID also exists at the height of the minimum speed and the maximum amplitude. These pronounced and striking effects which are all centered on the same height for a given TID, exist just below the F layer peak and suggest trapping in that region.

4. DETERMINING THE F REGION CRITICAL FREQUENCY FROM SATELLITE-BORNE NOISE MEASUREMENTS: C.M. Rush and J. Buchau, Air Force Geophysics Laboratory, Hanscom AFB, MA.

A means of determining the F2 region critical frequency using noise measurements made on-board satellites orbiting above the F2 peak is investigated. Values of foF2 observed on ionograms recorded by the ISIS 2 satellite were compared against corresponding records of the ISIS AGC voltage trace superimposed on the ionograms. The difference between foF2 and the frequency at which the AGC trace displayed a continuous enhancement above the cosmic background level, was taken as a measure of how well noise measurements can be used to infer the sub-satellite values of foF2. It is seen that above regions of the globe where ground-based HF noise is high and the ionospheric structure does not display severe horizontal gradients, measurements of noise breaking through the ionosphere can be used to determine foF2 generally to within 1.0 MHz. Comparison of daytime and nighttime measurements over the ocean shows a considerably smaller difference between foF2 and noise breakthrough at night. It is postulated that this feature is due to multihop propagation modes that are attenuated less at night than during the day.

5. AN ANALYTICAL MODEL OF THE MAIN F-LAYER TROUGH: C.P. Pike and J. Buchau, Air Force Geophysics Laboratory, Hanscom AFB, MA.

Tabulated values of F-layer critical frequency (foF2), that were scaled from ISIS-2 topside ionograms, were used to study the main F-layer trough. These foF2 values were selected because they contained good examples of the trough near midnight, in mid-winter, and under quiet and disturbed geomagnetic conditions. The study shows that the steep electron density gradient that characterizes the poleward wall of the trough is typically equal to 4.3×10^4 electrons cm^{-3} $degree^{-1}$ The wall extends over about 3° of latitude. At the latitude of the base of the poleward through wall, the electron density is typically 4.8×10^4 electrons cm^{-3} (foF2 = 2.0 MHz). The trough is 4° wide in latitude at 2 MHz; that equatorward from the poleward trough wall. Likewise, the trough is 11° wide at 2.5 MHz and 19° wide at 3.0 MHz. An equation is given in the text that can be used to characterize foF2 values in the trough in near real-time based on readily observable geophysical parameters.

6. THE LATITUDINAL STRUCTURE OF THE AURORAL IONOSPHERE: R.R. Vondrak and M.J. Baron, Stanford Research Inst. Menlo Park, CA.

The Chatanika radar can probe the ionosphere over a latitudinal extent that includes most of the evening auroral oval. Two-dimensional (altitude, latitude) maps of the electron density distribution indicate the latitudinal extent and location of such morphological features as the plasma trough, diffuse aurora and discrete arcs. Spatial resolution is typically 5 km and several latitudinal scans from horizon to horizon can be made each hour. Repeated measurements provide information about local-time variations and temporal changes related to magnetic activity. Information that can be extracted from the radar measurements include most of the parameters necessary to specify the electrical and thermodynamic state of the ionosphere. Spatial variations in electrical conductivity can be inferred from the ionization measurements, and the simultaneous radar measurements of ion velocity provide information about the latitudinal variation of electric fields and electrojet currents. The thermal input to the ionosphere and upper atmosphere can be obtained from the measurements of Joule heating and the energy deposited by incoming auroral electrons. Example of the latitudinal variation of ionospheric parameters are shown for both quiet conditions and disturbed auroral activity.

7. RADAR MEASUREMENTS OF FIELD-ALIGNED AND HORIZONTAL CURRENTS IN AND NEAR AURORAL ARCS: Q. de la Beaujardiere and R. Vondrak, Stanford Research Inst., Menlo Park, CA.

The Chatanika incoherent scatter radar has been used to study the electric fields and horizontal currents associated with auroral arcs. Other ionspheric parameters determined from the measurements include both the total field-aligned current and the current carried by the incoming auroral electrons. The experiments were performed while the radar antenna was fixed and directed toward the geomagnetic west. The eastward and northward components of the horizontal electric field and current were computed from measurements of the ion velocity at two different altitudes. The parallel current was deduced from the divergence of the horizontal current. An example is given of a quiet pre-midnight arc aligned in the E-W direction. It is found that: 1) There is a N-S polarization field within the arc. 2) The westward electric field is correlated with the low energy (<3 keV) electron precipitation. 3) Outside the arc the horizontal current tends to flow in the E-W direction, while inside the arc it flows in a N-S direction. 4) Within the arc there is an upward Birkeland current of about 6×10^{-6} A/m^2. 5) This upward current is comparable to the difference between the energetic electron current within the arc and that outside the arc.

8. IONOSPHERIC LIMITATIONS ON ACHIEVABLE AZIMUTHAL SIDELOBE LEVELS: T.W. Washburn and L.E. Sweeney, Jr., Stanford Research Inst., Menlo Park, CA.

Spatial coherence properties of HF skywave signals have been measured to develop best-case estimates of ionosphere limitations on the azimuthal sidelobes achievable by an antenna array. An eight-channel coherent receiving system recorded signals from antenna elements arrayed in linear fashion with spacings ranging over either 10 m to 640 m or 40 m to 2.54 km. These two receiving configurations use three elements for each spacing to permit the separation of angle-of-arrival (linear

component of phase front) from residual phase fluctuations. A mid-latitude, 1300 km East-West path was instrumented to provide a saw-tooth SFCW signal for multipath discrimination and to generate ionograms for mode identification purposes. High precision measurements at each of the antenna elements were analyzed to estimate residual amplitude and phase fluctuations as a function of element spacing. Stable F-layer conditions were sampled over a period of several days. The smallest residuals measured indicate that, at best, an HF array might achieve sidelobe levels as low as -50dB a small fraction of the time for angle spacings of 10 to 30 degrees from the mainlobe.

9. THE MAGNETOPLASMA CAPACITOR: K.J. Harker and F.W. Crawford, Stanford Univ., Stanford, CA.

The plasma capacitor is an important diagnostic tool for the ionosphere. Knowledge of the plasma capacitor also sheds light on our understanding of its close relatives, the probe and the antenna. A study has been made of the role of the open-orbit electron trajectories in determining the impedance of a specularly-reflecting capacitor filled with uniform magnetoplasma. These open-orbit trajectories, which arise from the cycloidal motion of electrons striking the capacitor plates, give rise to a resistive component of the impedance. They also quench the fine structure of the impedance function associated with the temperature resonances. Results will be presented of studies by the authors in which the impedance of specularly-reflecting coaxial and planar magnetoplasma capacitors has been determined by microscopic and macroscopic approaches.

Commission J - Session 3

Thursday, October 14 0900 - 1215
ASTRONOMICAL IMAGE FORMATION I
Chairman: R. Bracewell

1. THE VLA PROJECT: A.R. Thompson, National Radio Astronomy Observatory, Socorro, NM

The Very Large Array is a radio astronomy project now being constructed by the National Radio Astronomy Observatory under contract from the National Science Foundation. The array will produce maps of the sky at radio wavelengths with resolution comparable to pictures obtained with large optical instruments. It is located on the Plains of San Augustin, 52 miles west of Socorro, New Mexico and will consist of 27 antennas arranged in an equiangular wye-shaped formation with nine antennas on each arm. The antennas are 25-meter diameter, fully-steerable paraboloids on altazimuth mounts, and can operate at wavelengths down to 1·25 cm. The arms of the array are 21 km long. A double rail track runs along each arm of the array and carries a special transporter vehicle which moves antennas from one station to another to vary the configurations. A Cassegrain feed system covers wavelengths of 18-21, 6, 2 and 1·3 cm. The electronic system includes cryogenically cooled front ends, a phase-stable local oscillator system, a TE_{01} mode waveguide communication system, and a digital delay and correlator system. The initial operation with six antennas is planned in early 1977 and full operation by 1981.

The paper reviews the progress to date including performance details on the antennas, front ends, and waveguide.

2. TWO-DIMENSIONAL MAXIMUM ENTROPY RECONSTRUCTION OF RADIO BRIGHTNESS: S.J. Wernecke, Stanford Electronics Labs, CA

This paper describes an iterative procedure for maximum entropy reconstruction of radio brightness maps from noisy interferometer measurements. The method yields a map that obeys the positivity constraint and is, in a sense, the smoothest of all brightness distributions that would reproduce the data within tolerances imposed by measurement error statistics. This approach acknowledges the fact that signal-to-noise considerations have a strong influence on useful resolution; fine structure appears in the map only if justified by measurement accuracy.

The particular function that is maximized is the difference between an entropy measure, which is the integral of the logarithm of the brightness, and a quadratic error term that depends on the disagreement between the reconstruction and the data. The major computational burden of evaluating the error term is shown to be a two-dimensional convolution sum, which can be calculated by fast Fourier transform (FFT) techniques. The efficiency of the FFT provides a tremendous computational savings with the result that maximum entropy reconstruction on a moderate-sized grid (64 x 64) is practicable at reasonable cost. Several comparative examples are shown, and a critical assessment of the results is offered. The paper concludes with mention of a number of topics needing further investigation.

3. A MATHEMATICAL-STATISTICAL DESCRIPTION OF THE ITERATIVE BEAM-REMOVING TECHNIQUE (METHOD 'CLEAN'): U.J. Schwarz, Kapteyn Astronomical Inst., Groningen, The Netherlands

The method 'CLEAN' (Hogbom, 1974) has been used successfully under a variety of circumstances. The present analysis has been made to get a better understanding of the method. The main results can be summarized as follows:

1) Convergence. A criterion is derived, which is always satisfied when applied to data derived from a Fourier transform (e.g. synthesis observations or spectra from auto-correlators) providing the weights used in the F.T. are all non-negative.

2) The F.T. of the solution is shown to be a least-squares fit to the original observed quantities (i.e. visibility or cross-correlation functions) if the solution consists of a smaller number of components than the number of independent observations.

3) An algorithm is developed which is equivalent to 'CLEAN' with an infinitesimally small loop gain.

4) A statistical analysis of the effect of noise in the observations is applied in order to investigate how well the method works to interpolate and extrapolate missing observations.

5) A new way to define a 'clean' beam is proposed which is related to the statistical analysis.

4. ON DECONVOLVING APERTURE SYNTHESIS MAPS BY THE "CLEAN" PROCEDURE: L.R. D'Addario, National Radio Astronomy Observatory, Socorro, NM

A procedure which has become popular in radio astronomy for removing sidelobe artifacts from synthesis maps is known as "clean" (Hogbom 1974). It attempts to decompose the object into point sources by a computationally efficient algorithm. In this paper, it is pointed out that difficulties are to be expected when the object is not accurately representable as points; an appropriate modification to the algorithm is suggested. Also, it is noted that the usual practice of convolving the point-source model with a "clean beam" function results in a map which is always inconsistent with the original measurements. Finally, the effects of representing the map by its samples on a fixed, finite grid (for convenience in digital computation) are investigated.

5. HYBRID PROCESSING OF APERTURE SYNTHESIS DATA: T.W. Cole, CSIRO, Sydney, Australia

Radio imaging by earth-rotation aperture synthesis is a two-step process. The instrument measures samples of the spatial frequency plane which must then be transformed to produce the map. The transformation is conventionally done in a digital computer but recent developments place doubt on the ability of purely digital devices to perform the required transformations effectively. In spectral line synthesis the data for 32 (or more) maps of 1024 x 1024 points can be produced each 12 hours and the analysis of this synthesis data requires interactive

cycling between the spectral frequency plane and map plane. The pure bulk of computation can swamp even large digital systems. Hybrid processing, combining the speed of analogue processing with the flexibility and accuracy of the digital computer, is one way to reduce this data processing bottleneck. As a result of a study of possible approaches with the Westerbork array, a number of original hybrid processors are presented. They include coherent optical, incoherent optical, and electron beam devices. Several problems emerge and recommendations result.

6. ANALOG OPTICAL PROCESSING FOR MAP SYNTHESIS: L.E. Somers, National Radio Astronomy Observatory, Charlottesville, VA

Aperture synthesis radio telescopes sample a correlation function associated with the radio sky by means of an array of interferometers. The correlation function is, under certain assumptions, related to the Fourier transform of the radio sky brightness. Thus there is need for an effective means of performing this transformation. Digital processors using the Fast Fourier Transform algorithm can usually fill this need. However the larger telescopes (e.g. the VLA) and certain experiments on some smaller telescopes require processing capability which may not be conveniently or economically available from digital processors.

Analog optical processors perform a direct Foureir Transform between the exit pupil and the image plane of the processor. The present state-of-the-art in optical processor technology suggests a very useful instrument can be built for use with the VLA. It would have application in both the continuum and spectral-line modes of operation.

This paper will present the general VLA map synthesis problem, the most attractive electro-optic processing configurations, a review of processor design considerations, and a qualitative assessment and description of map defects due to certain processor error sources.

It should be noted that this, or any other contemporary opticam image processor, does not stand alone. Rather, it is a major processing instrument with unique capabilities and limitations which is supported by and interfaced with a digital facility. The combination is truly a hybrid processor.

7. APERTURE SYNTHESIS AS HOLOGRAPHY: T.W. Cole, CSIRO, Sydney, Australia

Strong parallels exist between Fourier transform holography and earth-rotation aperture synthesis. Both are two-step imaging processes requiring a Fourier transform to reconstruct. In aperture synthesis, the reference wave is derived from one antenna of an interferometer system and interferes (correlates) with the signal from the other elements. The radio system has great flexibility since it has cables, amplifiers, phase-shifters, delay compensation, correlators and digital storage and control.

The resulting spatial frequency values can be regarded as the components of a computer generated hologram. The paper discusses the steps needed to convert the digital values to a photographic hologram. Examples of real, Westerbork data reveal the high accuracy required of the photographic recorder. The reconstructions of the holograms are used to identify types of recording errors.

The paper concludes by discussing an approach to recording which uses gratings to greatly reduce the accuracy limits required of the optical recorder.

8. ASTRONOMICAL IMAGING WITHOUT PHASE: T.W. Cole, CSIRO, Sydney, Australia

In several areas of astronomical imaging, one measures the amplitude of the spatial frequency values of the image without the ability to measure the phase of these components. Examples include long baseline radio interferometry and optical speckle interferometry. In other situations the measured phase is extremely noisy compared with the amplitude. This is common in interferometry when strong ionospheric or tropospheric gradients occur. With only the amplitudes it is shown that one obtains the autocorrelation of the true image and this paper presents an iterative procedure which resolves the autocorrelation into the true image to within a single, overall ambiguity of 180° of image rotation.

The procedure contains a continual check on the reliability of the solution and relies upon the high statistical redundancy of the typical astronomical image. It is one of a class of image dependent processing methods and general comments on these are given.

The technique is illustrated with maps obtained from the Westerbork array by neglecting phase.

Commissions A and B - Session 5A

Thursday, October 14 1400 - 1715
PHYSIOLOGICAL AND BEHAVIORAL EFFECTS
Chairman: R. Phillips, Battelle Northwest Laboratories

1. EFFECTS OF SINGLE EXPOSURES TO 2450 MHZ MICROWAVE IRRADIATION ON RAT BEHAVIOR: M.I. Gage, U.S. Environ. Protection Agency, Research Triangle Park, NC.

Eight male Sprague Bawley albino rats (Charles River CD) were trained to alternately press each of two bars in an operant conditioning task for food pellet reinforcement. After the animals learned this task and stable baseline performance was achieved, changes in this operant behavior during daily sessions immediately following exposure to 2450 MHz microwave irradiation were observed. The rats were tested after single one or 15 hour exposures to 2450 MHz (CW) irradiation at incident power levels of 0.5, 1, 5, 10, 15 and 20 mW/cm^2. Exposures to 15 and 20 mW/cm^2 for 15 hours suppressed the rate of bar press alternations, but exposures to the same levels of microwaves for only one hour did not suppress the behavior. After 20 mW/cm^2, rats displayed a minimum of 40% decrease in rate of task performance and 30% of the rats did not perform at all on this task. This study indicates that microwave power densities just above the allowable occupational exposure levels can adversely alter animal behavior. It also suggests that exposure duration, even in an environment where temperature and humidity are well controlled, is an important variable in determining microwave toxicity.

2. THERMAL AND NEUROENDOCRINE EFFECTS OF LONG TERM, LOW LEVEL MICROWAVE (2450 MHz,CW) IRRADIATION: S.-T. Lu, N. Lebda, S.M. Michaelson, S. Pettit and D. Rivera, School of Medicine and Dentistry, Univ. of Rochester.

Long-Evens rats, acclimated to the laboratory environment and procedures for two weeks and preconditioned three times to the equilibration and exposure procedures, were irradiated with 2450 MHz microwave (CW) at 1, 5, 10 and 20 mW/cm^2 for 1, 2, 4 and 8 hours. Before exposure, a three-hour equilibration period was utilized for control and irradiated rats. Post-irradiation rectal temperature varied with incident power densities and duration of exposure. None of the average group rectal temperatures exceeded that of circadian rhythmicity of the sham irradiated except the groups that were exposed to 20 mW/cm^2 for 4 to 8 hours. Again, a consistent elevation in individual rectal temperature exceeding the confident limits for each duration of exposure could only be found in rats exposed to 20 mW/cm^2 for 4 to 8 hours.

Weight loss did not exceed the fiducial limits of sham exposures, although it tended to vary from group to group. The adrenal gland weight varied between groups without a consistent change in rats exposed to different incident power densities and durations. Pituitary weight did not vary significantly. Thyroid weight changed without any consistency.

Serum thyroxine was found to be transiently elevated at 1 mW/cm^2 for four hours. Consistent and significant depression of serum thyroxine was observed in rats

exposed to 20 mW/cm^2 for 4 to 8 hours. Serum corticosterone or Growth Hormone levels did not vary significantly from control.

Thus, it is concluded that 20 mW/cm^2 incident power density (absorption rate approximately 5 W/kg) exceeded the thermoregulatory capacity of rats. The changes in the thyroid function is a result of thermoregulation.

Acknowledgement: This paper was prepared under contract No. FDA 74-111 (PHS, FDA, DHEW) sponsored by the EMR Project Office, BUMED and SURG, Dept. of the Navy, and under contract with the U.S. Energy Research and Development Administration at the University of Rochester Biomedical and Environmental Research Project and has been assigned Report No. UR-3490-963.

3. LOW INTENSITY MICROWAVE EFFECTS ON THE SYNTHESIS OF THYROID HORMONES AND SERUM PROTEINS: W.D. Travers and R.J. Vetter, Purdue Univ., W. Lafayette, IN.

The purpose of this study was to investigate the effects of chronic, low level microwave exposure on the levels T_3, T_4 and TSH and on the serum protein composition in rats. Animals were exposed to no more than 10 mW/cm^2 of 2450 MHz microwaves 8 hours per day for 21 consecutive days. Serum hormone levels were determined weekly by radioimmunoassay techniques, and serum protein composition was analyzed electrophoretically. The results and their significance on the low level exposure of man to microwave radiation will be discussed.

4. IRRADIATION OF RATS BY LOW LEVEL 918 MHz MICROWAVES: DELINEATING THE DOSE-RESPONSE RELATIONSHIP: D.E. Myers, R.H. Lovely, A.W. Guy, Univ. of Washington School of Medicine, Seattle, WA.

Eight male rats were exposed for 13 weeks to 918 MHz CW microwaves at an average incident field strength of 2.5 mW/cm^2. Exposure took place for ten hours every night yielding 910 total hours of irradiation. The exposure system consisted of cylindrical waveguides capable of delivering circularly polarized guided waves (TE_{11} mode) and plexiglass living chambers which provided standard laboratory conditions for the rodents. The waveguides allowed easy quantification of the fields for each chamber independent of other rodents being simultaneously exposed. Daily recordings of body weight and food and water intake demonstrated no significant differences between the eight irradiated and eight sham-irradiated controls. Four, eight and twelve week blood samples showed no differences in serum chemistry (i.e., Ca, Na, K, Cl, BUN, CO_2, ion gap and glucose). Corticosterone levels sampled at the end of the radiation period gave no indications of stress. During the 11th week, serial assessments were made of rectal temperatures and behavioral repertoire, neither demonstrating a significant effect of the microwave exposure. Finally, neither one- nor two-bottle saccharin preference tests suggested the presence of malaise. The significance of these results with respect to chronic exposure of rats to 10 mW/cm^2 (which does influence several of the parameters assessed), will be discussed.

5. BEHAVIORAL AND PHYSIOLOGICAL EFFECTS OF CHRONIC PULSE-MODULATED MICROWAVE RADIATION IN RATS: R.H. Lovely, D.E. Myers, R.B. Johnson, and A.W. Guy. Univ. of Washington School of Medicine, Seattle, WA.

Eight male rats were irradiated for three months with 918 MHz microwaves pulse-modulated at 11 Hz, for 10 hr/night, and at an average power density of 2.5 mW/cm^2 (spatially averaged over the cross-section of the exposure chamber). The exposure apparatus consisted of cylindrical waveguide capable of delivering circularly polarized guided waves (TE_{11} mode) and a living chamber designed to be compatible with laboratory conditions required by rodents. The cylindrical waveguide allowed for easy quantification of the fields in terms of incident power, total absorption, and specific absorption rate (SAR) for each exposed animal, independent of other rodents being simultaneously exposed. Physiological and behavioral comparisons between the eight irradiated and eight sham-irradiated control rats included daily food and saccharin/water intake. In addition, aperiodic assessments were made of deep colonic temperatures, behavioral repertoire during radiation, and serum chemistry (i.e., calcium, sodium, potassium, chlorine, blood-urea-nitrogen, CO_2, ion gap, glucose, as well as basal and ether-stress-induced levels of corticosterone). The results of these assessments will be discussed in terms of the biological effects of equivalent CW average power density as well as in terms of the existing literature.

6. EFFECTS OF CHRONIC ATHERMAL MICROWAVE RADIATION ON INNATE AND LEARNED BEHAVIORS IN RATS: D.S. Mitchell, W.G. Switzer, and E.L. Bronaugh, Southwest Research Inst., San Antonio, TX.

A multimode microwave (MW) exposure chamber was designed, calibrated, and employed to investigate the effects of chronic 2.45 GHz continuous-wave radiation at an equivalent plane-wave power density of 5 mW/cm^2 on one innate and two learned behaviors in rats. Relative to sham-irradiated controls, irradiated subjects displayed (a) statistically significant increases in locomotor activity, (b) reliable evidence of disrupted differential responding during asymptotic discriminative operant reward conditioning, but (c) no significant differences in Sidman avoidance conditioning performance. Comparisons with pre-irradiation baseline data revealed that the observed effects emerged almost immediately following the initiation of MW exposures and persisted throughout the course of a 5-hour per day, 22-week irradiation sequence. Daily core temperature sampling produced no evidence of whole-body heating in irradiated rats.

It was concluded that the observed behavioral effects are consistent with a general activation hypothesis, and although the exact mechanism remains unclear, suggest the possibility of MW-induced alterations in CNS activity.

Evaluation of the present findings in conjunction with those reported by other investigators suggests that a given behavioral outcome may depend in complex ways upon specific combinations of irradiation parameters. The need for increased standardization in laboratory techniques and paradigms was stressed, with particular emphasis on modes and procedures of irradiation.

Commissions A and B - Session 5B

Thursday, October 14 1400 - 1715
BEHAVIORAL EFFECTS
Chairman: R.H. Lovely, Univ. of Washington School of Medicine

1. BEHAVIORAL EFFECTS OF RESONANT ELECTROMAGNETIC ENERGY ABSORPTION IN RATS: J.A. D'Andrea, O.P. Gandhi, and J.L. Lords, Univ. of Utah, Salt Lake City.

Previous experiments have established the conditions of resonant electromagnetic energy absorption for the laboratory rat. To further explore the behavioral effects of this phenomenon, two experiments have been conducted using a monopole-above-ground radiation chamber. Twelve male Long Evans rats were trained to respond on a variable-interval reinforcement schedule (30 s, average) in the radiation chamber. Rats performed the task in a relatively microwave transparent Plexiglass enclosure (25 x 16 x 13 cm).

Six animals, while responding, were exposed to 20 mW/cm^2 CW radiation at frequencies of 400, 500, 600, and 750 MHz. Exposures were with the electric field parallel to the long axis of the rat. Over a period of several weeks, each rat was exposed once to each frequency. Colonic temperature was monitored before and after radiation exposures. Greatest behavioral suppression occurred at 600 MHz.

The remaining six animals, while responding, were exposed to 600 MHz radiation in both CW (20, 10, 7.5, and 5 mW/cm^2) and pulsed (1000 pps, 200 mW/cm^2 peak, pulse duration; 30 and 3 microseconds) modes. Preliminary data indicate behavioral su-pression occurs at 15, 35, and 53 minutes of radiation exposure for 20, 10, and 7.5 mW/cm^2 CW radiation, respectively.

2. IRRITABILITY AND AGGRESSION IN MAMMALS AS AFFECTED BY EXPOSURE TO ELECTRO-MAGNETIC ENERGY: A.H. Frey and J. Spector, Randomline, Inc., Huntingdon Valley, PA.

To determine the effects of electromagnetic energy on irritability or aggression, we aversively stimulated pairs of male rats to induce fighting. Tail pinch, applied with a hydraulic system, was employed as the aversive stimulus. By use of a double blind technique, we quantified and compared the fighting behavior of exposed and sham-exposed groups. There were statistically significant differences in irritability or aggression demonstrated by the exposed and sham-exposed groups.

3. FIXED INTERVAL BEHAVIOR IN RATS EXPOSED TO LOW POWER DENSITIES OF MICROWAVES: J.N. Sanza and J. de Lorge, Naval Aerospace Medical Research Lab.

Behavioral effects of 2.45 GHz microwaves 100 percent amplitude modulated at 120 Hz were studied at 8.8, 18.4 and 37.5 mW/cm^2 power densities. Rats were exposed while performing in a response chamber constructed of styrofoam. Lever pressing reinforced with food pellets on a fixed interval 50 second schedule was disrupted by 37.5 mW/cm^2 in two rats responding at high rates. Lower power densities, 8.8

and 18.4 mW/cm^2, had no observable effect on lever pressing in these rats. In two rats responding at low rates, no effects on lever pressing at any of the power densities were observed. However, general motor activity in all rats, regardless of response rate on the lever, was changed at 18.4 and 37.5 mW/cm^2 power levels. The animals tended to remain in one location at these higher power densities. The results are interpreted as illustrating an interaction between metabolic heat produced in the more frequently responding rats and microwave radiation. In addition, the experiment demonstrates a potential means of determining low power density effects on behavior other than lever pressing.

Commission B - Session 6

Thursday, October 14 1400 - 1715
POLES AND TRANSIENTS
Chairman: F.M. Tesche, Science Applications, Inc.

1. A CRITICAL LOOK AT SEM--SOME OPEN QUESTIONS AND POSSIBLE ANSWERS: R. Mittra, Univ. of Ill., Urbana, Ill.; and L.W. Pearson, Univ. of Kentucky, Lexington, KY.

Since the concept of SEM was first introduced by Baum [1] several years ago, many workers have contributed to its development and have demonstrated its usefulness to a wide variety of practical problems. However, some fundamental questions have also been raised both with regard to the completeness of SEM, and its utility in the 'early time' period which is often of most practical interest. A number of workers have found that a Class-1 pole series representation is not adequate. It has also been argued that either an entire function contribution or time varying coupling coefficients is necessary in the early time period. The latter is called the Class-2 representation [2,3].

In this paper we critically examine the entire function question which has remained unanswered to-date, and suggest a systematic test that can establish the presence or absence of this function within numerical error tolerance.

Next, we address ourselves to the important question regarding the validity of the canonical SEM Class-1 pole-series representation in the early time period and suggest that this representation is in general incomplete. Finally, we introduce a new, modified form of Class-1 representation for the early time period. A unique feature of this form is that it preserves the classical Class-1 format that allows convenient equivalent circuit modeling not available in Class-2. Some features of the new representation are discussed from a comparative point of view and the conclusions are summarized.

[1] C.E. Baum, "On the singularity expansion method for the solution of electromagnetic interaction problems," AFWL EMP Note IN 88, Dec. 1971.

[2] C.E. Baum, "The singularity expansion method," in Transient Electromagnetic Fields, L.B. Felson, Ed., Heidelberg: Springer-Verlag, 1976, ch. 3, pp. 129-179.

[3] F.M. Tesche, "On analysis of scattering and antenna problems using the singularity expansion technique," IEEE Trans. Antennas Propagat., Vol. AP-21, No. 1, pp. 53-62, January 1973.

2. POLES AND ZEROS OF THIN BICONICAL ANTENNAS: C.-T. Tai, Univ. of Michigan, Ann Arbor, MI.

The poles and zeros of the impedance function of thin biconical antennas in the Laplace-transform domain have been investigated. We have found only two pairs of layers of poles and zeros in contrast to more than two layers of poles for cylindrical antennas [F. Tesche, IEEE AP-21, p. 53, 1973] and for thin spheroidal antennas [L. Martin, IEEE AP-22, p. 266, 1974]. While the characteristics of the first layer of the zeros of the impedance function are similar to those of the cylindrical and the spheroidal antennas the distribution of the second layer appears to be quite different.

The poles of the transfer function describing the receiving current of a center loaded biconical antenna have also been studied. For purely resistive loading one finds that the poles of the transfer function are located on curves which link the poles and the zeros of the impedance function as the loading changes from short-circuit condition (R = 0) to open-circuit condition (R = ∞). Some simple interpretations of these results are given based on the natural complex frequencies of terminated transmission lines. (The research reported here is supported by the National Science Foundation under Grant ENG 75-17967.)

3. A NUMERICALLY-EFFICIENT METHOD FOR LOCATING SEM POLES: R. Mittra, Univ. of Ill., Urbana, IL; and L.W. Pearson, Univ. of Kentucky, Lexington, KY.

The Singularity Expansion Method representation provides an efficient means of describing the transient electromagnetic response of apertures and scatterers. One virtue of the representation is that it allows a catalogued description of the electromagnetic behavior of an object with few prior restrictions on the illuminating field other than its bandwidth. The price paid for this comprehensive representation is that of a rather extensive amount of numerical calculation in arriving at the representation.

In this presentation, we report a variational approach which is designed to provide computational economy to the process of locating the complex singularities (poles) of the scattering object. The method begins with a good a priori estimate of the pole and generates an objective function for a zero search algorithm using moment matrix calculations. The conventional means of searching for the zeros of the matrix determinant requires on the order of $N^3/3$ "operations". The present method requires on the order of N^2 operations.

The required estimate of the pole might be obtained from physical considerations, from pole data, from a closely related problem, or from isolation procedures such as argument number scanning. Another alternative is the conventional zero search result for a modest-sized moment matrix. The more efficient method may then be used to refine the result with a larger system matrix. Numerical procedure for using the variational approach to pole-searching is described in the paper.

4. A PROCEDURE TO FIND SIMPLE POLES FROM MAGNITUDE-ONLY REAL-FREQUENCY INFORMATION: J.N. Brittingham, E.K. Miller, and J.L. Willows, Univ. of Calif., Livermore, CA.

In previous work a procedure has been presented that uses frequency domain data to find the SEM (Singularity Expansion Method) poles and residues (J.N. Brittingham, E.K. Miller, and J.L. Willoss, "A Technique for Obtaining Simple Poles from Real-Frequency Information," The National Conference on Electromagnetic Scattering Theory, University of Illinois at Chicago Circle, Chicago, Illinois, June 15-18, 1976; also see Lawrence Livermore Laboratory, Report UCRL-52050, April 1976). The procedure, which we denoted as Frequency Domain Prony, after a related time-domain technique based on Prony's method (M.L. Van Blaricum and R. Mittra, "A Technique for Extracting the Poles and REsidues of a System Directly Form its Transient Response," IEEE Transactions on Antennas and Propagation, Vol. AP-23, No. 6, November 1975) requires knowledge of both the magnitude and phase of the data.

A new procedure for finding the SEM poles and residues using only the magnitude of the frequency response is presented, a technique that has obvious advantages, especially when using experimental data. Some results using the magnitude-only procedure are given and compared to results obtained in other ways. (This work was performed under the auspices of the U.S. Energy Research and Development Administration under contract number W-7405-ENG-48.)

5. AN EXPERIMENTAL TRANSIENT TRANSFER FUNCTION VIA PRONY'S METHOD: M.L. Van Blaricum, Mission Research Corp., Santa Barbara, CA; and D.H. Schaubert, Harry Diamond Laboratories, Adelphi, MD.

The terminal voltage response of an antenna can be obtained for any arbitrary incident waveform if the time-domain receive transfer function is known. The transfer function can be obtained from a transient experimental range if the induced voltage at the terminals can be measured when the antenna is illuminated with a known electric field. The measured induced voltage and incident field are normally digitized, Fourier transformed to the frequency domain, deconvolved to give a frequency domain transfer function, and finally Fourier transformed back to the time domain to give the time-domain transfer function. This processing is laborious, generally introduces noise, and gives only a graphical representation of the transfer function.

This paper demonstrates that Prony's method can be used with experimental transient data to obtain an accurate representation of the antenna's transfer function. Prony's method is applied to both the terminal voltage and the measured incident field to reduce each to a sum of complex exponentials. The Laplace transform of the transfer function is then written in closed form, which is more useful than a graphical representation. This approach also gives the experimenter more insight into the behavior of the antenna through the pole representation and allows a means for removing noise and extraneous signal components. The examples given are from the Harry Diamond Laboratories' transient test facility.

6. SUPPRESSING SOME NOISE DIFFICULTIES IN PRONY PROCESSING: D.L. Lager, A.J. Poggio, and H.G. Hudson, Univ. of California, Livermore, CA.

The determination of the complex natural frequencies and complex amplitudes which characterize transient data is difficult in the presence of noise. Even the calculation of the predominant parameters is affected by noise. In order to minimize these effects, the noise problem is being systematically studied with the noise-induced aliasing problem being the first considered.

It is shown in this paper that by using a low pass filter whose cutoff is set in a notch in the signal spectrum the aliasing problem is circumvented. The effect of the filter is shown to be minimal if the cutoff is properly chosen while the converse is also well illustrated. Some guidelines for use of ideal filtering of the numerical data are presented and some results from processing experimental data which has previously been shown to be highly unreliable without filtering is now shown to be possible. (This work was performed under the auspices of the U.S. Energy Research and Development Administration under contract no. W-7405-ENG-48.)

7. RANDOM ERRORS IN PRONY'S METHOD: D.G. Dudley (Univ. of AZ), Summer Visitor, Lawrence Livermore Laboratory, Livermore, CA.

Recent advances in analytical and experimental electromagnetic techniques associated with object identification have caused a renewed interest in the representation of a known function by a complex exponential series (Prony's Method). It is well-known that the method, which requires formation of a sequence of samples of the known function, can transform small perturbations in the sampled data into large variations in parameters associated with the exponential series. This effect is present even in systems so simple that they can be represented by two terms in the expansion. We consider small perturbations in the sampled data for the two-term case and find that although the system evaluation process is non-linear, the perturbations go through linearly. We adopt a statistical description of the perturbations and produce probability distribution functions for each step of the process. As a result of the analysis, we give error bounds for the two-term case and give some extensions to the general system. (This work was performed under the auspices of the U.S. Energy Research and Development Administration under contract no. W-7405-ENG-48.)

8. TRANSIENT RESPONSE OF A HELICAL ANTENNA: B.K. Singaraju, Dikewood Industries, Inc., and R.L. Gardner, Univ. of Colorado.

In this work, transient response of a helical antenna over a ground plane is calculated using the singularity expansion method (SEM). Pocklington and Hallen type integral equations are derived for a helical antenna. It is shown that these equations simplify for large pitch angles. Natural frequencies and natural modes for a helical antenna are calculated analytically from the Hallen type integral equation while numerical results are obtained by using Pocklington form of integral equation. Trajectories of the natural frequencies as the pitch angles of the helix is changed are plotted. These trajectories explain why a helical antenna performs well at some frequencies which are some functions of its length.

Using singularity expansion method the short circuit current induced on the antenna is calculated. Using the terminal impedance calculated by the SEM approach, the induced terminal voltage is obtained. Two examples involving a triangular and a rectangular incident pulse are treated in detail along with comparisons with the measured responses.

9. THE IMPULSE RESPONSE OF RECTANGULAR FLAT PLATES: C.L. Bennett, Sperry Research Center, Subdury, MA.

Recently coupling integral equation solutions with asymptotic techniques has become of interest. This paper presents the impulse response augmentation technique which combines the smoothed impulse response solution of the space-time integral equation with known variations of the actual impulse response as given by geometric optics, physical optics, or geometric theory of diffraction. This technique which operated on the far field has been demonstrated for the case of a sphere and shown to be in good agreement with the theoretical response, both in the time domain and in the frequency domain. Results have also been obtained for a prolate spheroid and for a right circular cylinder. In this paper the impulse response augmentation technique is applied to the case of a rectangular flat plate. Results at various angles are presented and discussed for both TE and TM polarizations.

Commission B - Session 7

Thursday, October 14 1400 - 1715
FIBER AND INTEGRATED OPTICS I
Chairman: D.C. Chang, Univ. of Colorado

1. THE NATIONAL SCIENCE FOUNDATION PROGRAM IN OPTICAL COMMUNICATION SYSTEMS: E. Schutzman, National Science Foundation, Washington, D.C.

A coherent program effort in Optical Communication Systems was initiated at the National Science Foundation in January 1972. The goal of the program is to provide useful and fundamental information for long-range, high-capacity communication system. The technical area under investigation is broadly divided into two classes; namely, devices and systems. In the device effort, projects involve both integrated optical and discrete components with a view toward single-mode applications. The major emphasis in the systems area is the determination of the conditions under which the atmospheric channel will prove to be a viable communication link. This part of the program possesses a strong experimental component. Other important characteristics of the overall program include interaction between device and systems people, and among grantees from the university and their industrial colleagues. At the present time, twenty-five projects are being supported.

2. SURVEY OF INTEGRATED OPTICS WORK IN THE U.S.: J.R. Whinnery, Univ. of California, Berkeley, CA.

There have been recent dramatic advances in guided-wave optical devices and although only a few functions have so far been integrated onto a single substrate, the individual devices are being applied and there is promise for integration in the future. The most dramatic advances have occurred with respect to semiconductor lasers, with GaAs and GaAlAs lasers now operating at room temperature with long life. A variety of techniques, including chemical etching, liquid-phase epitaxy and ion bombardment have been successfully used for fabricating wave guides on these materials. Similar advances have been made with respect to guiding and electro-optic effects on $LiNbO_3$ and $LiTaO_3$ and some important applications of these materials will be described. Recent acoustooptic Bragg diffractors will also be reported. A few unconventional approaches, including liquid-crystal devices, magneto-optic devices and guiding by curved dielectric surfaces, will be described.

3. ON NON-CIRCULAR AND INHOMOGENEOUS FIBER OR IOC WAVEGUIDES: C. Yeh, Univ. of California, Los Angeles, CA.

Since the attainment of glass fibers with attenuation below 3 dB/km, communication via optical fibers is no longer a dream but a reality. Practical optical fiber and integrated optical circuit (IOC) waveguides may take on many different forms. Understanding of the propagation characteristics of optical signals along guiding structures depends on the availability of analytic or numerical solutions of the problems. Analytic solutions are known for only a few light-guiding structures with simple geometrical shapes, such as circular cylinders, elliptical cylinders, or planar layers. Approximate solutions are also available for homogeneous rectangular cylinders provided that the refractive index of the core region is only slightly higher than that of the surrounding region. The need to have a method that is capable of providing the solutions to the problem of waveguiding

along practical guiding structures, which may be inhomogeneous optical fibers with noncircular core cross-sections or may be inhomogeneous channel or embossed integrated optical waveguides, is quite apparent.

Significant advances in recent years in the successful application of the infinite element method to the complicated structural and continuum mechanics problems provided the impetus for us to search for the possible application of the finite element technique to problems involving optical waveguiding. It will be demonstrated that the finite element technique can be easily used to predict the behavior of guided signals along non-circular and inhomogeneous guides of practical interest.

4. CURVATURE DISCONTINUITIES IN INTEGRATED OPTICAL GUIDING STRUCTURES: E.F. Keuster and D.C. Chang, Univ. of Colorado, Boulder, CO.

Recent investigations by the authors have examined the scattering of a surface wave at convex and concave curvature discontinuities in a lossless reactive guiding surface. In these approaches, a "boundary layer" was used which emphasized the relation to a straight waveguide, while at the same time retaining the multiple reflection phenomena characteristic of concave surfaces. In this paper, structures more accurately representing those actually used in integrated optics will be considered, such as the dielectric slab, or the single dielectric interface which supports the so-called "edge-guided" variety of whispering gallery mode. The radiation through this mechanism is compared with that continuously radiated by the surface wave as it propagates around a curved section. It is shown that either of these contributions can be dominant for realistic choices of the guide parameters.

5. COUPLED MODE APPROACHES TO SPATIALLY PERIODIC MEDIA IN INTEGRATED OPTICS: J.A. Kong, Mass. Inst. of Tech., Cambridge, MA.

In the study of periodic media with applications to various active and passive components in integrated optics and in holography, coupled mode approaches prove to be the simplest method leading to results that can be easily interpreted physically. Conventional coupled mode equations are first order differential equations derivable directly from field equations by discarding terms involving second order derivatives. However once these second order terms are discarded, the boundary conditions for a given boundary value problem can no longer be suitably handled by these first order equations.

In this report we summarize the derivation, the solution and the application of a new set of second order coupled mode equations. The coupled mode equations reduce, in the appropriate limits, to those used by Klein and Cook, Kogelnik, Phariseau, and Raman and Nath. Their relationship with the modal approach by Chu and Tamir is compared and discussed. To illustrate, we solve the problem of reflection and transmission by a slab periodic medium. The reflected modes, absent in the other theories, are shown to be very significant in the application to integrated optics and holography. The results are applied to the interpretation of experimental data for electrooptical modulators.

6. HIGHER-ORDER BRAGG INTERACTIONS IN PERIODIC MEDIA: D.L. Jaggard and C. Elachi, Calif. Inst. of Tech., Pasadena, CA.

The extended coupled waves (ECW) theory is applied to active and passive longitudinally periodic media at all Bragg resonances. Both inverting and non-inverting bandgaps appear which depend upon Bragg order and coupling type. Multiharmonic periodicities allow control of feedback strength and can cause bandgaps to disappear if properly phased. Stability criteria are applied to find explicit values for instability threshold, frequency and temporal growth in infinite active media. It is found that odd-order gain coupling can cause instabilities with zero or slightly negative average gain.

Applications of the ECW theory to higher-order reflection and transmission DFB filters show the effect of boundary coupling and various periodicity profiles.

Higher-order DFB laser characteristics show an asymmetry in the longitudinal mode spectrum. Threshold gains are proportional to η^{-2N} or η^{N} for index and even-order gain coupling or odd-order gain coupling where N is the Bragg order and η is the periodicity perturbation.

Higher-order coupling in transversely-periodic media can be treated in a way similar to the previous cases.

7. COUPLING EFFECTS BETWEEN TE AND TM MODES ON STRIP AND SLOT WAVEGUIDES FOR INTEGRATED OPTICS: S.T. Peng and A.A. Oliner, Polytech. Inst. of New York, Brooklyn, NY.

All solutions for integrated optics waveguides which have so far appeared in the literature assume the presence of only a single TM or TE wave in the waveguide transverse direction. In fact, however, such a single mode incident on the strip or slot transverse boundaries inevitably excites the other mode type. In many cases this coupling is quantitatively very small, although in some cases it can be significant. Even more interesting, however, are some of the qualitative implications.

Some of these implications, together with numerical results for both dielectric strip and metallic slot waveguides, will be presented in the talk. Two principal implications are: (a) almost all modes in principle become leaky (rather than completely bound) due to the coupling, and (b) for TM modes on the slot waveguide, a resonance effect occurs for specific film thicknesses which produces a dramatic reduction in the attenuation of the waveguide.

8. RESONANT POLARIZATION CONVERSION AND BEAM SHIFT ON PLANAR MULTILAYERED STRUCTURE: H. Kitajima, Univ. of Ill., Urbana, IL, and K. Hano, Kyushu Inst. of Tech., Kitakyushu, Japan.

In this paper we show resonant polarization conversion and beam shift on a planar structure composed of four layers: a top (input and output) region, a gap, a film-waveguide, and a substrate. In case the substrate is an anisotropic or a gyrotropic medium and the other layers are all isotropic media, TM- and TE-waves in the film are coupled by the off-diagonal elements of the dielectric tensor of

the substrate. Furthermore, under the optimum condition, polarization of the incident field from the top region is almost completely converted to the cross polarization. This conversion characteristic has the same form as that of conventional coupled resonators. When the gap is an anisotropic medium and the other layers are all isotropic media, the difference between the attenuation constants of the TM- and TE-waves in the gap gives rise to another interesting characteristic. Instead of the polarization conversion, one obtains a large beam shift nearly twice the ordinary beam shift of a prism coupler. These characteristics may be used for modulation or for switching.

9. MODAL COUPLING IN CONTINUOUS SPECTRUM FOR INTEGRATED OPTICAL GUIDING STRUCTURES: V. Daniele and R.S. Zich, CESPA(CNR) and Instituto di Elettronica e Telecommuicazioni, Politecnico di Torino, Italy; and I. Montrosset, Instituto di Elettronica e Telecommunicazioni, Politecnico di Torino, Italy.

This work aims to develop a computing technique, usable for a wide class of configurations and materials, for the calculation of the propagation characteristics of guiding structures for integrated optics. In particular, the dispersion curves of such structures, together with the field distribution for each mode, are evaluated.

This method can be defined "a spectral perturbation technique" and consists in formulating the problem through the coupling of continuous and discrete modes of a simpler structure, whose modal characteristics are known. In the case of a slab or of an optical fiber with arbitrary cross section and refractive index profile, the propagation of the electromagnetic wave can be interpreted in terms of coupling of the free-space modes (continuous spectrum) due to the presence of the dielectric material. In this phenomenon, a discrete spectrum also arises, which can be correctly interpreted as a perturbation, and which gives the set of moded guided by the structure.

In general, the modal coupling can be taken into account by introducing appropriate transmission lines representing the modes of the unperturbed structure, subject to mutual coupling cecause of the equivalent volume currents representing the perturbation.

This formulation leads to a homogeneous integral equation, whose eigenvalues are related to the propagation constants of the modes of the perturbed structures. For the solution of such equation the moment method has been found quite convenient. In the particular case of mode coupling in free space, Hermite polynomials have been used, thus simplifying the evaluation of the matrix representing the kernel of the integral equation.

Calculations for the case of a dielectric slab with constant and parabolic refractive indexes have been made. It has been observed that a finite number of eigenvalues represent the discrete spectrum. It has also been noted that the eigenvalues of the discrete spectrum do not vary appreciably by increasing the number of test functions, while those of the continuous spectrum are unstable. The numerical results are in good agreement with the theoretical ones, which are known by other methods.

Commission F - Session F5

Thursday, October 14 1400-1715
RADIO OCEANOGRAPHY
Chairman: Don Barricks

1. A MODEL FOR SEA CLUTTER INTERMITTENCY AT EXTREME GRAZING ANGLES: L. Wetzel, Naval Research Lab., Washington, D.C.

The behavior of microwave sea clutter at extreme grazing angles (0 - 1°) tends to be spiky and irregular, with ill-defined statistics. Intuition suggests that at these extreme angles, most of the surface is in shadow, and only an occasional peak is visible to the radar. In order to sharpen this intuition, the conventional shadowing function (viewed here as a "stochastic height-gain function") is taken to define a scattering threshold whose height above the mean surface is a function of grazing angle and average surface slope. Using the spatial analogue of the familiar idea of "surges" and "fades" of a thresholded random process, the surface is found to be pockmarked by scattering islands of relatively constant size, but whose density (spacing^{-2}) is a sensitive function of grazing angle and sea slope. This model raises some interesting questions about the practical determination of grazing angle, the interpretation of scattering models, and the meaning of shadowing. These questions will be discussed in terms of the model and its application.

2. FINE TIME SCALE, TWO DIMENSIONAL SEA SURFACE SPECTRA IN THE HIGH FREQUENCY RANGE TAKEN FROM SEA PHOTOGRAPHS: T.G. Konrad and R.S. Kasevich, Johns Hopkins Univ., MD., and J.R. Rowland, and T.W. Flanagan, Raytheon Company, MA

During the 1975 Joint North Sea Wave Project (JONSWAP) experiment, time series photographs of the sea surface (four frames per second) were taken from a tower. The purpose of this experiment was to determine the time dependent behavior of the high frequency wave spectra, i.e., in the wavelength range from 3 to 30 cm.

Several twenty minutes periods on different days under different sea conditions have been processed using the Stilwell optical Fourier analysis technique. Equipment for the rapid processing of the optical photographs has been developed. The resulting two-dimensional slope spectra were then detected, false color coded, and photographed. The time series photographs of the two-dimensional spectra, in the form of a slow motion movie, clearly show the modulation in the high frequency portion of the spectra as well as directional changes. The extent and manner in which the spectra change over short time periods, a quarter of a second or less, is graphically illustrated.

In addition, quantitative measurements of the sea spectra at selected directions and wave numbers have been made using a mask and a traveling diode in the Fourier plane. Examples of time series of the spectral energy at fixed wave numbers obtained using this technique will be shown.

3. HF SKYWAVE RADAR MEASUREMENTS OF COASTAL AND OPEN OCEAN SURFACE CURRENTS: J.W. Maresca, Jr., J.R. Barnum and K. L. Ford, Stanford Research Inst., CA.

Using the WARF, a high frequency (HF) skywave radar located in central California, the feasibility of remotely measuring the radial component of the ocean surface current along the coast and in the open ocean was demonstrated during three independent experiments. The difference between the radar inferred ocean wave Doppler or

phase velocity and the theoretical Doppler or phase velocity for waves in still water is a measure of the magnitude of the ocean surface current. The total Doppler of the principal backscatter return is the sum of the ionospheric and ocean wave Dopplers. A reference in the vicinity of the ocean scattering area that will produce an echo in the backscatter return is sufficient to compute the ionospheric Doppler. Two experiments were conducted in the Gulf of Mexico and one experiment was conducted in the North Pacific Ocean. Coastal lands and offshore oil platforms in the Gulf and a moving ship carrying a calibrator in the North Pacific Ocean were used as references. A comparison of the magnitude of the radar-derived ocean surface current and theoretical estimates of the ocean surface current showed fair agreement.

4. EFFECTS OF FOAM COVERAGE ON INTERPRETATION OF RADIOMETRIC TEMPERATURE MEASUREMENT OF OCEAN WATER: Lawrence A. Klein, The Joint Institute for Acoustics and Flight Sciences, VA.

Ocean foam coverage is one of the uncertainties in interpreting radiometric measurements of ocean temperature. To aid in the interpretation, a program was begun to build an ocean foam generator and to measure the brightness temperature of the foam-water combination. The unique feature of the foam generator is the frit material used to control the bubble diameter of the foam. Foam was produced by passing compressed air, from copper tubes running under the frits, upward through the salt water solutions laying on top of the 4' x 4' frit enclosure. The foam was confined by plexiglass walls. Depth of foam coverage was controlled by regulating the air flow and by varying the water depth. Sodium chloride solutions were used in most of the experiments. Some actual sea water samples were used, however, to establish that the effects seen with sodium chloride were indeed characteristic of sea water also. Data were collected at C-, X-, and K-microwave bands with both horizontally and vertically polarized antennas.

5. PROCESSING OF SAR OCEAN WAVE DATA: R.A. Shuchman and J.S. Zelenka, Env. Research Inst. of Michigan, MI.

Propagating ocean wave data collected by a Synthetic Aperture Radar (SAR) is not suited to conventional processing techniques which assume a stationary target. A SAR assumes a linearly moving imaging platform, uniform propagation paths, and stationary targets. Moving ocean waves introduce perturbations to the Doppler frequency shift, and when processed in a conventional manner produce images of waves that are dispersed and thus defocused in the azimuth (along-track) direction.

The relative velocity of moving wave trains, and thus defocusing of the SAR images, can be compensated in a processor by readjusting its azimuth focus by an amount proportional to the relative velocity of the wave trains. The azimuth refocusing required to image specific oceanwave trains was determined theoretically for both 3 cm and 24 cm SAR systems. The dependence of depth of focus, f-number and focal length of the processor on radar system parameters and relative target velocity were theoretically determined.

Preliminary empirical results support the theoretically determined relationships. The defocusing of ocean waves may potentially be used to discern wave direction in the open sea by observing the defocusing of wave images as the azimuth focus adjustment is varied about the plane of best focus.

6. MICROWAVE MEASUREMENT OF ORBITAL SPEEDS OF OCEAN WAVES: W.C. Keller and W.J. Plant, Ocean Sciences Division, Naval Res. Laboratory, Washington, D.C.

If an ocean wave is illuminated by a microwave beam small compared to the ocean wave length, the scattered field is Doppler shifted by the velocity of the small scale waves or other scatterers which ride the larger wave. This scatterer velocity may differ from the orbital velocity due to the augmented wind drift, and to higher order Bragg scattering. Our wavetank studies show, however, that this difference is small when the phase speed of the large wave is large compared to that of the small scatterers. Hence, a focussed microwave beam can be used as a wave probe analogous to a conventional wave staff except that it measures orbital speed rather than wave height. Several examples of power spectra and acutocrelations of orbital speeds of solitary waves, breaking waves, and lower amplitude swell measured at Nags Head, N.C., are shown to illustrate the technique.

7. FORWARD SCATTER AT UHF FROM A TWO-DIMENSIONAL COASTAL SEA: THEORY AND EXPERIMENT: K.R. Carver, Physical Science Laboratory, New Mexico State Univ., N.M.

The angular spectrum of the mean power scattered from a two-dimensional sea is calculated and presented in parametric numerical form for an assumed wide-sense stationary surface, using both the Beckmann and DeLorenzo-Cassedy models. In addition, results are presented for measured UHF temporal spectra obtained by time-recording the 468.8 MHz signal from the satellite SMS-2, incident at an 8° grazing angle over a shallow coastal two-dimensional sea (off Waihi Beach, New Zealand) of state 2 or less. These spectra, obtained as the Fourier transform of recorded power fluctuations, are strongly peaked at about .08 Hz, in accordance with the observed 12 s period waves dominating the specular scatter zone on the days measurements were made. The measured fluctuations do not arise from diffuse scatter, but come instead from specular zone modulation of the coherent component. The corresponding narrow-band spatial spectra are used as input to the DeLorenzo-Cassedy scattering model which has been modified to allow numerical computations without approximations on the correlation length. Polar diagrams of scattered power are presented with surface roughness as a parameter, giving a clearer picture of the roles played by both diffuse and specular scatter as well as a better appreciation of the Rayleigh-Kerr roughness criteria.

8. AAFE RADAR ALTIMETER MEASUREMENTS OF THE OCEAN SURFACE: W.F. Townsend, NASA Wallops Flight Center, VA.

The AAFE Altimeter, a state-of-the-art ocean tracking radar altimeter system designed to have an altitude resolution (noise) of 10 cm RMS or less over a range of significant wave heights of 1 to 10 meters, has recently been developed. This system also provides real time measurements of significant wave height and the ocean backscatter coefficient (σ_o) at nadir. The AAFE Altimeter is installed on a NASA Wallops Flight Center C-54 aircraft and is currently being flown over the ocean surface for the purpose of evaluating its performance capabilities. As a part of this ongoing effort an intensive set of data was taken over the North Atlantic off the coast of Newfoundland during February 1976. Significant wave heights within the range of 1 to 8 meters were observed and the system performance achieved was generally excellent. Results obtained from this experiment will be presented. In particular, altitude resolution, ocean backscatter coefficient, and return waveform shape as a function of significant wave height will be shown.

9. MODIFICATION AND EXTENSION OF THE CCIR GROUNDWAVE PREDICTION PROGRAM FOR ROUGH SEA PATHS: T. Kaliszewski, GTE-Sylvania, Inc., Communication Systems Div., Neeham, MA.

The groundwave prediction program supplementing the CCIR Recommendation 368-1 and prepared by Joachim, Mao and Boyle (Telecommunication Journal, 40(9), pp. 596-602, 1973) has been modified and extended to allow predictions to be made over rough sea paths involving both ground-based and elevated antennas. The prediction program utilizes the results of the analyses by Bremmer and van der Pol. A unified approach to the predictions in both land and sea environments is achieved through the introduction of the concept of an apparent sea conductivity. The modification accommodates both the Phillips and Neumann-Pierson ocean wave height spectra. Sample results show consistent agreement with the more extensive computations of Barrick (Radio Science, 6(5), pp. 517-533, 1971).

Commission F - Session F6

Thursday, October 14 1400-1715
DOPPLER RADAR STUDIES OF THE ATMOSPHERE
Chairman: J.L. Green, National Oceanic and Atmospheric Adm.

1. REAL TIME WIND MEASUREMENT IN CLEAR AIR WITH PULSE-DOPPLER RADAR: R.J. Doviak, L. Hennington, D. Sirmans, D.S. Zrnic', Nat. Severe Storms Lab., Norman, OK, and R.G. Strauch, Wave Propagation Lab., Boulder, CO.

Covariance and spectral processing of Doppler signals enhance clear air detection. In situ measurements of temperature structure constant suggest that clear air scattering may be sufficient to allow, with available meteorological pulse-Doppler radars, boundary layer wind measurement so that shear can be observed in real time. Doppler derived wind profiles are compared with local radiosonde data. Dual-Doppler measurement of clear air wind preceding deep convection is possible so convergence and convection in a thunderstorm's formation stages can be determined to provide further insight into storm genesis. Real time Doppler velocity measurements covering large areas of clear air regions are shown.

2. OBSERVATION OF VELOCITY VARIATIONS DUE TO A GRAVITY WAVE IN THE TROPOSHERE AND LOWER STRATOSPHERE BY THE SUNSET VHF PULSED DOPPLER RADAR: J.L. Green, R. Hyde, T.E. VanZandt, W.L. Clark, Aeronomy Lab., National Oceanic and Atmospheric Adm., Boulder, CO.

The Sunset Radar is a large VHF pulsed Doppler radar located near Boulder, Colorado, that is capable of continuously measuring wind velocities in the troposphere and lower stratosphere by means of spectral analysis of coherent echoes from the air. Gravity waves were observed on a number of occasions in the spring of 1976. On one occasion, March 15, 1976, the velocity variations observed by the radar were nearly sinusoidal with a period of 6 ± 0.5 minutes and were coherent over the region 4 to 12 km above mean sea level. The period, phase velocity and direction of a similar, simultaneous wave have been determined from nearby microbarograph array variations. The polar front jet stream was overhead at the time, with a peak wind speed of 65 m/s and vertical shears as large as .020 s^{-1} in the 6-7 and 10-11 km regions. The Richardson number was less than .25 in both these regions.

3. REFLECTIVITY STUDIES WITH THE SUNSET VHF PULSED DOPPLER RADAR: J.L. Green, T.E. VanZandt, J.M. Warnock, and W.L. Clark: Aeronomy Lab., National Oceanic and Atmospheric Adm., Boulder, CO.

The echoes observed by the Sunset VHF pulsed Doppler radar are almost continuous in both height and time in the troposphere and lower stratosphere, in contrast to the intermittent echoes observed by non-coherent meteorological radars (e.g., Hardy and Katz, 1969). The greater sensitivity of the Sunset radar system is primarily due to coherent integration and Doppler spectral analysis, which lead to a minimum detectable volume reflectivity and a minimum structure constant C_n^2 with 1 km range resolution at 10 km range of 2×10^{-21} m^{-1} and 10^{-20} $m^{-2/3}$, respectively, compared with 10^{-16} m^{-1} and 10^{-16} $m^{-2/3}$, respectively, for non-coherent radars.

If the reflection actually comes from only part of the sampled volume, these minimum detectable quantities are proportionally larger in the reflecting volume. Several lines of evidence suggest that indeed the reflections usually come from layers much thinner than 1 km. In particular, the statistics of wind shears derived from photographic observations of smoke trails (Rosenberg and Dewan, 1974), show that this probability of at least one 25 m layer in a 1 km range gate being unstable is at least

99.4% in the troposphere and 80% in the stratosphere, consistent with the Sunset observations.

4. COMPARISONS OF WINDS MEASURED BY A SENSITIVE VHF RADAR WITH RAWINSOUNDINGS: J.M. Warnock, J.L. Green, T.E. VanZandt, R.H. Winkler, and W.L. Clark, National OCeanic and Atmospheric Admin., Boulder, CO.

Winds and mountain lee waves in the troposphere and lower stratosphere observed by a large VHF pulsed Doppler radar located near Sunset, Colorado, are compared with nearly simultaneous rawinsoundings made in February, 1975. About twenty raobs were launched successfully by NCAR's Field Observing Facility from Tabernash, Colorado, located 14 km west of the continental divide. Many of the balloons were carried by the prevailing west wind near to the Sunset radar facility, located 20 km east of the divide. In the boundary layer the correlation between the two measurements is not good. As the balloons approached Sunset, however, the agreement between the two measurements steadily improved and became excellent at nearest approach. These observations confirm that the VHF pulsed Doppler radar technique does indeed measure the wind profile. Also, these observations of the wind at two near by locations together with the standard Denver rawinsoundings provide data on the spatial structure of the wind field during mountain lee wave activity and on calm days.

5. BOUNDARY LAYER WIND MEASUREMENTS WITH AN FM-CW DOPPLER RADAR: R.B. Chadwick, W.C. Campbell, K.P. Moran, and R.G. Strauch, NOAA/ERL/Wave Propagation Laboratory, Boulder, CO.

Microwave FM-CW Doppler radars are potentially able to measure the wind profile in the lower atmosphere under all weather conditions. In situ measurements of C_n^2 in the lowest few kilometers indicate that the radar reflectivity factor should be sufficient to allow the measurement of wind profiles in the optically clear air to at least several hundred meters altitude with typical FM-CW radars. In clouds or precipitation, the FM-CW Doppler radar velocity measures particle motion, just as a pulse Doppler radar, except that its minimum range is less than 20 m and its range resolution can be less than 10 m.

We have operated an FM-CW Doppler radar intermittently during the past twelve months in the relatively dry environment near Boulder, Colorado. Although continuous scattering between the minimum observable range and clear air scattering layers has never been detected with an FM-CW Doppler radar without Doppler processing, we are able to measure continuous wind profiles when the Doppler operating mode is employed. Wind measurements will be presented and uses and limitations will be discussed.

6. REFRACTIVE INDEX VARIANCE AND ITS HEIGHT DISTRIBUTION IN DIFFERENT AIR MASSES: E.E. Gossard, NOAA/ERL/Wave Propagation Laboratory, Boulder, CO.

With the advent of radars capable of detecting backscatter from turbulent inhomogeneities in the clear air, there is renewed interest in the refractive character of the atmosphere. The ratio refractive index structure constant and its spatial and temporal

distribution are of particular importance.

The general refractive properties of air masses are discussed. Based on certain assumptions, the distribution of optical and radio refractive index structure constants are then calculated and the results are compared with the limited observational data available.

7. DOPPLER DETECTION OF WINDS IN THE VICINITY OF THE TROPOPAUSE USING A UHF BACKSCATTER RADAR: B.B. Balsley, Nat'l. Oceanic and Atmospheric Admin., Boulder, CO, and D.T. Farley, Cornell Univ., Ithaca, NY.

We describe a technique to measure wind velocities at tropopause heights with a frequency-coherent UHF radar. The wind velocity determined using the Chatanika Radar Facility near Fairbanks, Alaska is shown to be in good agreement with almost-concurrent Fairbanks radiosonde data.

Commission J - Session 4

Thursday, October 14 1400 - 1715
ASTRONOMICAL IMAGE FORMATION II
Chairman: R. Bracewell

1. RECONSTRUCTION OF BRIGHTNESS DISTRIBUTIONS FROM VLBI DATA USING 'CLOSURE' PHASE: P.N. Wilkinson, A.C.S. Readhead, Calif. Inst. of Tech., Pasadena, CA.

An iterative technique has been developed for the analysis of multi-station VLBI data for which fringe amplitude and 'closure' phase information are measured. An important feature of the method is that the Fourier transform of the restored brightness distribution plus the remaining noise yields the observed amplitudes and 'closure' phases identically.

The method uses an initial source model to predict the visibility phases on a sufficient number of the baselines to be able to solve for those on the remainder with the aid of the 'closure' phases. The resulting complex visibility data are then inverted and analysed using standard 'clean' techniques to yield a first "map" of the source. This is then used to predict the required visibility phases in the next interation.

Tests with simulated data have shown that the process converges quickly and correctly if the source is fairly simple or, in the case of more complex sources, if the initial model is a fair guess at the actual brightness distribution. If, as for example in our data on 3C147, one of the components in the source is barely resolved on the longer spacings this component can be used as a phase reference. The resulting 'map' of the more extended structure is then only limited by the extent of the u,v coverage and the ability of the 'clean' process to take this into account.

2. OBSERVATIONS OF H_2O MASERS WITH AN ANGULAR RESOLUTION OF 0.00038 SECONDS OF ARC: J.M. Moran, Center for Astrophysics, Cambridge, MA, B.F. Burke, R.C. Walker, M.I.T., Cambridge, MA, L.I. Matveyenko, L.R. Kogan, V.I. Kostenko, Inst. for Space Research, Moscow, USSR, and I.G. Moiseev, Crimean Astrophysical Observatory, Simeiz, USSR.

A very long baseline interferometric experiment was conducted on February 20, 1976 using the 37 meter antenna of the Haystack Observatory in Westford, Mass., and the 22 meter antenna of the Crimean Astrophysical Observatory in Simeiz, Crimea, USSR for the purpose of measuring the angular sizes of galactic water vapor masers. The baseline length was 7370 kilometers and the fringe spacing was 0.00038 arc seconds at the observing wavelength of 1.35 cm. Both stations were equipped with maser amplifiers and hydrogen maser frequency standards. The coherence time of the interferometer was about four minutes. The table below lists the sources for which interference fringes were detected, along with the visibility and angular size of the smallest component in each source.

source	visibility	angular size (milliarcsec)
W3(c)	0.15	0.29
W3(OH)	0.22	0.25
W49	0.25	0.24
W51	0.70	0.14
ON1	0.43	0.29
ON2	0.18	0.40
S158	0.20	0.38

No interference fringes were observed on the sources W75S, NGC7538, and Orion A.

3. VLBI APERTURE SYNTHESIS OBSERVATIONS OF H_2O MASERS IN HII REGIONS: R.C. Walker, B.F. Burke, A.D. Haschick, P.C. Crane, M.I.T., J.M. Moran, Smithsonian Astrophysical Observatory and Center for Astrophysics; K.J. Johnston, Naval Research Laboratory; K.Y. Lo, Calif. Inst. of Tech.; J.L. Yen, Univ. of Toronto; N.W. Broten, T. Lake, Nat'l. Research Council, Ottawa; E.W. Greisen and S.S. Hensen, Nat'l. Radio Astronomy Observatory

A system for aperture synthesis mapping of spectral line VLBI sources, based on the phase of a reference feature, has been developed and applied to data from a five-station experiment at 1.35 cm. The system consists of modified versions of the spectral line VLBI programs (Moran, J.M., 1973, Proc. of I.E.E.E., 61, 1236) and the NRAO spectral line interferometer package (Greisen, E.W., 1975, The NRAO Line Interferometer: A Manual) along with the necessary interface programs. Maps have been made of H_2O maser emission from HII regions, based on data collected in March 1975 using the telescopes at Haystack, MA, Green Bank, WV, Algonquin Park, Ont., Maryland Point, MD, and Owens Valley, CA. These maps confirm that many spectral features are in fact blends of several spatially separated emission regions.

Commission J - Session 5

Thursday, October 14 1400 - 1715
INSTRUMENTATION
Chairman: G.R. Huguenin, Univ. of Mass.

1. THE AUTOMATED METERWAVE TELESCOPE AT THE FIVE COLLEGE RADIO ASTRONOMY OBSERVATORY: J.H. Taylor, G.R. Huguenin, and D.J. Helfand, Univ. of Mass., Amherst, MA.

The FCRAO meterwave telescope consists at present of four fixed, 120-foot (36.5 m) diameter spherical reflectors with movable feed antennas capable of tracking sources in delination range between +10 and +74° for up to six hours. A broadband receiving system permits simultaneous observations at two frequencies: 225 and 400 MHz. There are identical receiving systems for each of two orthogonal lunar polarizations. Array phasing is accomplished following conversion to an intermediate frequency. For pulsar observations the array output at each observing frequency is fed into a 64-channel de-dispersing receiver system. The de-dispersed signals are then synchronously averaged in a 4 x 1024 channel signal averaging computer. Integrated pulse profiles are accumulated for five minutes and then written on magnetic tape for further off-line processing.

The operation of this fairly complex telescope system is fully automated and since January 1975 has been operating unattended 24 hours a day. The tasks assigned to the computer (DEC PDP-12) for attended observing include control of antenna pointing, tracking, and phase-delays; for pulsar observing it must also update the Doppler-shifted pulsar period corrected for Earth's motion every 5 minutes and perform various data logging functions. In the automated mode several other tasks formerly performed by the operator, along with system monitoring activities are also assigned to the computer. An automated calibration sequence is also run on a strong continuum source to provide a daily check on antenna pointing and flux calibration. The automated operation has been quite successful and is providing a very valuable body of uniform data on the pulsars.

2. THE MILLIMETER-WAVE TELESCOPE AT THE FIVE COLLEGE RADIO ASTRONOMY OBSERVATORY: G.R. Huguenin, Univ. of Mass., Amherst, MA, and A. Cohen, Electronic Space Systems Corp., Concord, MA.

A 45-foot (13.7 m) diameter fully steerable paraboloid manufactured by ESSCO has been erected at the FCRAO. This randome-enclosed, precision antenna will be used to make millimeter-wavelength radio astronomy observations. The telescope is nearing completion and should be ready for astronomical observations in the late fall of 1976. Current error estimates suggest a final unweighted surface error of 0.11 mm rms and a weighted surface error of ~0.08 mm. Reasonable antenna efficiency is expected at λ1.3 mm where a half power beamwidth of 24 arc-seconds is predicted.

Pointing and tracking performance of 3-arc-sec and 2 arc-sec rms respectively is expected which will be adequate for use at λ1.3 mm. Cassegrain optics are employed.

The controlled randome environment should permit operation at full efficiency whenever atmospheric propagation conditions are favorable. The telescope has incorporated into it certain features permitting use of an advanced cryogenics enclosure to house maser and other low noise receiver systems.

3. AN ADVANCED CRYOGENIC ENCLOSURE FOR ULTRA-LOW-NOISE MILLIMETER WAVE RECEIVERS: A.G. Cardiasmenos, G.R. Huguenin, K.S. Yngvesson, Univ. of Mass., Amherst, MA.

An Advanced Cryogenic Enclosure for low-noise millimeter-wave receivers is described, which will be used on the Five College Radio Astronomy Observatory (FCRAO) 13.7 meter diameter millimeter-wave radio telescope. The main considerations taken into account through implementation of this system are:

1) The system should offer the observing scientist a choice of using receivers, over as wide a range of frequencies as possible, in order to maximize the scientific usefullness of the telescope and to enable adaptation of the observing program to atmospheric conditions. All receivers are therefore simultaneously housed in the advanced cryogenic enclosure and are cooled continuously.

2) The system should be adaptable to a large variety of receiver types. For example, millimeter-wave masers and Josephson junctions may require pumped liquid helium, (~2K), some masers operate in liquid helium at atmospheric pressure (4.2K) whereas cooled Schottky-barrier diode mixers operate well at 20°K. All these options are satisfied in the new system.

3) A run-time of at least a week with minimum down time for liquid helium fills and maintenance is realized with this new system, which represents a considerable advance for state-of-the-art cryogenic technology utilized for microwave receiver systems in Radio Astronomy applications.

4. MILLIMETER-WAVE TRAVELING-WAVE FOR RADIO ASTRONOMY: A.G. Cardiasmenos, J. Grey, J.F. Shanley and K.S. Yngvesson, Univ. of Mass., Amherst, MA.

This paper describes two traveling-wave masers (TWM's) to be used in the near future as preamplifiers on the Five College Radio Astronomy Observatory (FCRAO) 13.7 meter millimeter-wave radio telescope near Amherst, Mass. The masers operate in the frequency ranges 20-26 GHz and 85-95 GHz, respectively.

The 20-26 GHz TWM is an improved version of the ruby maser design which has been used at several observatories-Hat Creek (UCB), Maryland Point (NRL), Haystack (NEROC), and Itapetinga (Sao Paulo, Brazil). We will describe the new periodic structure and rugged mechanical design of this maser and give results of noise temperature and stability measurements. Expected system noise temperature on the telescope is 50 K.

The 85-95 GHz TWM employs FE^{3+}-TiO_2 as active material, incorporated into a new type of millimeter-wave propagating structure, using what we term the slot-fed image-guide mode. This structure is designed to allow single-mode propagation from 20 to 120 GHz in order to couple the signal wave (e.g. 88 GHz) and three pump waves (45, 47, and 115 GHz, respectively) to the active maser crystal. This maser uses a unique uniaxial ferrite in a resonant isolator configuration, to achieve stable gain. Measurements on this maser will be described. Expected system noise temperature on the telescope is 100 K.

5. THE ANGULAR DISTRIBUTION OF AURORAL KILOMETRIC RADIATION: J.L. Green, D.A. Gurnett, S.D. Shawhan, Univ. of Iowa, Iowa City, IA.

Measurements of the angular distribution of auroral kilometric radiation (AKR) are presented using observations from the Hawkeye 1, IMP 6, and IMP 8 satellites. The wave experiments on Hawkeye 1 and IMP 6 provide electric field measurements of AKR in narrow frequency bands centered at 178, 100, and 56.2 kHz and IMP 8 provides an additional frequency band centered at 500 kHz. From a frequency of occurrence survey, at satellite radial distances greater than 7 R_e (earth radii), it is shown that AKR is preferentially and instantaneously being beamed into solid angles of approximately 3.5 steradians at 178 kHz, 1.8 steradians at 100 kHz, and 1.1. steradians at 56.2 kHz, directed upward from the night time auroral zones. Simultaneous multiple satellite observations of AKR in the northern hemisphere show that the radiation occurs simultaneously throughout these solid angles and that the topside plasmapause acts as an abrupt propagation cutoff on the night side of the earth. On the day side of the earth this abrupt cutoff at the plasmapause is not observed.

The results of a computer ray tracing model qualitatively describing the propagation characteristics of AKR are also discussed. This model assumes small source locations emitting radiation at different frequencies from altitudes of 1.5 to 3.5 R_e in the auroral zone at 24 hour magnetic local time.

Commissions A and B - Session 6A

Friday, October 15 0900 - 1215

SELECTED TOPICS

Chairman: S.W. Rosenthal, Polytech. Inst. of N.Y.

1. FREE WATER AND THE MICROWAVE CONDUCTIVITY OF TISSUE: H.P. Schwan and K.R. Foster, Univ. of Pennsylvania.

A review of precision dielectric measurements on muscle tissue at frequencies of 0.1 and 10 GHz is presented. Over this frequency range, the tissue conductivity can be adequately represented by the sum of a Debye relaxation function, and a constant term accounting for the electrolyte content of the tissue. The characreristic frequency of the Debye relaxation is 20 GHz, the same as for pure water; its amplitude is consistent with the known water content of the tissue. These observations support two important conclusions. First, the microwave dielectric properties of tissue can be adequately predicted from measurements near 100 MHz, and from the known dielectric properties of water. From an electric point of view the tissue can be approximated by a suspension of nonconducting proteins in an electrolyte solution at these frequencies. Second, while (from other studies) a relatively few "bound" or motionally restricted water molecules are present in the tissue, our results indicate that they play no major role in the absorption of microwave energy by the tissue. The dielectric data appear to contradict the hypothesis that most of the tissue water has motional properties significantly different from those in bulk water.

2. EFFECTS OF 960 MH_z MICROWAVE ON ISOLATED GUT SEGMENTS: G.R. McArthur, James L. Lords, and C.H. Dürney, Depts. of Bioengineering, Biology, Electrical Engineering (respectively), University of Utah.

Low level CW, 960 MH_z radiation of isolated segments of rat gut causes an increase in the activity of the gut preparation. A strain gauge pressure transducer (P23AC Stratham) was used to monitor the wave forms in a canulated section of rat gut comprising the pylorie region of the stomach and the first 6 to 8 cm of the intestine. The preparation owas suspended in isothermal, aerated, modified Ringer's solution. Microwave radiation was applied with a parallel peate capacitor type irradiator. The dose rate was calculated from temperature measurements made with the liquid crystal optical fiber temperature probe.

Previous work in this laboratory has shown that similar radiation applied to isolated turtle and rat hearts causes brodycardia. These effects are thought to be neurally mediated by the release of transmitter substances from the autonomic system. Generally these effects can be modified by the addition of drugs effective at synapses within the autonomic nervous system. In the heart of sympathetic and parasympathetic effects can be separated by the application of drugs which selectively block these two divisions of the autonomic nervous system. Experiments to determine if similar drug treatment can be used to identify neural effects in the gut are in progress.

3. MICROWAVE IRRADIATION OF ISOLATED RAT HEARTS TREATED WITH ANS BLOCKING DRUGS: J. R. Reed, III, J. L. Lords, and C. H. Durney, Depts of Bioengineering, Biology, Electrical Engineering (respectively), University of Utah.

Microwave irradiation at 960 MH_z CW with dose rates approximately 1.5mw/gm, has been found to induce bradycardia in isolated perfused rat hearts when mild tachycardia would be expected if the interaction was based solely on the thermogenic properties

of the radiation. Further experimentation has suggested that this effect may be neurologic in origin because hearts treated with the parasympathetic blocking agent atropine at 5 x 10^{-7} g/ml exhibit strong tachycardia during irradiation while hearts treated with 5 x 10^{-7} g/ml propanolol, a sympathetic blocking agent, showed stronger bradycardia upon irradiation than the untreated hearts.

In the work reported here hearts in which both systems, parasympathetic and sympathetic, are blocked by the respective drugs showed no significant effect upon irradiation. With respect to these data it is hypothesized that the microwave energy interacts with the autonomic nerve remnants present in the excised hearts. Although the mechanism is as yet undetermined, it is believed that neurotransmitter is likely to be involved in the process.

The dose rate (absorbed power density) in the heart was calculated from the rate of temperature rise during irradiation. The temperature was measured by the liquid crystal optical fiber probe, which, being nonmetalic is not disruptive to the microwave field.

4. ENHANCED CYTOTOXIC EFFECT OF 3 HGz MICROWAVES FOR CELLS TREATED WITH MEMBRANE-INJURING SUBSTANCES: S. Szmigielski, M. Janiak and M. Kobus, Center for Radiobiology and Radioprotection and Dept. of Medical Microbiology, Univ. Medical School, Warsaw, Poland.

Irradiation of cell cultures with 3 GHz microwaves at non-thermal (5 mW/cm^2) power densities resulted in stimulation of cell metabolism (increased oxygen consumption, increased synthesis of nucleic acids and proteins, increased multiplication of viruses) during few hours after irradiation, while irradiation of the cultures at subthermal (20 mW/cm^2) power densities leads to temporary inhibition of cell metabolism and function with the regeneration of cell population 24 hours after session of irradiation (S. Szmigielski et al, Ann.N.York Acad. Sci., 1975, 247,263; Phys. Med. Biol., 1975, 20,825). Biological membranes, including cellular and intracellular (lysosomal) membranes are suggested as primary targets for the injuring effect of subthermal and thermal power densities of microwaves.

In view of this a series of experiments was performed on cells treated with subcytotoxic (not resulting in detectable increase of number of dead cells stained with supravital dyes) concentrations of highly purified enzymes injuring cell membranes - bacterial phospholipases (staphylococcal sphingomyelinase and phosopholipase C from Clostridium perfringens). Digitonine in concentration 10^{-6} M was used as control membrane-injuring substance (inhibition of sodium pump and Na-K-activated ATP-ase). All the experiments were performed on established cell cultures (WISH and FL lines) in the stationary phase of growth (48 hrs after passage).

Control cells and cells treated with the above membrane-injuring substances were irradiated with 3 GHz microwaves (anechoic chamber, far field conditions, single session of irradiation lasting 1 hr) at different field power densities - non-thermal (5 mW/cm^2), subthermal (20 mW/cm^2) or thermal (40 mW/cm^2). Viability of the cells and morphologic observation were performed, as well as incorporation rate of ^{3}H-thymidine, ^{3}H-uridine and ^{3}H-glycine and intracellular level of cyclic AMP were controlled.

Treatment of cell cultures with subcytotoxic concentrations of the above membrane-damaging enzymes and digitonine enhanced markedly the inhibitory effect of microwaves at subthermal and thermal power densities.

5. EFFECT OF 3 GHz MICROWAVES ON EXPERIMENTAL VIRAL INFECTIONS IN MICE (HERPES, VACCINIA): S. Szmigielski, M. Luczak, M. Janiak, M. Kobus, and B. Laskowska, Center for Radiobiology and Radioprotection, and Dept. of Medical Microbiology, Univ. Medical School, Warsaw, Poland.

Irradiation of cell cultures with 3 GHz microwaves at subthermal field power densities (20 mW/cm^2) resulted in lowering of virus multiplication and temporary inhibition of cell metabolism (S. Szmigielski et al, Ann.N.York Acad. Sci., 1975, 247,263). The inhibitory effect on multiplication of viruses was still more pronounced after irradiation of cell cultures at higher power densities (40 mW/cm^2) or after application of hyperthermia (41 and 43°C) (S. Szmigielski et al, Arch. virol., 1976, in press)

In view of the above, a series of experiments was performed in mice infected with viruses (Herpes or Vaccinia) under controlled conditions and irradiated with 3 GHz microwaves (anechoic chamber, far field conditions, 40 mW/cm^2, 2 hrs daily). Irradiation with microwaves was performed during different periods (2-14 days) before and/or after infection with viruses.

Irradiation before viral infection did not change the course of disease, as measured by number of typical lesions on tail (vaccinia) or survival rate and occurrence of encephalitis (herpes).

Irradiation after viral infection resulted in strong inhibition of replication of infective virus particles and lowering of number of typical lesions on tail (vaccinia). In mice infected with herpes viruses survival in groups irradiated with microwaves was much higher (10-14/ 16), as compared to controls 0-2/ 16), significantly lower was the occurrence of encephalitis. The best results were obtained in animals irradiated during first 3 days after infection (period of varaemia), less effective was irradiation during later phases of the disease.

6. EFFECTS OF RADIOFREQUENCY RADIATION ON PERIPHERAL VASCULAR PERMEABILITY: R.P. Liburdy, USAF School of Aerospace Medicine, Texas.

The effects of radiofrequency (RF) radiation on absorption of sheep red blood cells (SRBC) in unsensitized Sprague-Dawley rats were investigated. RF radiation (26 MHz, 2000 mW/cm^2 causing a 1.5°C increase in rectal temperature) were administered for ten minutes on six successive days to three groups of ten test animals. On day six, four hours postexposure, SRBC at 10^8 cells in 50 µl were injected subcutaneously into the hind footpad of each animal. Breadth of the footpad was determined by micrometer before injection and four hours postinjection. RF treated animals showed decreased footpad enlargement of 47.5% ($0.05 < P < 0.1$) and 36.8% ($0.05 < P < 0.1$) over that observed in sham exposed or warm air stressed animals, respectively. Pathology indicated in all animals that SRBC evoked a mild localized inflammatory reaction, as judged by microscopic histoexamination. These results suggest that RF radiation may be associated with increased vascular permeability over that due to frank thermogenic stress.

Commissions A and B - Session 6B

Friday, October 15 0900 - 1215
SELECTED TOPICS
Chairman: H. Kritikos, Univ. of Pa.

1. OBSERVATIONS CONCERNING BIOLOGICAL ACTIVE, NATURAL ELECTROMAGNETIC RADIATION OF EXTREMELY LOW INTENSITY: R. Szul, M. Szul, Technical University of Wroclaw, Poland.

Existence of the natural sources of the coherent electromagnetic radiation in the frequency range of about 1420 MHz has been stated. This radiation is supposed to be generated by molecular generators exposed to geomagnetic fields. In those generators magnetic dipole transitions occur under the influence of the perturbations of these fields. The main source of this radiation is water excited by alternating magnetic or electromagnetic fields. There are also other natural materials and plastics to which similar effects are pertinent. Using indirect methods the power densities were estimated like from the dipole antenna fed with power in the range of 10^{-18} to 10^{-22} W. The shape of the radiation pattern of the field sources depends upon the mode of excitation and the shape of the source. It has been confirmed that for some power densities this radiation in practice was attenuated very little in material media, immersed in magnetic field. This phenomenon could be explained on the ground of quantum physics. The radiation reacts only with resonant elements, molecular and macroscopic, causing changes of the radiated field and other parameters. It has been found that man and animals have specific centres generating coherent electromagnetic radiation in the frequency range of about 1420 MHz, and that react to the radiation generated by natural and artificial sources down to the threshold value of the power of extremely low intensity.

2. ASCORBIC ACID LEVELS IN RABBIT EYES AFTER SINGLE AND REPEATED EXPOSURE TO MICROWAVE RADIATION: E. S. Ferri, U.S. Dept. HEW, Bur. of Radiological Health, Div. Biological Effects, Winchester, Mass.

A reported early response to the induction of microwave cataracts has been a change in the ascorbic acid content of rabbit lens. We have raised the question of whether this reduction continues to occur beyond that reported and whether repititive subthreshold exposures will evoke a similar resonse.

To test this theory, the right eyes of New Zealand white rabbits were exposed 2 inches from the crossover of a Direct C antenna to a power density of 500 mW/cm^2 for 8 minutes. This resulted in cataract formation after a latent period of 3-7 days. At various intervals after exposure (5 min. 1/2 hr., 12 hr., 18 hr., 1 week, 2 weeks, and 4 weeks) both the right and left eyes were removed, and ascorbic acid was assayed in the aqueous, vitreous and lens by the method of Roe (Roe, J. H., Method of Biochemical Analysis, Vol. 1, Interscience, Inc., New York, 1954). The eyes of unirradiated control animals were assayed following the same procedure.

The aqueous humor shows an immediate decrease in ascorbic acid levels in irradiated eyes, and this decrease continues up to 1 week post-irradiation. At 2 weeks values are normal. Levels in the lens appear to decrease at a slower rate and do not reach as low levels as in the aqueous, but again show recovery at 2 weeks to normal values. Erratic results were obtained for the vitreous humor. All values for unirradiated eyes, including controls and left eyes of animals, showed normal levels as reported in the literature.

Ascorbic acid was also assayed in irradiated eyes of rabbits exposed to repetitive short durations of microwave radiation. One week post-irradiation was chosen as the sacrifice and assay time because levels of ascorbic acid had been demonstrated to be at their lowest value at this time in the eyes of the acutely exposed animals. Data accumulated to date show no lowering of ascorbic acid levels in the eyes of these animals. These results suggest that chronic subthreshold exposures totaling over three times in duration those of an acute nature do not provoke a reaction which affects ascorbic acid levels in the eye.

3. DOSE RATE RELATED EFFECTS ON THE OXYGEN CONSUMPTION OF MICE DURING AND AFTER MICROWAVE IRRADIATION: H. S. Ho and W. P. Edwards, Bureau of Radiological Health, FDA, USPHS, HEW, Rockville, MD.

Currently, controversy exists over the thermal versus "nonthermal" biological effects of microwave radiation. Rectal temperature measurements which are often used as indicators of thermal stress may not be sufficiently reliable. In this investigation, the oxygen consumption rate is used as a biological indicator of thermal stress due to microwave radiation. Male CF1 mice are irradiated singly with 2450 MHz CW microwave in a waveguide apparatus with incident power levels of 0 (sham), 0.09, 0.3, 0.6, 1.7, and 3.3 W, resulting in corresponding average absorbed dose rates of 0 (sham), 1.5, 5, 10, 25, and 45 mW/g. The environmental conditions are 24°C, 60% relative humidity, and air flow rate of 76 ml/min. The rate of oxygen consumption of the mouse is determined at 5 minute intervals by means of a paramagnetic oxygen analyzer before, during, and after each irradiation. Each of the stages lasts for 30 minutes. Results of the experiment indicate reduction of oxygen consumption in addition to the previously reported avoidance behavior at average absorbed dose rates of 25 and 45 mW/g. Significant oxygen consumption reduction is also observed at 5 and 10 mW/g even though avoidance is not observed at these average absorbed dose rates and environmental temperature. The animal homeostatic mechanism apparently balances the total heat load to the organism by reducing its total metabolic heat rate to compensate for small heat load increases due to microwave radiation.

4. RADIOFREQUENCY RADIATION DOSIMETRY HANDBOOK: C.C. Johnson, C.H. Durney, P.W. Barber, H. Massoudi, and S.J. Allen, Depts of Bioengineering and Electrical Engineering, Univ. of Utah, and USAF School of Aerospace Medicine, Brooks Air Force Base, TX.

Considerable effort has been expended recently in both biological experimentation and theoretical analysis of radiofrequency (RF) electromagnetic radiation effects on humans and experimental animals. An important part of this work is dosimetry, the determination of the amount of energy that is absorbed in the tissues. In order to provide the link between biological effects observed in irradiated animals and corresponding biological effects which might occur in man, it is necessary to have theoretical methods for relating absorbed energy in man and animals to the incident radiation intensity. A handbook of data has been compiled to fill this need.

This paper describes the handbook and summarizes the dosimetric data contained therein. Homogeneous spheroidal and ellipsoidal models of humans and animals have been used in calculating the data. Extensive graphs of calculated specific absorbed power versus frequency for typical monkeys, baboons, dogs, rabbits, guinea pigs, rats, mice, eggs, pupae, as well as several typical human forms in planewave radiation are included. Such data should prove to be very valuable to researchers in microwave

biological effects because it will provide a convenient means of estimating the specific absorbed power in the animal in terms of the incident fields or power density, and extrapolating observed animal effect to humans. For example, an experimenter who desires to study possible effects produced in humans irradiated by a planewave of 10 mW/cm^2 power density at 20 MHz with a specific orientation in the fields could look at a curve in the handbook and find the calculated specific absorbed power density in an average man. He could then look at other curves and find the required incident planewave power density required to produce the same specific absorbed power density in rats, mice, monkeys, etc. As an example, one finds that the incident planewave power density required for a mouse would be about 27 times greater than that for the man for the same average specific absorbed power.

Commission A and B - Session B8

Friday, October 15 0900 - 1215
FIBER AND INTEGRATED OPTICS II
Chairman: R.L. Gallawa, ITS

1. RECENT PROGRESS OF FIBER OPTICS IN JAPAN: T. Nakahara, Sumitomo Electric Industries, Ltd.

This paper describes the recent progress of the research and development of fiber optics in Japan. Review is made on recent developments of fiber-making, cabling, fiber splicing, experimental results on optical communication system associated with opto-electronics components.

Transmission characteristics of optical fibers such as attenuation and pulse spreading are reviewed from the viewpoint of their structures. Various methods of fiber strengthening and structuring cables are described from the viewpoint of mechanical strength and optical properties.

Methods and coupling efficiencies of detachable connectors and permanent fiber splicing are reviewed. Review is made on the experimental results of optical fiber communication systems. Also the coupling techniques between a light source and an optical fiber are described.

2. FIBRE OPTICAL COMMUNICATION IN GERMANY: Stefan Maslowski, AEG-Telefunken Research Inst., Ulm/Germany.

A review will be given of the activities and the present state of the art in the fibre optical communication field in the Federal Republic of Germany.

3. SOME ASPECTS OF FIBRE OPTICS RESEARCH IN FRANCE: D. B. Ostrowsky, Nice, France.

4. OPTICAL FIBER COMMUNICATIONS IN COMPAGNIE GENERALE D'ELECTRICITE: M. Rousseau, R. Boirat and J. Ernest, Laboratories de Marcoussis, Compagnie Generale d'Electricite, Marcoussis, France.

5. TRANSMISSION OF INFORMATION VIA OPTICAL FIBER: T.A. Eppes, J.E. Goell, C.K. Kao, ITT Electro-Optical Products Div., Roanoke, VA.

Optical fiber communication has advanced rapidly since the prediction of practicality by Dr. C. Kao of ITT-STL in 1964. Fibers with attenuations of 2 dB/km have been drawn. Compact multifiber cables with short length tensile strengths of 500 lbs. and attenuations of under 6 dB/km have been produced, and long lived operations of GaAs lasers and LEDs suitable for use with fibers has been demonstrated.

Initially, advantages such as freedom from interference make the use of optical fiber transmission attractive in specialized applications. Later, optical fibers will be used in conventional point to point links. Advantages offered will include reduced cost and increased repeater spacings which, in some cases, will eliminate field repeaters. Optical fibers are also attractive for use in data buses, because of their small size and wide bandwidth. Ultimately, the use of fibers will greatly reduce

intermachine wiring and permit increased interconnection flexibility. Because of their small size, optical fibers can be incorporated in mechanical and electrical load carrying cables. Thus, once fiber strength problems are solved, they will be used in applications such as TV inspection of undersea drilling operations. Integrated optical circuits will expand the usefulness of fiber optics for communication by increasing the bandwidth of point to point systems and allowing efficient multiplexing for data buses.

This paper will present potential applications of optical fiber transmission, and describe present optical fiber technology and advances needed to realize the potential applications.

6. SOME LIGHTWAVE COMMUNICATIONS STUDIES: D. Gloge, Bell Laboratories, Holmdel, N.J.

In today's exploratory fiber systems, multimode fibers have a clear advantage over single-mode fibers: Precise grading of the core refractive index can equalize mode delays to the extent that multimode transmission of 44.7 Mbits/s (DS3 rate) seems feasible over several miles. With fiber loss reaching the 1 to 3 dB range, the avoidance of microbending loss in the cabling process and low splicing losses become ever more important. Bell Laboratories system experiment at the DS 3 rate indicates the state of the art. Aside from better control and reliability of available components, the future may bring a shift to longer wavelengths where scattering loss and material dispersion in fibers is less severe. And there will be exploration of fiberguide applications at bit rates other than DS3. This talk illustrates some hardware designs for potential light-wave communications systems, explains the concepts and gives some thoughts on possible trends.

7. COUPLING FIBRES TO INTEGRATED OPTICAL CIRCUITS: P.J.R. Laybourn, C.A. Millar, G. Stewart, and R.H. Hutchins, Electronics and Electrical Engineering, Univ. of Glasgow, U.K.

The use of optical integrated circuits in an optical communications system as terminal and repeater modules will require some form of coupling to the glass fibres linking the system. Because of the wide discrepancy in waveguide profiles between thin film optical circuits and circular cladded fibres, butt jointing presents an inherent mismatch. Transverse distributed coupling arrangements have been conceived, operating between selected phase-matched modes in the guiding structures. Coupling takes place through the evanescent fields of the guides; the attenuating effect of any fibre cladding must therefore be minimized.

Two possible approaches have been considered. By modifying the refractive index of the cladding region of a circular fibre, it is possible to increase the evanescent field amplitude at the surface of the fibre sufficiently for useful coupling to take place with an adjacent guide. Fibre guides with an exposed core, such as planar ribbons of open-sandwich construction, are particularly suitable for distributed coupling. The mode structure and coupling characteristics of these sandwich ribbons have been studied extensively, and high coupling efficiencies have been readily achieved. The exposed core makes the ribbon fibres unsuitable for transmission over any distance, but it is proposed that sections tapering from the sandwich guide to a circular cross-section could be fabricated to overcome the problem.

8. FUTURE NASA APPLICATIONS OF FIBER OPTICS: A. R. Johnston, Jet Propulsion Lab., Pasadena, CA.

The rapidly developing technology of fiber optic data transmission has many applications of future interest to NASA, both in space and on the ground. The status of several NASA tasks involving fiber optics will be briefly reviewed, and the motivations behind them will be examined.

The first applications being considered for fiber optics in space are related to the space shuttle, where both avionics data transmission and video signals are of interest. the consequences of the wide temperature variations, and long term radiation effects expected in space will be discussed.

Fiber optic data transmission may also be of interest for ground based on-site data transmission systems. Several such applications will be discussed. Typically, the EMI immunity expected with fiber links, and the very large data throughput capability with a small fiber waveguide are of primary interest.

In addition, supporting technology development activities will be described.

9. LOW THRESHOLD FIBER OPTIC LASERS: B.S. Kawasaki, K.O. Hill and D.C. Johnson, Communications Research Centre, Ottawa, Canada.

The advent of low-loss single-mode glass optical fiber has made possible a new class of CW lasers using stimulated Brillouin scattering, and stimulated Raman scattering as the gain mechanisms. We have achieved low threshold continuous-wave oscillation by both these mechanisms using an argon-ion laser to pump long lengths of single-mode fiber and have demonstrated high conversion efficiencies, of the order of 50%. New results on the threshold and spectra of these devices will be presented. Continuous operation over a period of several hours has been observed in these lasers. The Brillouin laser was constructed in both a ring-resonator configuration and a Fabry-Perot configuration. The former configuration has possible application as a sensitive ring gyro. The latter can be made to operate in a simultaneous cascade of frequencies covering more than 400 GHz and is potentially a source of picosecond pulses. The CW Raman laser has a wide gain bandwidth and has been observed to oscillate at several discrete frequencies over a 3 nm range. This laser is a possible source of broadly tunable coherent radiation.

Commissions C and E - Session CE1

Friday, October 15 0900 - 1215

ELECTROMAGNETIC COUPLING TO LEAKY CABLES

Chairman and Organizer: James R. Wait, U.S. Department of Commerce

1. THE RELATION BETWEEN THE "INTERNAL" AND THE "EXTERNAL" PARAMETERS OF A LEAKY COAXIAL CABLE: K.F. Casey, Electrical Engineering Dept., Kansas State Univ., Manhattan, KA.

The transmission-line equations used to describe the current and voltage on a leaky coaxial cable involve four parameters which describe its distributed series and shunt immittances and the distributed voltage and current sources which represent the effect of external excitation. These "internal" parameters have been useful in EMP-related research devoted to minimizing externally-generated internal signals.

Engineers using leaky coaxial cables for leaky-feeder communications have been principally concerned with fields outside the cable. The external coupling impedance, which relates the external axial electric field to the total cable current, is a useful descriptor of the "external" behavior of these cables.

In this paper we present the relation between the "internal" or transmission-line parameters and the external coupling impedance for a class of leaky coaxial cables. The external coupling impedance can be represented as a ladder network whose elements are simply related to the transmission-line parameters of the cable and to the properties of its outer dielectric jacket. It is also shown that for anisotropically shielded cables the external coupling impedance alone is insufficient to describe the external behavior of the cable; it must be augmented by a relation involving the total magnetic current carried by the cable.

2. ELECTROMAGNETIC FIELD PENETRATION THROUGH THE SHIELD OF A COAXIAL CABLE: P.L.E. Usleghi, Dept. Information Engineering, U. of Illinois at Chicago Circle and J.E. Bridges, IIT Res. Inst., Chicago.

Coaxial cables are often responsible for electromagnetic interference, because the outer conductor, or shield, of the cable is not impenetrable to electromagnetic radiation. Thus, when an external field is incident on the cable, some energy leaks through the shield into the cable and propagates to its terminations. This leakage generally occurs in two different ways: (a) magnetic field related penetrations principally due to current flowing on the exterior of the shield and characterized by a surface transfer impedance Z_T; (b) electric field related penetrations through holes in the shield, due to charge accumulated on the shield's outer surface, and described by a shunt admittance Y^T.

Standardized measurements of the cable penetration parameters Z_T and Y^T have been presented. In particular, Z_T has been measured by means of triaxial and quadraxial testing fixtures, which essentially consist of a hollow metal cylinder surrounding the cable. The various fixtures correspond to different impedance terminations of cable and tester. A known TEM field is produced between the cable shield and the surrounding fixture, and the voltage induced at either end of the cable by field penetration through the shield may be measured and related to Z_T and Y^T. A theory which is valid for arbitrary impedance terminations of cable and tester and for all frequencies has previously been developed only for the surface transfer impedance. In some published

works only Z_T was measured; in others, the measured quantity was a mixture of Z_T and Y^T, but was attributed to Z_T only. In both cases, the consequence is an inaccurate predictionof the cable response to external fields.

In this paper, a general theory is presented that leads to the determination of both Z_T and Y^T for cables and fixtures with arbitrary impedance terminations and at all frequencies. The formulas for specific triaxial and quadraxial fixtures as well as for electrically short cables are obtained as particular cases. Some consideration is given to practical measurement aspects and to the comparison of the various possible testing fixtures on a practical basis.

3. COUPLING INTO COAXIAL CABLES FROM CURRENTS AND CHARGES ON THE EXTERIOR: C.E. Baum, Air Force Weapons Laboratory.

In an electromagnetic interference environment such as the nuclear electromagnetic pulse (EMP) the question of cable shielding is significant. No such shield is perfect. One then has the problem of understanding the quantitative description of the coupling of these undesired external noise signals into the cable interior, and thence to the cable termination.

The telegrapher's equations with sources serve as a starting point. There are a series voltage source and a parallel current source on a per unit basis in the incremental equivalent circuit. For an open transmission line these are related to magnetic and electric coupling respectively. For a shielded cable these are related to the current and charge per unit length respectively on the shield. An interesting case is the braid wire shield modeled as a perfect conductor perforated with many small apertures. In this latter case the coupling parameters can also be readily related to the change in the inductance and capacitance per unit length associated with these apertures. Suitably designed experiments can directly measure both the series voltage source and parallel current source per unit length as separate parameters.

The above concepts can be generalized somewhat to a combined voltage and current together with combined sources. They can also be generalized to the coupling into N-wire cables.

4. PROPERTIES OF MULTILAYER CABLE SHIELDS: E.F. Vance, Stanford Research Inst., Menlo Park, CA.

The shielding properties of high coverage coaxial shields can be characterized by two parameters -- the transfer impedance and the transfer admittance. The transfer impedance relates the induced internal voltage per unit length to the shield current, and the transfer admittance relates the induced internal current per unit length to the shield voltage or surface charge density.

When two or more leaky shields such as braided-wire are used to obtain greater optical coverage and better circuit isolation, the overall shielding characteristics can be specified in terms of an equivalent transfer impedance and an equivalent transfer admittance. If the two shields are shorted together at electrically short spacings along the cable, the equivalent transfer impedance can be expressed as a simple relation containing the transfer impedances and internal impedances of the individual shields and the inductance of the shield-to-shield transmission line. Similarly the equivalent transfer admittance depends on the transfer admittances of the individual

shields, the electrical distance between the shield-to-shield shorts, and the capacitance per unit length of the shield-to-shield transmission line.

In the more general case when the shields are not shorted together, the overall transfer impedance is a function of the transfer admittances of the individual shields as well as the propagation factors and characteristic impedances of exterior and shield-to-shield transmission lines. The overall transfer admittance depends on the transfer impedance and the transmission line parameters. For cables of finite (but not electrically small) length, overall transfer impedance and admittance depend strongly on the cable length because of the resonances and antiresonances of the shield-to-shield transmission line.

5. CURRENTS INDUCED ON GROUPED UNDERGROUND ELECTRICAL CONDUITS BY AN ELECTROMAGNETIC PULSE ORIGINATING ABOVE THE SURFACE: S. Frankel, Frankel & Associates.

This paper concerns an engineering study intended to yield a relatively-simple formulation for the currents induced by an incident electromagnetic field on the individual members of an array of parallel, equal-radius, round conduits buried beneath the earth's surface.

It is supposed that the array is buried sufficiently below the surface that wave propagation along the array is as though it were buried in an infinite medium.

The conduits are assumed terminated in conducting structures so constituted that negligible current flows between the array and the terminating structure. At the same time, however, these terminations cause the conduits to be conductively connected to one another at the ends.

As a result the total current flowing on any conduit is the sum of corresponding components of two vectors: (1) an antenna-like vector, in which the array acts like a single composite conductor of unconventional cross section; (2) a transmission-line type of vector, in which the array behaves like a short-circuited two conductor transmission line.

Detailed results for a number of configurations (of up to eight conduits) are given.

6. A GENERAL THEORY ON RADIATION FROM A SMALL APERTURE DRIVEN BY A COAXIAL-LINE: D.C. Chang, University of Colorado, Boulder, CO.

A pair of coupled, vector integral equations are formulated for finding the tangential electric field at the aperture. A subsequent use of a small aperture assumption allows us to reduce the integral equations to those of quasi-static type. Solution of these equations can be derived from three canonical integral equations; two correspond to the normal magnetic field distribution at the aperture when immersed in an incident tangential static magnetic field and one for the scaler potential at the aperture due to an incident static electric field normal to the aperture. Solutions to these canonical equations are well-known for the special cases of circular and elliptical apertures. The reflection of transmission coefficients in the coaxial-line caused by the aperture radiation are then expressed explicitly in terms of some moment functions associated with the solution of these canonical problems. Analytical expresssion for the equivalent circuit elements representing

both the localized effect of the aperture and the radiation characteristics of the external surface of the outer cylinder are obtained. Our approach therefore requires no assumption on the validity of Bethe's small aperture theory as in a more conventional method.

Commission F - Session F7

Friday, October 1 0900 - 1215
SCINTILLATIONS AND THE TURBULENT ATMOSPHERE
Chairman: V.H. Rumsey, University of California

1. POWER SPECTRA OF IONOSPHERIC SCINTILLATIONS: T. Bemis and C.H. Liu, Electrical Engineering, University of Illinois at Urbana-Champaign.

Power spectra of intensity fluctuations of the scintillating transionospheric radio signals have been studied by many investigators in the effort to understand the structure of the ionospheric irregularities and to model the transionospheric communication channel. Recent multi-frequency scintillation observations have shown that the power spectra exhibit different features depending upon the strength of the scintillation. A unified theory that applies to both weak and strong scattering is needed to interpret the data. In this paper, we shall investigate the possibility for such a theory. Applying the Parabolic Equation Method, a general equation governing the behavior of the intensity spectrum, applicable to the ionospheric scintillation geometry, is derived. The equation is solved under different approximating assumptions corresponding to various physical situations. The results are applied to interpret the features of the observed scintillation power spectra.

2. SCINTILLATION OF 4/6 GHz SIGNALS ON LOW ELEVATION ANGLE EARTH-SPACE PATHS: J. M. Harris, COMSAT Laboratories.

Long term measurements of 4/6 GHz signal amplitude fluctuations on earth-space satellite paths with elevation angles near 5° are reported. The occurrence and magnitude of measurements of temperature, relative humidity, pressure, and wind velocity. In addition, data from an acoustic sounder, colocated with the 4 GHz receiver, is analyzed and presented for correlation between probable path turbulence and the scintillations. Fading statistics and the frequency spectrum of the amplitude fluctuations are also given.

3. TROPOSPHERIC SCINTILLATION AT MICROWAVE FREQUENCIES ON AN EARTH-SPACE PATH: Robert Crane, Env. Res. and Tech., Inc., Concord, Mass.

Tropospheric angle-of-arrival and amplitude scintillation measurements were made at X-band (7.3 GHz) and at UHF (0.4 GHz). The measurements were made using sources on satellites with 12 day orbits. The angle-of-arrival of the ray path to a satellite changed slowly allowing observations of fluctuations caused by atmospheric irregularities as they slowly drifted across the ray path. The fluctuations were characterized by the rms variations of elevation angle and the logarithm of received power (log power).

Over a one-year period, 458 hours of observation were amassed spanning every season, time of day, and weather conditions. The results show strong scintillation occurrences below 1-2° elevation angles characterized by a number of random occurrences of multipath events that produce deep fades, angle-of-arrival fluctuations, and depolarization of the received signal. The log power fluctuations ranged from 1-10 dB rms, at elevation angles below 2° to less 0.1 dB at elevation angles above 10°. The elevation angle fluctuations ranged from 1 to 100 millidegrees (mdg) at elevation angles below 2° to

less than 5 mdg at a 10° elevation angle. Comparable fluctuations in elevation angle are expected for bias refraction correction models based upon the use of surface values of the refractive index.

4. STATISTICAL DEPENDENCE OF INTENSITY FLUCTUATIONS OF A LASER BEAM ON THE PATH LENGTH THROUGH SIMULATED TURBULENT ATMOSPHERE: A.K. Majumdar and H. Gamo, School of Engineering, University of California, Irvine, CA.

We report the results of a series of experiments in which statistics of intensity fluctuations of a single-mode 15 mW He-Ne 6328 Å laser beam propagating over multifolded paths (obtained by a series of equi-spaced 1.75"x1" flat mirrors) in a laboratory simulated turbulence was measured as a function of path length. The strength C^2 of this turbulence, produced by 10 small adjustable heaters was measured with a high sensitive differential thermocouple system (7.6 micron diameter wires and observed frequency response of 770 Hz) and could be controlled in the ranges of 50×10^{-12} to 14.0×10^{-11} $m^{-2/3}$. The one way path was 2.5 meter and 13 of such multipaths were considered. We have measured histograms, central moments and cumulants up to 8th order, coefficients of skewness (γ_1), excess (γ_2) and variation (γ_0) and temporal frequency spectra. With increased paths, more asymmetric shapes of the histograms with longer tails favoring more towards log-normal (even if not exactly same) than the estimated m-distribution were noticed; γ_1 and γ_2 were increased and γ_0 approached a limiting value of about 0.6 (for $C_n^2 \sim 10^{-12}$ $m^{-2/3}$). Path-dependence of broadening of power spectra (including low-frequency and high-frequency behaviour) and Tatarski's critical frequency f_m of normalized spectra were studied with physical meanings.

5. BEAM DISTORTIONS IN TURBULENT MEDIA: L.S. Taylor, Naval Surface Weapons Ctr., Silver Spring, Md., and Electrical Engng. Dept., Univ. of Md.

In order to study the beam deforming properties of turbulence we form the quantities (beam moments)

$$R_x^{(p)}(z) = \int_{-\infty}^{\infty} \int x^p I(\underline{r}) d\underline{\rho}$$

where $\underline{\rho}$ represents the transverse coordinates (x,y), $d\underline{\rho}$ = dxdy and $I(\underline{r})$ is the intensity. The quantities $R_x^{(p)}$ are measures of beam displacement and distortion: $R_x^{(1)}$ is the x-position of the beam centroid, $R_x^{(2)}$ is a measure of beam x-width, $R_x^{(3)}$ a measure of beam x-curtosis, etc. We also consider the transverse spatial spectrum of the beam:

$$\hat{I}(\underline{n}_T;z) = \int_{-\infty}^{\infty} \int I(\underline{r})\, e^{-j\underline{n}_T \cdot \underline{\rho}}\, d\underline{\rho}$$

Compact analytic expressions are obtained from the mean-square n^{th} moments and spatial frequency spectra of the intensity profiles of beams propagating in turbulent media. The theory is based on the assumption of the existence of a phase autocorrelation which is a function of the transverse difference coordinates and is illustrated using the approximation of linear optics and the Rytov approximation. The theory can be applied to determine the collimation or focusing capabilities of optical systems in the presence of turbulence.

6. SPACE-TIME TURBULENCE STATISTICS: V.H. Rumsey, University of California.

For many years the space-time statistics of wave propagation in a turbulent medium have been handled by the frozen model (Taylor hypothesis) or by a variety of ad-hoc models that were insigated by the observed failure of the frozen model, which, however, has proved to be by far the most effective. It is usually based on the Kolmogoroff analysis which shows that the purely spatial structure function on the velocity fluctuations in the inertial range of the turbulence spectrum varies as the two-thirds power of the spatial lag. The same postulate of an inertial range provides a reliable basis for the space-time statistics. It shows that the space-time structural function has the form of:

$$\sqrt{r^{4/3} + \varepsilon^{2/3}\, t^2}$$ where r = space lag, t - time lag

and ε = dissipation power,

in a reference frame in which the mean velocity of the medium is zero. This result and the associated spectra, which put the space-time statistics on a proven physical basis, are in qualitative agreement with observations, and are particularly necessary for dealing with optical propagation through still air.

7. DIFFRACTION LIMITED RETRO-REFLECTION THROUGH TURBULENCE: A.A. Rhomberg and V.H. Rumsey, University of California.

Observations have shown that the effect of turbulence on received intensity in laser propagation over distances of several kilometers is cancelled when the path of propagation is folded back to the point of origin by means of a corner-cube retroflector. Simple theoretical considerations show that this is to be expected provided that the propagation time is much less than the period of the highest temporal frequency in the turbulence spectrum. The same considerations show that the optics used to concentrate the power need have no better spatial quality than the imperfections introduced by the turbulence, except for the corner-cube. Similarly the optics need be stable only over times comparable to or shorter than the propagation time.

8. ANGULAR SPECTRUM MEASUREMENTS OF ATMOSPHERIC TURBULENCE: A.R. Lewis and V.H. Rumsey, University of California.

The unique property of the theoretical formula for the angular spectrum of a point source seen through a turbulent medium is that it is related in simple closed form to the integrated structure function of the turbulence. It therefore provides measurements of it with a home-made telescope over a 5 Km path show a remarkable confirmation, over a range of 1000:1 in intensity, of the Kolmogoroff two thirds law, and of the underlying theory of wave propagation through a turbulent medium.

Commission F - Session F8

Friday, October 15 0900 - 1215
EM DEVICES, MEASUREMENTS AND THEORY
Chairman: A. H. LaGrone

1. NASA/AAFE BREADBOARD PULSE COMPRESSION RADAR ALTIMETER: E. Kulikauskas, Hughes Aircraft Co., CA.

Design and acceptance flight test results of the next generation spacecraft altimeter are described. The experimental high resolution breadboard system is designed to operate from an aircraft at 10 Kft above the ocean and to accurately measure altitude, sea wave height and sea reflectivity. The mini-computer controlled Ku-band system provides an extensive digital recording capability and the following six basic variables for experimentation purposes: pulse width, PRF, early and late gate widths, tracker bandwidth and track point. The system employs early and late gate outputs for tracking the surface of the sea; 24 filters are implemented for anlaysis of the leading edge of the sea return signal for wave height estimation. Signal bandwidths of 360 MHz are obtained using a reflective array compression (RAC) line. Stretch processing is used to achieve 1000:1 pulse compression. The system range command LSB is 0.62 ns or 9.25 cm. A second order altitude tracker, aided by accelerometer inputs is implemented in the system software. Noise, bias, and calibration submodes are interleaved with the radiate submode under computer control and provide data for periodic filter gain alignment and system delay calibration. During acceptance flight tests the system demonstrated an altitude resolution capability of 2.1 cm and sea wave height estimation accuracy of 10%.

2. SKYLAB S-193 RADAR ALTIMETER PULSE-TO-PULSE CORRELATION MEASUREMENTS: E.J. Walsh, NASA Wallops Flight Center, VA.

Mode 3 of the S-193 radar altimeter was designed to study pulse correlation as a function of pulse spacing, SNR and pulse length. The mode began with the transmission of pairs of pulses separated by 819.25 μs with four of the Sample and Hold (S&H) gates sampling the first pulse return while the other four sampled the same relative positions on the second return. After data from 104 pairs of pulse returns were recorded (in 1.04 seconds) the pulse separation was reduced to 409.65 μs with the S&H gates at the same relative positions on the return pulses and another 104 pulse-pair returns were sampled. After repeating the procedure four more times with the pulse-pair separation being reduced successively to 153.65, 76.85, 19.25 and 1.04 μs the S&H gates were shifted to sample later portions of the return pulses and the six pulse-pair separations were stepped through again. After additional shifts this procedure generated composite pulse returns at the six pulse-pair separations. The observations were in good agreement with the predictions of a Monte Carlo simulation. The variation of correlation for the 76.85 μs separation provided information on the azimuthal pointing of the antenna boresight.

3. AN EXAMINATION OF NEAR NORMAL INCIDENCE BACKSCATTERING FROM THE GREAT SALT LAKE DESERT AREA OF UTAH: G.S. Brown, Applied Science Assoc., Inc., Apex, NC

Measurements of backscattered power and average waveforms from the Great Salt Lake Desert Area by the Skylab S-193 radar altimeter have resulted in the hypothesis that such terrain could be electromagnetically characterized as specular. Further detailed

examination of the pulse-to-pulse fluctuation statistics clearly show the exponential nature of the post-detection (square law) voltage fluctuation. Since purely specular terrain cannot, by definition, give rise to such a high degree of fluctuation, the specular model for this process is considered to be inappropriate. Furthermore, estimates of the rms surface height based upon laser profilometer measurements show that the coherent or specular component would be severely attenuated due to the factor $\exp(-4k_0^2 \langle \zeta^2 \rangle)$.

In order to explain these measurements, a model is presented in which the surface is characterized by a very small rms surface slope. Under this condition, the backscattered power approaches the specular limit and the average return waveform becomes very nearly equal to the system point target response, i.e. σ° asymptotically approaches a delta function. This model also supports the low noise character of the altitude data observed over the area. Laser profilometer measurements of rms surface height and correlation length in the same general area are shown to result in a rms surface slope which supports the model. Since specular reflection depends upon the rms surface height and random scattering is characterized by the rms surface slope, the distinction between the two mechanisms is very important.

4. REMOTE PROBING OF TURBULENCE WITH SPECTRAL BROADENING MEASUREMENTS: R. Woo and F.C. Yang, Jet Propulsion Lab, Calif. Inst. Tech., and A. Ishimaru, Electrical Engng. Dept., University of Washington.

In this paper we present an analysis of the spectral broadening of monochromatic radio waves by refractive index fluctuations. Using the parabolic equation method we derive the Fourier transform of the mutual coherence function for a spherical wave, and thus the spectrum of the signal. We assume that the spectrum of the refractive index fluctuations is power-law with spectral index p. Applying the results to the solar corona we show that the shape of the signal spectrum gives information on p while the width of spectrum information on the intensity of refractive index fluctuations and solar wind velocity. These techniques are demonstrated with experimental data obtained with the Helios spacecraft.

5. RADIATIVE TRANSFER THROUGH RADOMES: K.R. Carver, Physical Science Lab., New Mexico State Univ.

This paper presents a theoretical model of radiative transfer through a radome as well as radiometrically measured losses for a typical aircraft radom at 1.4, 18, 22 and 37 GHz. Previous models have been limited to flat sheets normal to the direction of incidence and with no mutual coupling to the antenna. The present model can be used for obliquely inclined radomes such as are encountered in practical aircraft radiometers. In this case, the available noise power from the antenna terminals will depend in the usual way on the antenna loss and temperature, but the dependence on the radome insertion loss becomes more complicated, requiring a knowledge of both principal and cross-polarized components of the antenna gain as well as the angular dependence of both perpendicular and parallel components of the randome insertion loss. At typical thicknesses and incidence angles commonly encountered in millimeter-wavelength radiometers, thickness tolerance variations can have pronounced polarization-dependent effects on the apparent brightness temperature. Both theoretical and measured data are presented which demonstrate the importance of the tolerance effect on the measurement of radome insertion loss. The

effect of multiple scattering from near-field radomes is also discussed, along with measurements showing the resonant effect which can occur at lower frequencies.

6. THE FRESNEL ZONE NEAR PERIAPSIS DURING DEEP PLANETARY OCCULTATIONS OF SPACECRAFT: T. A. Croft, Stanford Research Institute, Menlo Park, CA.

When a spacecraft goes behind a planet, it may be able to maintain communication with Earth for a time by virtue of the inward refraction of the radio waves by the planet's atmosphere. In the deeper atmospheres, such as that of Venus, there is a "critical level" at which the radius of ray curvature equals the distance to the center of the planet. When this occurs, the occulation refraction angle can increase without limit and radio contact is possible well behind the limb of the planet.

Scintillation is often observed during such occultations of spacecraft. The correct interpretation (or prediction) of this phenomenon depends in large measure on a proper knowledge of the size of the Fresnel zone near raypath periapsis where there is turbulence which causes the scintillation. A method will be given for calculating the vertical extent of the first Fresnel zone when propagation is near the critical level. The unusual circumstances require a careful definition of "Fresnel zone" which can be applied unambiguously to a region wherein the radio rays are undergoing refraction. From the Huygens-Fresnel principle, it appears best to define the zone boundary as the locus of points reached by a path with a length $\lambda/2$ longer than the main ray. It is found that such a Fresnel zone is quite large compared to that which has been indicated in recent occultation literature. For example, at the critical level of Venus for a wavelength of 13 cm, the first Fresnel zone is about 300 meters high even in the most extreme case when rays travel near the critical level for an indefinite distance.

7. APPLICATION OF JOINT GAUSSIAN STATISTICS TO INTERPLANETARY SCINTILLATION: G.C. Valley and D. L. Knepp, Calspan Corp., Buffalo, N.Y.

The third and fourth intensity moments are calculated for a stochastic electromagnetic field whose quadrature components and excess coefficients are derived and compared to the expressions for Rice-Nakagami and log-normal statistics. The joint Gaussian intensity moments depend on three moments of the scattered electromagnetic wave, the in-phase and quadrature variances and the correlation coefficient; these three moments are calculated in the first Born approximation to illustrate application of the joint Gaussian results to interplanetary radio star scintillations. With this approximation, observations of skewness versus scintillation index are related to combinations of correlation length and spectral index for the solar wind electron number density fluctuations. This weak scattering relationship suggests a number of observational tests of the joint Gaussian hypothesis.

8. ON RESOLVING AMBIGUITY IN THE DETERMINATION OF INITIAL POLARIZATION IN ABSOLUTE TOTAL ELECTRON CONTENT MEASUREMENTS: I. Keroub, Radio Observatory, Israel; J. A. Klobuchar, A.F. Geophysics Laboratory, Hanscom AFB, MA; and H. Soicher, U.S. Army Electronics Command, Ft. Monmouth, N.J.

In order to resolve the ambiguity in the determination of initial ground received polarization angle in the Faraday Rotation Angle, several methods have been proposed. In this communication, we analyze and propose a new simple method to determine this initial angle. The method is based on determining the difference of phase path lengths

between the left and right handed circularly polarized channels by employing the technique of inversion of inputs to the receiver. We compare then these results with those obtained by other methods.

In this way, we ameliorate the evaluation of the absolute determination of Total Electron Content (TEC), which is particularly important at night when the TEC values are low.

Another possible application might be the reduction of discrepancies when comparing TEC results

1) from several stations, and
2) from different methods - i.e., Faraday and group delay

Commission J - Session J6

Friday, October 15 0900 - 1215
SOLAR SYSTEM AND GALACTIC RADIO ASTRONOMY
Chairman: D. Shaffer

1. CO and HCO^+ IN THE DIRECTIONS OF TAU A AND CAS A: T.H. Troland and C. Heiles, Univ. of California.

We report on observations of CO (115 GHz) and attempts to detect HCO^+ (89 GHz) in the directions of Tau A and Cas A. In the direction of Tau A we have possibly detected a CO absorption line at 12 km/s having a line temperature of 0.3°K, no HCO+ features are observed to a limit of 0.2°K. We have also mapped CO emission across the face of Cas A and at selected positions up to 30' off source. At nearly every position the CO emission consists of components corresponding to the local and Perseus arm HI absorption features. Typical line temperatures are 1 to 4°K, angular structure exists on a scale of 1' or less. We compare the CO data for Cas A with HI optical depth in front of the source, with the optical filaments, and with 5 GHz H_2CO adsorption on and off source. For the HCO+ transition in the direction of Cas A, we find that the line temperature is less than 0.2°K.

2. HIGH RESOLUTION POLARIMETRY OF THE SUN AT 3.7 and 11 cm WAVELENGTHS: K.R. Lang, Physics Dept., Tufts University, MA.

The four stokes parameters are presented for interferometric observations of the Sun at wavelengths of λ = 3.7 cm and λ = 11 cm with angular resolutions between 2.7 and 36.7 seconds of arc. An Hα solar flare of importance SN and type C has a radio wavelength (λ = 3.7 cm) size of 5 seconds of arc, a flux density of 0.3×10^{-22} W m^{-2} Hz^{-1}, and a brightness temperature on the order of 10^7 °K. The radio flare is 30% left circularly polarized at λ = 3.7 cm, 70% left circularly polarized at λ = 11 cm, and no detectable linear polarization was observed at either wavelength. During a forty hour observation of Sunspot region McMath No 13926 no substantial variations in circular polarization were observed, whereas one hour prior to the eruption of a solar flare dramatic changes in circular polarization were observed. Small scale features whose angular sizes are on the order of five seconds of arc exhibit changes of circular polarization of up to 80%, and we believe these changes are related to the emerging magnetic fields which trigger solar flares. At times other than those immediately preceding flare emission, the degree of circular polarization was the same at the two wavelengths but the sign was reversed. This situation can be explained if magnetic fields of intensity H < 1000 gauss and electron densities of $N_e \geq 10^7$ cm^{-3} are present. With these values of H and N_e gyroresonant absorption can explain the observed circular polarizations. Observations of the small scale, time varying emission of the quiet sun confirm that this emission is quasi-periodic with time scales of minutes, and that the emission is probably thermal bremsstrahlung.

3. INTENSE ELECTRON PLASMA OSCILLATIONS ASSOCIATED WITH TYPE III SOLAR RADIO BURSTS: D.A. Gurnett and R.R. Anderson, Dept. of Physics and Astronomy, Univ. of Iowa.

Plasma wave electric field measurements on the HELIOS-1 and -2 spacecraft in orbit around the sun have detected intense electron plasma oscillations associated with the generation of Type III solar radio bursts, confirming the theory for the generation of these radio emissions first proposed by Ginzburg and Zheleznyakov in 1958 and subsequently refined by many other investigators. Of a total of twenty-one Type III radio bursts detected by HELIO-1 and -2 during the first 16 months of in-flight

operation, a total of five events show the simultaneous occurrence of electron plasma oscillations at the local electron plasma frequency as the apparent source of the radio emission sweeps over the spacecraft. Source positions are determined by direction finding measurements both by HELIOS and from the earth. In several events the simultaneous arrival of the energetic, 1 to 40 keV, electrons producing the plasma oscillations has also been observed. Comparisons with current theories for the non-linear coupling of plasma oscillations to electromagnetic radiation confirms that the plasma oscillation intensities ($\sim$ 10 mV m^{-1}) are sufficiently large to account for the intensity of the Type-III radio emission at low frequencies.

4. MICROWAVE CONTINUUM MEASUREMENTS OF COMETS: R. W. Hobbs, S. P. Maran, and J. C. Brandt, Lab. for Solar Physics and Astrophysics, NASA-Goddard Space Flight Center, MD

Comets Kohoutek (1973f), Kobayashi-Berger-Milon (1975h) and West (1975n) were observed at 3.71 cm with the NRAO Interferometer and various combinations of interferometer elements and baselines. The ephemeris predictions for comets near perihelion are usually not accurate enough to permit precise tracking with this instrument, but are adequate to insure that the source does not drift very far from the peak of the 6-arc-minute envelope beam. Thus, the 25-mfu unresolved source associated with the nuclear region of Comet Kohoutek and the 30-mfu unresolved source associated with Comet West were each observed to drift in fringe phase over the observing intervals of 9 hours on 10-11 January 1975 and 10 hours on 5 March 1976 U.T., respectively. However, the observed drifts agree exactly with those calculated from the actual cometary positions determined a posteriori from optical measurements. (Kohoutek was also detected at 2.8 cm with the 140-ft. reflector.) Comet West was not detected on 4 March 1976 although it was measurable on 5 March. As is well known, three splittings occurred in this comet, producing four observed nuclei, one of which, "nucleus C", was a short-lived object. Calculations by Z. Sekanina from the optical astormetric data indicate that "C" split off the main nucleus "A" on 5.8 ($\pm$0.3) March, which can be compared with 5.7 March, the mean time of our observing interval. Comet Kobayashi-Berger-Milon was not detected; however, the 2σ upper limit of 12 mfu equals the expected flux if one simply scales the Kohoutek radio source according to the inverse square of the distance from the Earth. The observed radiation can be interpreted as thermal emission from ice grains of a few mm in size that fill a region of several hundred km radius around the nucleus. Such a region, called the "icy-grain halo," was postulated by A. Delsemme to explain certain optical phenomena in comets. However, the mass loss required to produce an icy-grain halo that can account for the microwave fluxes observed thus far cannot be continuously maintained by a cometary nucleus. Thus, if the model is correct, the microwave sources must be transient.

5. THE STRUCTURE OF THE SiO MASER IN ORION A: K. J. Johnston, J. H. Spencer, P. R. Schwartz, E. O. Hulburt. Center for Space Research, Naval Research Lab. Washington, DC. J. M. Moran, Center for Astrophysics, Cambridge, MA.

The $v = 1$, $J = 1 \rightarrow 0$ maser transition of SiO (43 GHz) towards Orion A was observed with the Haystack Observatory's 120 foot antenna in January 1976. The various spectral components in the source were found to be spatially coincident to within 3". In contrast the H_2O maser features were spread over a region having a 30" diameter. No interference fringes were observed from a VLBI experiment between Haystack and NRL. It was concluded that the maser features were larger than 0".001.

6. PULSAR OBSERVATIONS AT THE FIVE COLLEGE RADIO ASTRONOMY OBSERVATORY: D.J. Helfand, G,R, Huguenin, and J.H. Taylor, Dept. of Physics and Astronomy, Univ. of Mass., Amherst, MA

Daily observations of pulsars at two frequencies have been made at the FCRAO for over 5 years. Flux variations have been observed on timescales of from 2 days to 300 days. The fluctuations at the two frequencies are not in general well correlated. Strong limits have been set on the amplitude of any periodic modulation in the range 2 days to 150 days for most sources. However, for PSR 1133+16, observation of a 60 day cyclic flux change suggests a precession of the neutron star. The shapes of the pulsar mean profiles have remained remarkably constant. Measurements of the pulse arrival times have yielded a number of interesting results. Positions have been determined to an accuracy of better than $0''.1$. The first radio astronomically-determined proper motion was obtained in 1974, and proper motions for several more pulsars have since been detected, which imply transverse velocities of from 50 km/sec to over 500 km/sec. Irregularities in the pulsar period are being studied in a search for clues to the internal structure of the neutron star. Several large period discontinuities have been observed. Comparison of the arrival times at the two frequencies yields information on the fluctuations of the intervening interstellar medium.

7. AUTOCORRELATION MEASUREMENTS OF PULSAR POLARIZATION WITH 8-μs TIME RESOLUTION: J. M. Cordes, Dept. of Physics and Astronomy, Univ. of Massachusetts.

The polarization properties of pulsar PSR 1133+16 at 430 MHz were studied after removing interstellar dispersion distortion from data obtained at the National Astronomy and Ionosphere Center (Arecibo Observatory). With no post-detection smoothing the signals have a time resolution equal to the reciprocal of the receiver bandwidth (125 kHz), but since they also have only two degrees of freedom, estimation error is large. Therefore, autocorrelation functions of the Stokes parameters of single pulses were computed and summed -- thereby reducing estimation error while preserving the time resolution -- to study the average properties of short time scale structure.

Results show the presence of two temporal scales in pulses from PSR 1133+16, corresponding to micropulses and subpulses. Both subpulses and micropulses show fast polarization changes in the form of 90° transitions of the position angle and sense changes of the circular polarization. Within the context of current pulsar models, this behaviour is indicative of radiative transfer effects being an important determinant of the polarization and suggests that the temporal time scales correspond to spatial scales in the relativistic plasma in the pulsar. The results also suggest the presence of sub-microsecond structure which depolarizes the signals to approximately 60% polarization when they are smoothes over an 8-μs interval.

8. PULSAR DISPERSION REMOVAL WITH A SWEPT LOCAL OSCILLATOR: B. J. Rickett, Applied Physics and Information Science Department, Univ. of California.

The detection of rapid time variations (microstructure) in the radio radiation from the fainter pulsars is hampered by the competing requirements of a wide bandwidth for good sensitivity and fine time resolution. These difficulties can be overcome

by passing the signals through a mixer, with its local oscillator swept to track the dispersion frequency sweep rate, followed by a multi-channel spectrometer. The spectrum output is a time series of pulse intensity (Sutton, J.M., Staelin, D.H., Price, R.M., and Weimer, R., 1970, Ap. J., 159, L 89.). With the availability of digital auto-correlation spectrometers at many observatories this method has become more attractive.

The paper will give details of the method; in particular effective time resolutions and total R.F. bandwidths will be discussed as a function of dispersion measure and center frequency. The need to sweep the sampling frequency in the digital auto-correlator will be discussed. Simulations in which dispersed noise pulses are computer processed by the method will be presented, including the effects of one-bit auto-correlation.

9. RADIO ASTROMETRIC STUDIES OF PULSARS AND RADIO STARS USING THE NRAO 35-KM INTERFEROMETER: D.C. Backer, Radio Astronomy Lab., Univ. of CA., and R.A. Sramek, National Astronomy and Ionosphere Center, Arecibo, PR.

Since May 1974 we have been monitoring the positions of pulsars and two radio stars relative to a (presumed) extragalactic frame of reference. The formal accuracy of our interepoch comparisons is 0".01, allowing proper motion determinations with errors around 0".005 yr^{-1} at present.

The results of the first epochs of these measurements have been published (Backer and Sramek, A.J. June 1976). We will discuss the latest results on pulsar proper motions.

Since May 1975 we have observed two radio "stars" Algol and Sag A (compact). The known (from optical studies) parallactic and orbital motions of Algol should serve as an external calibration of our method. Measurement or a limit on the motion of Sag A relative to an extragalactic frame of reference is of interest on three accounts: (a) the solar galactic motion produces an apparent proper motion of 0".005 yr^{-1} relative to the galactic barycenter; (b) the motion of this unexplained object in the galactic-center potential well is of interest; (c) since scattering along our line of sight broadens the intrinsic source diameter to 0".2 (1/3 of our interferometer lobe spacing at 2.7 GHz), our observations will place limits on (or measure) the wandering of the centroid of the scattering angular distribution.

Commissions A and B - Session 7A

Friday, October 15 1400 - 1715

HYPERTHERMIA

Chairman: D.I. McRee, Nat'l. Inst. of Environmental Health Sci.

1. A COMPARATIVE HEATING PATTERN STUDY OF DIRECT CONTACT APPLICATORS IN MICROWAVE DIATHERMY: G. Kantor and T.C. Cetas, Bureau of Radiological Health, College of Medicine, Univ. of Arizona.

Inhomogeneously filled rectangular waveguides, circularly polarized antennas and other radiators appropriate for microwave diathermy were considered in this comparative study of direct contact applicator heating patterns. In addition, low power emitters (usually operating at power levels of less than 10 Watts), the only direct contact radiators presently in clinical use, were investigated. Multi-layered planar and limb phantoms consisting of simulated bone (1 cm thick) and muscle material were irradiated at a frequency of 2.45 GHz, and then the midplane of each phantom was exposed to an infrared thermographic camera. Temperature profiles parallel to fat-muscle interface as well as normal to it were obtained to study maximum heating and depth of penetration of microwave energy in muscle tissue. The temperature profile produced in a planar phantom by an applicator, consisting of an open WR(430) rectangular waveguide partially filled with Teflon slabs to excite the TEM mode in the unloaded middle portion, has a broad, uniform center region. A birefringent crystal optical thermometer was placed in the mid-plane of each phantom to obtain temperature readings and cooling rates in the region of heating. Leakage radiation levels can be maintained below 5 mW/cm^2 (equivalent plane wave power density) if the applicator aperture size is considerably smaller than the phantom size.

2. HYPERTHERMIA BY LOCAL EM HEATING: K-M Chen and B.S. Guru, Michigan State Univ., East Lansing, MI.

One promising cancer therapy is to use a hyperthermia technique combined with chemotherapy or an ionizing radiation therapy. When the temperature of the cancerous part of the body is maintained a few degrees above the normal body temperature, the accompanying chemotherapy or radiation therapy may be found to be very effective in treating the cancer.

A study has been made to investigate the distribution of power deposition in a biological body with a cancerous part when the body was illuminated partially by an EM field. It was found that the cancerous part with a lower conductivity dissipated more power, causing a high temperature increase.

The scheme of heating a local region of a biological body by utilizing the whole-body EM illumination and changing the conductivity of the local region has also been studied. It was found that when the frequency of the EM field is in the range of 1 to 100 MHz, the increase of the conductivity of the local region usually causes a decrease, instead of an increase, in the absorbed power in that local region. For a microwave EM field, there may exist an optimum conductivity for the local region to gain the most effective EM heating.

3. DUAL BEAM TEM APPLICATOR FOR DIRECT CONTACT HEATING OF DIELECTRICALLY ENCAPSULATED MALIGNANT MOUSE TUMOR: A.Y. Cheung, T. Dao and J.E. Robinson, The Martha V. Filbert Radiation Therapy Center, Univ. of Maryland, Baltimore.

A microwave heating technique, in direct parallel to parallel opposed treatment field used in ionizing radiation therapy has been developed. The sources of irradiation are two opposite-directed "TEM" applicator operating at 2450 MHz. The applicator design consists of an open-ended rectangular waveguide, partially loaded with low loss dielectric slabs. Such a structure can support a TEM mode of propagation. The impedance mismatch generated from the TE to TEM transition and from the aperture-tissue boundary are compensated by a properly designed taper and a quarter-wave transformer. On direct contact with a tissue-equivalent slab, the TEM applicator heats uniformly in the transverse plane ($\pm$ .2°C at 45°C).

Exposed C3H mouse tumors, 1 cm in diameter transplanted to grow on the flank of mice, were encapsulated within simulated phantom materials with dielectric properties similar to that of the tumor to form a rectangular slab. The thickness of the slab along the direction of propagation is designed so that the super-position of two exponentially decreasing heating fields from opposite directions will generate a uniform temperature distribution. Two TEM applicators in direct contact with the slab, were used to heat from opposite sides at alternate time intervals of 5-50 seconds. Alternating at 30 seconds, two applicators operating at 30 watts for 10 minutes, produce a temperature of 42 $\pm$ .1°C over the entire tumor volume, as compared to a 2°C front to back drop when a single applicator is used alone under the same condition.

4. MICROWAVE HYPERTHERMIA AND Co-60 RADIATION TREATMENT OF HAMSTER MELONOMA: R.J. Vetter and G.A. Stoetzel, School fo Pharmacy and Pharmacal Sciences, Purdue Univ., W. Lafayette, IN; R. Shupe, Indiana Univ. School of Medicine, Indianapolis, IN.

The effect of microwave hyperthermia, alone and in combination with Co-60 radiation, and infrared hyperthermia alone, on an amelanotic melanoma specific to golden Syrian hamsters was investigated. In preliminary work, treatments with 250 kV x rays as high as 800 rads per treatment given on 5 consecutive days had no effect on melanoma growth, thus confirming radioresistance reported in the literature.

Duration of hyperthermia was 12 minutes and Co-60 exposure was 200 R per treatment. Experimental groups were divided into high and low tumor temperature subgroups (46.0°C and 41.5°C for infrared). Tissue temperature was difficult to control in the microwave groups resulting in wide variation in tumor temperatures. Tumor volumes and survival times were recorded to judge treatment efficacy.

Tumor regression and mean survival time in the high-temperature microwave plus Co-60 group were significantly greater than in all other treatment groups. This suggests that high temperature microwave hyperthermia increases radiosensitivity and should be considered as a potential adjunct to cancer radiotherapy.

Commissions A and B - Session 7B

Friday, October 15 1400 - 1715
THERAPEUTIC AND DIAGNOSTIC APPLICATIONS
Chairman: S.F. Cleary, Medical College of VA

1. THE USE OF SPONTANEOUSLY OCCURRING ANIMAL TUMORS FOR PRECLINICAL TESTING OF HYPERTHERMIA TREATMENTS: W.G. Connor, H.B. Roth, D.H. McKelvie, S.E. Wilson, and T.C. Cetas, Univ. of Arizona, College of Medicine, Tucson, AZ

Tumor systems occurring spontaneously in animals are being used as a testing ground for the development of heating and thermal dosimetric techniques that are to be used in hyperthermia treatments of human tumors. The animals, mostly dogs and cats, are referred by local veterinarians. Treatments consist of heat alone e.g. 43°C for 30 minutes, X-irradiation alone e.g. 4000 rads/4 weeks, or a combination of the two. Localized heating is induced by radiofrequency current fields (500 KHz), microwave diathermy (2450 and 915 MHz) or shortwave (27.1 MHz) diathermy. Temperatures are monitored with a nonperturbing fiber optic thermometer incorporating a birefringent crystal as a sensor and with thermistor probes. Thermographic techniques both in phantoms and, when possible, on the actual subjects are used to determine the thermal pattern. All thermometry is tied to a laboratory standards facility which is accurate to better than 0.01°C. The biological aspects are supported by cell culture and laboratory animal studies in adjacent laboratories. Complete veterinary facilities are located within the hospital. Radiation oncologists in the department consult regularly on the treatments.

2. COMBINED EFFECT OF MICROWAVE HYPERTHERMIA AND PURIFIED BACTERIAL TOXINS ON DEVELOPMENT OF SARCOMA-180 AND GUERIN TUMORS: S. Szmigielski, M. Bielec and M. Janiak, Center for Radiobiology and Radioprotection, 00-909 Warsaw, Poland.

Microwave hyperthermia of the whole body (mice irradiated at the anechoic chamber, far field conditions, 40 mW/cm^2, 3 hrs daily) results in inhibition of tumor growth (transplantable Sarcoma 180) (S. Szmigielski et al., Cancer Letters, 1976, in press). The inhibitory effect of microwave hyperthermia may be markedly enhanced by combination with cytostatics (cyclophosphamide, colcemide) or large doses of vitamin A (S. Szmigielski et al., in preparation). In the above combined treatment inhibition and regression of tumors was higher than in animals treated with each single factor (cytostatics or microwave hyperthermia).

In the present series of experiments mice with transplantable Sarcoma 180 or rats with transplantable Guerin tumor were exposed to microwave hyperthermia (40 mW/cm^2, 3 hrs daily) at various periods after transplantation of the tumor. Rectal temperature was measured during the whole period of irradiation (liquid crystall probe) and distribution of temperatures on the body surface was observed with use of AGA-680 thermovision (M. Bielec and S. Szmigielski, Phys. Med. Biol., 1976, in press). The animals were treated with highly purified Streptolysin O, staphylococcal phospholipase C (beta-hemolysin) or with cyclophosphamide (positive controls). The toxins were administered daily and given alone or in combination with microwave hyperthermia. Survival rate, weight and size of tumors and incorporation rate of ^{3}HOthymidine, ^{3}H-uridine and ^{3}H-glycine into tumor tissue was controlled.

Microwave hyperthermia resulted in inhibition of tumor growth in about 25-30% of animals, while the combined treatment with microwave hyperthermia and Streptolysin O resulted in regression of tumors in 50-70% of animals, depending on the time scheule of the treatment. The best results were obtained in animals treated in the phase of logarithmic growth of the tumors.

3. SUPPRESSION BY HYPERTHERMIA OR BY 2450 MHz MICROWAVES OF REPAIR OF DAMAGE PRODUCED BY IONIZING RADIATION: P-K Lai, C.A. Cain and H.S. Ducoff, Univ. of Ill., Urbana, Ill.

The lethal effect of gamma-radiation in normal or neoplastic mammalian cells is greatly reduced when a given dose is administered in two or more fractions separated by intervals of a few hours. This sparing effect of dose fractionation (Sdf) implies repair of some of the damage during the interval between fractions; Sdf is abolished if the irradiated cells are subjected to hyperthermia (41° - 43°C) between fractions. We have obtained comparable results using intact flower beetles, a model system much more amenable to experimental manipulations. Hyperthermia (43° - 45°C) for two hours after the first fraction not only abolishes Sdf during the 2-hour interval, but also causes protracted suppression of Sdf even if the treated beetles are returned to the normal incubation temperature of 30°C for several hours before the second gamma-radiation exposure. Similar suppression of Sdf was obtained by 2-hour exposure to 2450 MHz radiation after the first gamma-irradiation. These results suggest the feasibility of using microwaves to produce localized hyperthermia in tumors while permitting normal tissues to repair damage during fractionated radiotherapy.

4. APPLICATION OF MICROWAVE RADIOMETERS TO DIAGNOSTIC MEDICINE: A.H. Barret, P.C. Myers, MIT Dept. of Physics and Research Laboratory of Electronics, and N.L. Sadowsky, Faulkner Hospital Dept. of Radiology.

Microwave radiometers at 1.3 and 3.3 GHz have been developed for mapping the thermal radiation from the human body. As with infrared thermography, regions of high or low brightness may be associated with pathological conditions, such as malignant tumors or vascular blocks. Microwave radiometry has coarser spatial resolution than infrared thermography ($\sim cm^2$ rather than $\sim mm^2$), but greater depth sensitivity ($\sim$cm rather than $\sim$0.1 mm) because of the relative transparency of tissue at microwave frequencies. The temperature sensitivities are comparable (0.1°C). Laboratory experiments have indicated microwave capability of subsurface sensing in human tissue. Clinical application to detection of breast cancer has been attempted, using a dielectric-filled waveguide antenna, and a point-by-point mapping technique, with over 2000 patients and over 20 cancers at Faulkner Hospital, Boston. True positive and true negative rates of over 70% are indicated. These are comparable with infrared thermography and xeromammography detection rates for the same set of patients.

Commissions A and B - Session 8A

Friday, October 15 1400 - 1715
DEVELOPMENTAL AND MUTAGENIC EFFECTS
Chairman: W.F. Pickard, Washington Univ., St. Louis

1. CAN ELECTROMAGNETIC WAVES CAUSE CONGENITAL ANOMALIES?: R. Rugh and M. McManaway, U.S. Dept. of HEW, Publ. Health Service, Food and Drug Admin., Bureau of Radiol. Health, Rockville, MD.

A total of 145 CF1 white mice with timed pregancies were used either as unirradiated controls or were exposed individually for 4 minutes to 2450 MHz microwave radiation in a waveguide mean of 99.12 to 114.6 mW/g average absorbed dose rate (23.79 to 27.5 J/g average absorbed dose). The temperature was controlled at 25°C and humidity at 50%. A minimum of 10 pregnant mice were exposed on each gestation day from 0 to 11 inclusive to determine which day(s) were the most radiosensitive with respect to the microwave induction of fetal deaths and anomalies. It was found that day 8 showed a significant increment in fetal deaths and anomalies among those irradiated (controls 22.3% and 8 days 68.0%). The most frequent effects were resorptions and deaths, caused shortly after irradiation. With counts of congenital anomalies only, days 4 and 8 appeared to show percentage increments, but below significant levels for the number of animals; only 10% showed exencephalia (brain hernia) compared with less than 1% for controls. Examinations were made at 18 gestation days. This result fits in very well with those previously shown for effects of ionizing radiations, suggesting that day 8 is the most radiosensitive day for the mouse embryo and fetus.

2. MICROWAVE-INDUCED TERATOLOGY IN THE RAT: M.E. Chernovetz, Tulsa Univ.; A.F. Oke and D.R. Justesen, Univ. of Kansas School of Medicine and Kansas City Veterans Admin. Hospital.

Primigravid rats were exposed in a multi-mode cavity for 20 minutes to microwave radiation (2450-MHz, ∿30 mW/g) or to infrared radiation during one of seven days of gestation, the 10th through the 16th. Increments of colonic temperatures were equated for microwave and infrared treatments. Animals from a third group of dams were given a sham-exposure during one of the seven days. On the 19th day of gestation, fetuses were taken by Ceasarian section and after weighing were examined for structural abnormalities and signs of insult. Brains of fetuses that were sampled from each of the three treatment-groups were analyzed for levels of norepinephrine and dopamine. Findings: 1) extensive hemorrhagic signs were observed in fetuses after infrared and microwave radiation; 2) averaged fetal mass is slightly but reliably lower in infrared- and microwave-radiated subjects as compared to the averaged mass of controls; 3) averaged number of fetal resorptions does not differ for the control and infrered treatments but is highly elevated in association with the microwave treatment; 4) while the averaged whole-brain dopamine levels do not differ greatly over the three conditions of treatment, the averaged level of whole-brain norepinephrine is reliably lower in microwave-treated fetuses than in their control or infrared-treated counterparts.

The findings warrant the conclusion that highly intense microwave irradiation (LD∿10) is a stressor but one with sequelae that differ somewhat from those produced by conventional sources of thermal stress.

3. THE EFFECT OF REPEATED MICROWAVE EXPOSURE IN NEONATAL RATS: R. Guillet and S. Michaelson, Dept. of Radiation Biology & Biophysics, Univ. of Rochester.

Neonatal rats (Long Evans Hooded, Blue Spruce Farms, Altamont, NY) were exposed to 40 mW/cm^2, 2450 MHz, CW, radiation for five minutes each day from day one to day six of life. On postnatal day 7, the rats were either sacrificed, exposed to 2450 MHz, CW for a seventh time, or injected with ACTH. Twenty minutes after the final exposure or injection, the pups were sacrificed. Trunk blood and adrenal glands were saved. No difference was found in plasma corticosterone concentrations between the rats previously exposed to microwaves and control animals that were not exposed. Basal plasma corticosterone concentrations were less than 2 μg% in both groups. Following either microwave exposure or ACTH injection on day 7, plasma corticosterone levels remained low (<3 μg%) in both exposed and control animals. A statistically significant increase in adrenal net weight was noted in animals exposed to microwaves on the first six postnatal days. The cause and biological significance of this enlargement is unknown. Because the first 2-3 weeks after birth are very critical in the development of the rat, effects of microwave exposure during this period may be readily manifested at this time or at a later stage of life.

4. INSECT PUPAE TERATOGENISIS IN A STANDING WAVE IRRADIATION SYSTEM: R.G. Olsen, Naval Aerospace Medical Research Lab.

Pupae of the mealworm bettle, Tenebrio molitar, were irradiated in the standing wave region of a cw 4 GHz signal such that some of the pupae were positioned in an E-field maximum plane while others were positioned in an adjacent H-field maximum plane. The standing wave pattern was produced by reflecting a plane wave at normal incidence from a metal plate suspended in the far field region of a horn-irradiated anechoic chamber. The physical cross section of the irradiated pupae accounted for less than one percent of the reflecting plate area to insure a minimum field perturbation, and the long axis of each pupa was oriented parallel to the H-field vector.

For the reflected plane wave system where the microwave dose rate was calorimetrically determined to be less than 12 mW/gm in phantom insects, initial results show teratogenic effects of irradiation in pupae positioned in both the E-field maximum plane and the H-field maximum plane; furthermore, the teratological damage appears to occur as often in either position. This result indicates that for this frequency and orientation, each field quantity can independently produce effects similar to those previously seen at X-Band in waveguide irradiation systems.

Commissions A and B - Session 8B

Friday, October 15 1400 - 1715

ELF EFFECTS

Chairman: E. Postow, Nat'l. Naval Med. R&D Command

1. CHRONIC EXPOSURE OF PRIMATES TO ELECTRIC AND MAGNETIC FIELDS ASSOCIATED WITH ELF COMMUNICATIONS SYSTEMS: J.D. Grissett, Naval Aerospace Medical Research Lab.

A group of 30 experimental animals (Macaca mulatta) and 30 control animals were pair-matched by age, sex, weight, and medical history. The experimental animals were exposed continuously to magnetic and electric fields similar to those experienced by man in contact with the soil surface directly above a buried ELF antenna. Blood samples were drawn weekly for biochemical analysis. Physical examinations were given at six week intervals by a veterinarian. Clinical and blood chemistry results will be presented for 294 days of exposure.

2. 60-HZ ELECTRIC FIELD EXPOSURE SYSTEM FOR A MINIATURE SWINE COLONY: M.F. Gillis, J.L. Beamer, R.L. Richardson, C.H. Allen and W.T. Kaune, Battelle-Northwest, Richland, WA.

A facility is under construction which will permit the long-term study of electric field effects on miniature swine under well-defined conditions. It consists of a conducting-floor ground pad, nonconducting contiguous stalls, nonconducting roof and walls, and an overhead linear array of four tubular conductors connected to a high-voltage transformer. The design is intended to satisfy several criteria, including the following: (1) The voltage supply and electrode system must provide uniform, vertical 60-Hz electric fields of large magnitude. (2) The structures between the pad floor and electrode must not significantly perturb the applied field nor contribute to ozone production. (3) The facility must provide for animal comfort and routine husbandry throughout the year. (4) the animals will be individually stalled to minimize mutual shielding and permit farrowing in the field. (5) Remote monitoring of ambient conditions and observation of the colony while the field is on will be afforded by appropriate instrumentation. (6) A zero-field facility, otherwise identical to the experimental colony facility, will be provided for control animals. (7) The design should be such as to allow expansion for future animal generations with minimal expense and field interruption.

3. INTERACTION OF SWINE WITH 60 HZ ELECTRIC FIELDS: W.T. Kaune, J.L. Beamer, D.L. Hjeresen, R.D. Phillips and R.L. Richardson, Battelle-Northwest, Richland, WA.

Experiments were conducted to obtain information on the interaction of Hanford Miniature Swine with uniform, vertical, single-phase, 60 Hz electric fields. Four swine were individually tested during exposure to electric fields (to 55 kV/m) while housed in a plexiglass pen with a grounded metal floor.

The electrical resistance between the ground plane and the swine was about 2000 ohms. The current between the swine's mouth and the grounded watering fixture was a linear function of field strength and in no case exceeded 165 μAmps at a field strength

of 55 kV/m. The threshold for perception of a mouth to watering system current was measured in another experiment and was found to be greater than 225 μAmps for all of the swine.

At 20 kV/m the average short circuit current of four swine was 135 μAmps (S.D. = 11 μAmps). The electric field was markedly distorted by the swine's body and was increased by a factor of 6.7 at the top of the back. Calculations based on an ellipsoidal model of swine predict a value of 6.6 for this enhancement factor and a short circuit current of 125 μAmps at a field strength of 20 kV/m.

4. RESPONSE OF SWINE TO 60 HZ ELECTRIC FIELDS: D.L. Hjeresen, J.L. Beamer, W.T. Kaune, R.D. Phillips, and R.L. Richardson, Battelle-Northwest, Richland, WA.

Research is needed to establish an improved data base concerning possible biological effects of 60 Hz electric fields. Experiments were conducted to determine whether Hanford Miniature Swine (HMS) could be exposed to large electric fields without acute untoward effects and to determine the upper limit on field strength, up to 55 kV/m, that would not produce corona (hence ozone) on or near the animal, shocks from a drinking watering system, or visible hair stimulation. Four HMS were trained to drink from a watering system in response to a 750 Hz tone. Observations were made to detect any changes in drinking behavior as a function of electric field strength.

The drinking response and general behavior of swine appeared normal at field strengths up to 50 kV/m. No corona occurred on or near the swine at field strengths up to 55 kV/m. Animals standing on a grounded metal plate did not receive shocks from the grounded watering system at field strengths as high as 55 kV/m; swine insulated from ground received shocks at 10 kV/m. The threshold field strength for piloerection and hair oscillation was about 50 kV/m. Experimental evidence was obtained that indicated HMS perceive electric fields at 30 to 40 kV/m.

5. EFFECTS OF A 60-HZ ELECTROMAGNETIC FIELD ON LOCOMOTIVE & AGGRESSIVE BEHAVIORS OF MICE: R.F. Smith, Univ. of Kansas School of Medicine, D.R. Justesen, Kansas City Veterans Admin. Hospital.

Mice in small groups were observed for 24 to 48 hours for locomotor activity and for agression-related vocalizations during short (120-sec) but recurrent and aperiodic presentations of a 60-Hz field. The field was sinusoidal with a dominant magnetic component that was measured at 1.7 mWb/m, rms and its effects were analyzed in terms of strain of mouse, (DBA-2J, pigmented vs. CD-1 Albinos), circadian periodicity, and trend. Highly reliable and persistent increases of activity of a time-locked sort were observed during exposures of mice to the field. Both the strain of mouse and circadian period were reliable sources of variation. The influence of the field on the measure of aggressive behavior was much less incisive although the data suggest a two-fold reaction: inhibition during exposure followed by a rebound. Data from control experiments with anesthetized mice or with sham-exposed animals tend to exclude an artifactual basis of the observed alterations of activity.

Commissions A and B - Session 9B

Friday, October 15 1400 - 1715
FIBER & INTEGRATED OPTICS III
Chairman: A.F. Snyder, Australian Nat'l. U.

1. A UNIFYING RAY ANALYSIS OF MULTIMODE OPTICAL FIBERS: A.W. Snyder, Australian Nat'l. Univ., Canberra, Aust.

Nearly all problems of practical interest to the communication industry that involve propagation on multimode step or graded index fibers can be solved adequately by classical geometric optics. This includes a complete determination of pulse spread, accounting for the effects of material dispersion and fiber non-uniformities, when the fiber is illuminated by an incoherent or diffuse source. The results of this approach are the same as those using WKB modal methods only they are considerably easier to derive and they contain more direct physical significance.

Classical geometric optics does not account for losses that may be suffered by the small amount of power within the evanescent field that extends beyond the turning point of the ray, e.g. losses due to an absorbing cladding or due to rays undergoing tunnelling radiation because of curvature in the axis of the fiber or in its cross section. These effects are easily accounted for in the classical geometric optics analysis via a generalized Fresnel reflection coefficient which is derived from elementary plane wave theory.

In conclusion, it is unnecessary, and in our opinion inadvisable, to use concepts of mode theory for the analysis of multimode optical fibers.

2. MODAL PROPAGATION IN GRADED INDEX DIELECTRIC WAVEGUIDES: S. Choudhary and L.G. Felsen, Polytechnic Inst. of N.Y., Brooklyn, NY.

The asymptotic theory of evanescent wave tracking developed by the authors is applied to modal propagation in dielectric waveguides whose refractive index varies transversely to the direction of propagation. Because of the constraints imposed on modal fields (linear phase, plane phase fronts, transversely dependent amplitude), it is found that the eikonal equation and the hierarchy of transport equations can be integrated explicitly. Thus, one may generate the asymptotic expansion of the phase and amplitude of the modal field to any desired order in (1/k), where k denotes the large free-space wavenumber. After formulation of the theory, examples are discussed for which exact solutions of the wave equation are available. These include the parabolic and hyperbolic secant variations of refractive index. In both cases, one verifies that the asymptotic theory provides the exact expansion coefficients to any given order in (1/k). The asymptotic theory is then applied to polynomial profiles for which exact solutions are not available. Expressions for mode dispersion and group delay are provided and discussed.

3. PROPAGATION IN RADIALLY INHOMOGENEOUS OPTICAL FIBERS: O. Parriaux, Univ. College London, Torrington Place, London, G.B.; F.E. Gardiol, Chaire d'Electromagnetisme et d'Hyperfrequences EPF-L, Lausanne, Switzerland.

The development of graded-index, self-focusing optical fibers brought significant improvements in low-loss transmission and reduction of dispersion. These fibers

are complex structures presenting all at once losses, radial inhomogeneity and ansiotropy. The analytical study of wave propagation becomes then quite intricate, providing solutions only for particular simple situations.

The approach presented here utilizes a numerical integration method based on the principle of finite differences. The electromagnetic field is evaluated in thin concentric rings, the radii of which increase from the axis toward the outer boundary of the fiber. The material properties within each ring are assumed to be constant. The continuity conditions at the fiber boundary provide a dispersion relation which is solved by means of a computer.

The method is quite general and applicable to structures loaded with anisotropic, radially inhomogeneous, lossy electric and magnetic materials.

4. OPTIMIZATION OF POWER COUPLING EFFICIENCY FROM LIGHT SOURCES TO OPTICAL FIBERS: N.G. Alexopoulos, Univ. of Calif., Los Angeles, CA; A.Z. Solomin, Hughes Aircraft Co., Canoga Park, CA.

Although low loss optical fibers have become a reality, the problem of highly inefficient coupling of power from a light source to a fiber still persists. This loss of efficiency is mainly due to the surface roughness of the fiber end and its small acceptance angle. In addition, in the case of LED sources coupled to small numerical aperture fibers, the wide angle of emission of the LED yields low coupling efficiencies. Various schemes of microlenses have been utilized to minimize the coupling loss from the source to the fiber. The advantage of employing such microlens couplers lies in the fact that they increase the effective numerical aperture of the fiber, thereby increasing the power coupling efficiency.

In this paper a brief review of coupling devices is first presented. Furthermore, new schemes are discussed which include layered truncated spherical and conical couplers. These devices are optimized to focus light from a Gallium arsenide LED source onto the numerical aperture of the fiber. In the examples discussed in this paper, the domed layers of the spherical, or cylindrical layers of the conical couplers are composed of high index of refraction materials such as chalcogenide glasses or Gallium phosphides. In the efficiency vs. material properties calculations, emphasis is placed on all the coupler components including the LED bonding cement and encapsulants.

An analysis is presented which involves the development of an expression for the flux density for the propagation of rays through multiple refracting boundaries between the source and the receiver surfaces. By employing this expression various curves are obtained which show the percentage coupled power in terms of the sphere and cone truncation, number of layers as well as material parameters. Optimization of the coupled power is obtained by properly adjusting the number of layers, layer material properties and coupler dimensions.

5. ANALYSIS OF AN INHOMOGENEOUS SYMMETRIC CLADDED SLAB OPTICAL WAVEGUIDE: E. Colombini and G.L. Yip, McGill Univ., Quebec, Canada.

Inhomogeneous thin dielectric slab waveguides are of considerable current interest in view of their potential applications in integrated optics in forming a part of

the terminal processing optical circuitry, e.g. to improve delay distortion and to focus and shape a semiconductor laser beam etc. However, exact analytical analysis of such waveguiding structures are possible only for a very limited number of specified refractive index profiles.

In this paper, a detailed analysis of a symmetric cladded slab waveguide having a parabolic refractive index profile in the core is carried out. Two approximate techniques are used to obtain the dispersion curves and the field plots for both the even and odd TE and TM modes. The first technique involves quantizing the continuously varying index profile into discrete homogeneous steps and then analyzing the resulting multi-layer-core waveguide exactly to obtain approximate results for the original waveguide. The second technique employs the WKB approximation to a smoothed-out index profile so that the condition of slow index change relative to the wavelength is satisfied.

The two approximate methods are compared and their accuracies and relative merits will be discussed. The elimination of the singularity in the WKB field solution will also be discussed.

6. MODE CONVERSION AND RADIATION LOSSES IN OPTICAL FIBERS DUE TO BENDING: M. Miyagi and G.L. Yip, McGill Univ., Quebec, Canada.

With increasing interests in the optical fiber as a long-distance transmission line, one would encounter many practical problems which affect propagation characteristics of fibers. One of the most important problems is the mode conversion and radiation losses due to the inhomogeneities such as a bend, surface and core irregularities, and discrete scattering centers.

In this paper, the wave propagation in a step-index optical fiber with a curved section is treated theoretically. Generally speaking, the coupling to adjacent modes is most important and modes of a straight fiber couple only to modes of the curved fiber whose angular dependence is the same or differs by order one. However, HE (or EH) modes of a straight fiber do not couple to any EH (or HE) modes of a bent fiber, and no coupling occurs between TE and TM modes. Further, HE_{1m} mode in the straight fiber does not couple to TE (or TM) mode in the bent fiber when the polarization direction of HE_{1m} mode is parallel (or perpendicular) to the bending plane.

The radiation loss due to the two transitions between straight and curved fibers are calculated. It can be shown that in the case of incident HE_{11} mode, this loss decreases abruptly beyond the cutoff frequency of the next higher order modes and most of the powers of incident mode are converted to those of guided modes. The total losses including the radiation loss due to a uniform bend have also been calculated. It can be shown that the radiation loss due to transitions is still dominant in the case of large bending radius.

7. PROPAGATION PROPERTIES OF CYLINDRICAL DIELECTRIC GUIDES OF ARBITRARY CROSS SECTIONAL SHAPE: L.J. Eyges, Hanscom AFB MA.

A new technique is presented for calculating the propagation properties of a single homogeneous dielectric waveguide (optical fiber) of arbitrary cross sectional shape,

and the effects of mutual coupling in an ensemble of such guides. Integral equatior are derived for the two independent field components E_z and B_z. These equations incorporate the boundary conditions on the tangential components of E and B and satisfy the appropriate differential equations inside and outside the cylinder. The differential equations for E_z and B_z inside the guide are solved by well known expansions in Bessel functions and cylindrical harmonics, involving coefficients A_ℓ and B_ℓ. Combining these expansions with the integral equations we find a set of linear (matrix) equations for the A_ℓ and B_ℓ; all problems of matching interior to exterior solutions across the boundary are bypassed. The equations readily yield perturbation expansions for the properties of almost circular guides, and are nicely suited to direct numerical solution for more general cross sectional shapes. The method is easily extended to apply to two or more guides so it provides a practical scheme for calculating the propagation properties of rather general configurations of arbitrarily shape guides.

8. COUPLING BETWEEN RECTANGULAR OPTICAL WAVEGUIDES: P.L.E. Uslenghi and A.-G. Kazkaz, Univ. of Ill., Chicago, Ill.

The coupling between two rectangular dielectric waveguides embedded in a dielectric substrate is considered. The boundary-value problem is analyzed in the approximation of Marcatili [1], but the power transfer between the two guides is described by means of a first-order nonlinear differential equation. If the nonlinear term is neglected in the differential equation, then the approximation of Miller [2] is obtained. Miller's approximation was previously employed by Marcatili [1] in his analysis of the directional coupler.

The solution of our nonlinear equation, which is valid for an arbitrary distance bewteen the two guides, shows that the power is transferred back and forth between the guides. Design criteria are developed which yield the minimum coupling length for a preassigned percentage of power transfer. In particular, it is shown that 100% power transfer is possible only in the Miller-Marcatili approximation [1-2], which is a limiting case of our more general theory and corresponds to the physically unrealizable situation of an infinite distance between guides and an infinite coupling length. This research was supported by Grant AFOSR-72-2263.

[1] E.A.J. Marcatili, Bell Sys. Tech. J., Sept. 1969, pp. 2071-2102.
[2] S.E. Miller, Bell Sys. Tech. J., May 1954, pp. 661-719.

9. THEORY OF TRIANGULAR OPTICAL WAVEGUIDES: Y.-K. Lee and P.L.E. Uslenghi, Univ. of Ill., Chicago, Ill.

Triangular optical waveguides may be fabricated by preferential etching technique on crystalline substrates [1,2], as demonstrated in at least two different ways: a guide made of polyurethane (refractive index n = 1.56) on a silicon substrate (n = 3.5) with a separating layer of SiO_2 (n = 1.45) approximately one micron thick [3], and a guide of gallium arsenide (n = 3.6) on a GaAs substrate with a separating layer of $Ga_{1-x}Al_xAs$ ($n \approx 3.4$) [4]. In both cases, the guide cross-section is an isosceles triangle.

Light propagation in triangular waveguides is examined by an extension of Marcatili's analysis of the rectangular waveguide. A ray-tracing interpretation of the modal description is performed. Rough estimates of the cutoff frequencies for the various modes are given, and design criteria to allow for single-mode propagation are developed. This research was supported by Grant AFOSR-72-2263.

[1] R.M. Finne and D.L. Klein, J. Electrochem. Soc.: Solid State Science 114, 9, 965-970 (September 1967).

[2] S. Iida and K. Ito, J. Electrochem. Soc.: Solid State Science 118, 5, 768-771 (May 1971).

[3] C.-C. Tseng, D. Botez and S. Wang, Appl. Phys. Letters 26, 12, 699-701 (June 15, 1975).

[4] W.T. Tsang and S. Wang, Appl. Phys. Letters 28, 11, 665-667 (June 1, 1976).

10. RAY OPTICAL CALCULATION OF EDGE DIFFRACTION IN UNSTABLE RESONATORS: C. Santana, Inst. for Space Research,S.J.Campos, Brazil and L.G. Felsen, Polytechnic Inst. of NY.

A previously developed ray-optical theory for calculation of modal reflection and coupling coefficients due to edge discontinuities in homogeneously or inhomogeneously filled parallel plane waveguides is generalized to waveguides with non-planar boundaries. Treated in particular are the reflections from the open ends of a bilaterally truncated waveguide whose convex walls are confocal hyperbolas. This open configuration serves as a model for unstable optical resonators with cylindrical mirrors. The ray optically determined modal reflection and coupling coefficients for mirrors with large Fresnel number are shown to reduce to those in a previously employed local parallel-plane approximation when the Fresnel numbers are moderate. The analysis quantifies proposed ray-optical models for explaining the influence of edge diffraction on the behavior of the resonant modes.

Commission C/E - Session II

Friday, October 15 1400 - 1715
TELECOMMUNICATIONS VIA LEAKY CABLES
Chairman: K.F. Casey, Kansas State Univ.

1. FUNDAMENTAL PERFORMANCE OF LEAKY COAXIAL CABLES AND ITS APPLICATION TO TELECOMMUNICATIONS: K. Mikoshiba, Hitachi Cable, Ltd., Hitachi, Japan.

The coaxial lines with the outer conductor having periodic slots which act as effective radiating elements, so called Leaky Coaxial Cable (LCX) presented here, have been mainly developed and have been widely used in the field of railway radio communication in Japan. This paper describes a theoretical approach and experimental investigations of LCXs which have been developed in Japan, and applications of the transmission system with continuous guided radiation to telecommunication, such as railway-radio system for New High Speed Trank Line, vehicular communication in tunnel automatic vehicular control system of subway and so on.

2. SOME PROPERTIES OF THE STANDING WAVES ALONGSIDE RADIATING CABLES USED FOR COMMUNICATION IN TRANSPORTATION SYSTEMS: R. Johannessen, Standard Telecommunication Laboratories Limited.

The UK Transport and Road Research Laboratory and Standard Telecommunication Laboratories have over a 3 year period jointly studied the behaviour of Radiating Cables in environments typical of road and rail transportation systems. In such applications the standing waves which exist alongside the cables are of great importance.

A number of tests have been carried out to explore the nature of these standing waves. In one, the pattern alongside a cable was compared with that obtained when the same cable was moved half a wavelength along its axes. In another, the standing waves were compared along cables raised by different amounts above a conducting sheet. These experiments give an indication of the importance of the material in the immediate proximity to the cable.

The effect on the standing wave pattern when the termination impedance is altered has been studied, and some work has been carried out to explore the correlation in the path loss between a cable and aerials with different polar diagrams. The paper will describe the findings of this work and compare the merits of the different ways in which they can be utilized.

For those applications of radiating cables where the requirement includes data transmission, the standing waves are of particular importance. Results will be shown of tests in which the bit error rate in a standing-wave-free ratio link is compared with that arising when the cable standing waves introduce interference.

3. ON GREEN'S FUNCTION REPRESENTATIONS FOR A DIELECTRIC HALF SPACE: S. Choudhary, L.G. Felsen and A. Hessel, Polytechnic Inst. of NY.

Investigations of electromagnetic wave propagation along bare or coated wires or periodically slotted lines suspended above ground require the knowledge of the

phased line source Green's functions for a dielectric half space. When The Green's functions form a building block in the formulation of a modal dispersion relation, it is highly desirable for tractability and for ease of interpretation of the results to seek approximate rapidly convergent solutions. If k_1 and k_2 denote the wavenumbers in free space and in the ground, respectively, and d represents the source height, then in the range of interest, $k_1 d \ll 1$ while $k_2 d$ can be relatively arbitrary. Moreover, depending on the propagation characteristics of the wire or cable in the absence of the ground, the phase velocity of waves along the cable may be faster or slower than the speed of light. These parameter ranges admit of different approximation schemes applied to the rigorous Sommerfeld integral representation. While contributions from mode potentials having TE polarization with respect to the surface normal direction are generally well behaved, the TM potentials pose difficulties that are traceable to the Sommerfeld pole. Various formulations based on modified image techniques, convolutions, surface impedance concepts, etc., are critically examined, with special attention given to the convergence properties of the resulting field expansions.

4. LEAKY COAXIAL CABLES FOR GUIDED RADAR: J.C. Beal and N.A.M. Mackay, Queen's Univ., Kingston, Ontario, Canada.

Guided Radar is the name given to radar techniques adapted to the detection of obstacles along a specified linear route, such as in rail and road transportation and perimeter surveillance for security purposes.

Leaky coaxial cables are currently under investigation and development for continuous-access guided communications (CAGC) along similar routes and in tunnels in mining operations. These cables with their guided electromagnetic waves bound to the immediate vicinity of the cable lend themselves equally well to use in proposed Guided Radar systems.

This paper will describe ongoing experimental and theoretical work on Guided Radar, with an emphasis on the electromagnetic aspects. A two-cable technique has been developed in which parallel leaky coaxial cables are laid one on either side of a specified track. The outgoing pulse is then transmitted down one cable while the signal return from the target is received and processed at the output of the second cable. This approach appears greatly to improve the ratio of the return signal to the background clutter due to cable imperfections and the immediate environment. Extensive work is being conducted on the coupled line performance of long parallel cables and of the influence on this of the environment.

5. UNDERGROUND USE OF A COAXIAL CABLE WITH LEAKY STUBS: P. Delogne, l'Universite Catholique de Louvain; L. Deryck, l'Universite de Liege.

This work is concerned with leaky coaxial cables. A good understanding of the physical nature of the eigenmodes, and of the radiation process at frequencies high above cut off enabled us to imagine a more efficient use of these cables.

The optimal efficiency of the leaky cable used as support for propagation in tunnels consists in a compromise between a high leakage field and a low increase of the coaxial eigenmode attenuation. This is the main disadvantage of such a system.

To obviate this inefficiency, we got the idea to introduce periodically, in a well shielded coaxial cable, short stubs of leaky cable, as mode converters or radiators. A theoretical study enabled us to determine the properties of such a cable.

The results obtained show how to determine the optimal length of the leaky stubs.

Such a stub acts as a wide bandwith radiator and as a directional coupler.

The transmission line being shielded on the most important part of its length, increasing the leakage of the stubs has a negligible effect on the attenuation. Under the cut off frequency of the tunnel, the field level is more regular than in the case of the leaky feeder.

Numerous experiments were carried out at various frequencies and for various lengths of the stub and for different types of leaky cable, and were found in good agreement with theoretical prediction.

6. BEHAVIOUR OF A THREE BRAIDED COAXIAL CABLE IN A WIDE FREQUENCY RANGE:
B. Demoulin, P. Degauque, M. Cauterman and R. Gabillard, Lille Univ., Villeneuve d'Ascq, France.

In this paper, we present the shielding efficiency of a multi-braided coaxial cable and especially the case of a cable having three homogeneous braids. From the transmission line theory, we determine the disturbing voltages, far end and near end crosstalk which appear at the end of the cable when the outer braid is carried by a disturbing current I. At first, we consider a coaxial cable having three braids separated by an insulating material. The theoretical and experimental results, compared with those obtained with a single braided cable, show an improvement of the shielding efficiency in a frequency range. But at high frequency, when the braids are opened or terminated in a short-circuit, the resonances appearing between the braids are such that the screening performances become identical.

To damp down these resonances a first solution consists in reducing the thickness of the dielectric situated between the braids. This process becomes efficienct only when the dielectric thickness is strongly reduced, i.e. when the performances of the three braided cable are similar to those of the single braided cable. An other solution is to replace the insulating material between the braids by a dielectric having a low, but not zero conductivity.

At last, we can replace the second braid by a ferromagnetic material with a high permeability and by putting the inner and the outer braids very near of this magnetic material. If the ferromagnetic material is homogeneous, theoretical curves show that the shielding efficiency is better at high frequency. But the mechanical properties are such that the homogeneous layer of magnetic material could be used only in exceptional cases. In practice, the homogeneous layer must be replaced by a braid or a magnetic material tape for which the transfer impedance behaves as a self impedance restricting the performances in the high frequency range.

Commission F - Session F9

Friday, October 15 1400 - 1715
SCATTERING OBSERVATIONS AND EFFECTS
Chairman: W.P. Birkemeier, Univ. of WI

1. PULSE PROPAGATION IN A RANDOM MEDIUM: S.T. Hong, I. Sreenivasiah, A. Ishimaru, Univ. of Washington, Seattle, WA.

This paper presents the theory of pulse propagation in a random medium both in the weak and the strong fluctuation regions. It is based on solutions of parabolic equations for two-frequency mutual coherence function and is applicable to both random continuum (turbulence) and a random disturbance of discrete scatterers. In the weak fluctuation region, an approximate analytical solution is obtained showing coherent and incoherent intensities. The pulse shape in this region has a long tail. In the strong fluctuation region, the coherent intensity is negligibly small and the incoherent pulse shape approaches a universal form. This limiting form is studied in detail numerically, and the results are applicable to a wide range of practical situations. When the spectrum is gaussian, an analytical solution of two-frequency coherence function and a pulse shape can be obtained. As an example, an optical propagation in fog is considered. The coherence bandwidth of MHz is shown to be consistent with available experimental data. Another example is the broadening of a pulse from a pulsar. The pulse width is shown to be proportional to $\lambda^{22/5}$ which is in agreement with some experimental data.

2. SCATTERING OF ELECTROMAGNETIC WAVES FROM PRECIPITATION PARTICLES: B.G. Evans, N. Uzunoglu, and A.R. Holt, Univ. of Essex, Colchester, England.

This paper concerns the theoretical evaluation of scattering from raindrops and the use of such information in determining the transmission parameters, i.e. attenuation and depolarization in radio and satellite communication systems. A new integral formulation of the scattering problem is formulated and the method of solution for the scattering amplitude makes use of a spacial Fourier transformation. The method of solution is very stable, the equations satisfying the Schwinger variational principle and the computational complexities associated with other solutions such as the point-matching technique are considerably reduced. Thus the scattering amplitude for any incident polarization and observation angle is available from the computation.

Results of the computation are presented for the 11/14 GHz bands to be used in the European communications satellite and in INTELSAT V. In particular the variation of the scattering amplitude (hence attenuation and depolarization) with elevation angle are shown for linear and circular polarization cases. Also the scattering at angles other than the more familiarly quoted forward and backward are presented and their influence discussed. Similar results for the 20/30 GHz bands for which satellite experimentation has been undertaken via the ATS-6 satellite will also be presented.

3. BISTOTIC RADAR MEASUREMENTS OF TURBULENCE ANISOTROPY: W.P. Birkemeier, Univ. of Wisconsin, Madison, WI.

In several atmospheric probing experiments the bistatic radar scattering function profile at zero Doppler shift which represents reflected power as a function of

height was compared to the reflectivity profile of the atmosphere as measured by radiosonde flights near the common volume. The comparison indicated that the received power often exceeded the predicted value by amounts ranging up to 25 dB. Fairly consistant agreement was obtained only near the bottom of the common volume. Since the meteorologically determined reflectivity is proportional to the isotropic refractivity structure function coefficient C_n^2, the discrepancy between the observed and predicted signal strengths was explained by lack of isotropy (or by anisotropy) of the refractivity structure. Using a simple anisotropic turbulence model it was shown that signal enhancement over the value predicted by isotropic fields was equal to A^2 where A was the degree of anisotropy of the refractivity field. Degrees of anisotropy ranging from 1 to 6 were required to explain the observed data. At the same time the model predicted that in regions of enhanced reflectivity the azimuthal angular dependence of the scattering layers should be substantially increased. Testing the delay-Doppler signatures of the ten most prominent layers it was found that in eight cases the angular dependence was in good agreement with the degree of anisotropy implied by the reflectivity enhancement of the layer.

It was also noted that the degree of anisotropy implied by the radio data tended to increase with height. Since the stability of the atmosphere tends to increase with height for a while, it was pertinent to relate the radio estimated degree of anisotropy to the average dynamic stability of the atmosphere. Although the dynamic stability as measured by Richardson's number varied greatly with height, averaging the value of Richardson's number over each radar delay interval showed a definite increase in the average stability with height. A plot of these data suggests a general relation between the average degree of anisotropy $\bar{A}$ and the average Richardson's number, $\bar{R}_i$ as $\bar{A} \approx \log \bar{R}_i$.

4. S193 SCATTEROMETER DATA CORRECTION FOR HURRICANE AVA: V.H. Kaupp and J.C. Holtzman, Univ. of Kansas Center for Research, Inc., Lawrence, KS.

Hurricane AVA was sensed on 6 June 1973 by the S193 Rad/Scat flown on Skylab. Data were collected from the hurricane to obtain high wind speed and sea state baseline data from an orbiting microwave sensor. For this data pass, the Skylab vehicle was in the solar inertial (SI) attitude orientation and the S193 system configuration selected was the Cross-Track Non-Contiguous Right mode of operation with sequencing polarization. In the SI attitude, the scatterometer returned carrier frequency was Doppler-shifted out of the pass-band of the filters at some point in the data pass, and some of the more interesting wind-speed and sea-state data were essentially lost due to the fact that normal data processing techniques did not exist to recover it.

The hurricane AVA backscatter data collected by the S193 scatterometer have been corrected. This paper presents the data correction methodology, lists the corrected backscatter data for AVA, increasing AVA data by 62%, and includes plots of these corrected data.

The backscatter data presented in this paper are considered to be the only correct microwave data available from the hurricane AVA high wind speeds and sea state.

5. A FEYNMAN INTEGRAL APPROACH TO FORWARD SCATTERING IN A RANDOM MEDIUM:
B.R. Hood and R.H. Lang, George Washington Univ., Washington, D.C.

Recent work by Chow [1] on the application of Feynman integrals to the investigation of forward scattering in a medium with random large scale inhomogeneities will be reviewed. An exact solution to the parabolic equation for propagation of the field is obtained in terms of a Feynman integral. Using this integral representation various moments of the field can be obtained. These moments are then asymptotically evaluated in the limit of high frequency and small refractive index fluctuations. In particular, approximate expressions are obtained for the second order, fourth order and two frequency coherence functions. The expressions obtained are valid for arbitrary correlation lengths in both the transverse and longitudinal directions. When the longitudinal correlation length is reduced to zero the results coincide with strong turbulence results appearing in the literature. A comparison of these results with the Feynman integral approach will be presented.

[1] P.L. Chow, J. Math. Phys. 13, p. 1224, August 1972.

6. SCATTERING BY ROUGH SURFACES FULL WAVE AND PHYSICAL OPTICS SOLUTIONS:
E. Bahar, Univ. of Nebraska, Lincoln, Nebraska.

Three solutions for the scattered radiation fields from rough surfaces, excited by vertically polarized plane waves, are considered in this paper. In the first full wave approach we employ complete expansions of the fields and exact boundary conditions are irregular interfaces between two semi-infinite media are imposed. In the second solution we employ approximate impedance boundary conditions at irregular surfaces. Thus the ratio of the tangential electric to magnetic fields at the boundary is assumed to be independent of excitation. The third solution, which is the most familiar one, is based on the physical optics or Kirchoff approximation for the fields at the boundary.

Scattering from deterministic rough surfaces is considered first and applications to periodic and random rough surfaces are given.

Special attention is given to reciprocity and energy conservation relationships in electromagnetic theory and the three solutions are also examined at grazing incidence and for waves incident at the Brewster angle.

The full wave approach can also be applied to problems with arbitrary excitations such as Gaussian beams. Multiple scattering, shadowing by rough surfaces and scattering due to medium inhomogeneities can be accounted for in the full wave analysis. The full wave approach can also be applied to problems of depolarization by two dimensionally rough surfaces.

This study on irregular ground effects on radio wave propagation is relevant to problems of communication, navigation and active remote sensing.

7. EM WAVE SCATTERING FROM AND PROPAGATION OVER A PERIODICALLY ROUGH SEA SURFACE FOR A CYLINDRICAL EARTH MODEL: S.H. Cho and J.R. Wait, Univ. of Colorado, Boulder, Colo.

The perturbation methods have been the most useful in analyzing scattering from slightly rough sea surfaces. However, their validity is doubtful in the important resonant region where the spatial period is equal to one-half of the radio wavelength. In this case, the back scattered field from the rough sea via the ground wave is very strong and appears to have the most diagnostic value. To analyze this situation, we consider the diffraction from a magnetic line source on a finitely conducting cylinder having a modulated surface in the azimuthal direction. The resulting matrix of the coefficients of the component waves is inverted directly. Here, the guided waves on the cylinder are represented by creeping type waves and for each of these, an infinite number of spatial harmonics are excited as a consequence of the periodicity of the surface. Using this matrix formulation, we find that the perturbation methods are quite accurate if the maximum variation of the surface height is less than one-thirtieth of the spatial period. Actually, in the resonant region, each creeping wave splits into spatial harmonics in a different fashion. In this situation, the concept of single effective surface impedance may give us the largest error for the back scattered field. Fortunately, our more general formulation can lead to a relatively simple method to calculate the scattered field in this case. Finally, we compare these results with calculations based on an earlier analysis (S.H. Cho and J.R. Wait, Canadian Journal of Physics, in press) that represents the disturbed sea surface by a periodically modulated impedance boundary for a cylindrical earth model.

8. REFLECTION PROPERTIES OF PERIODIC SURFACES FOR GAUSSIAN BEAMS: J.W. Mink, U.S. Army Electronics Command, Fort Monmouth, NJ.

Buildings along the runways of airports are commonly constructed of materials having periodic surface profiles. These surfaces reflect microwave energy and create potentially unreliable guidance data due to multipath interference. Hence, to insure reliable navigation signals, it is important to know the magnitude and virtual source location of any signal reflected.

The theoretical reflection coefficients obtained for periodic surfaces are generally derived assuming that a plane wave is incident upon the surface and that a discrete spatial spectrum of plane waves is reflected from that surface. In this paper, an "effective" reflection coefficient is derived for a periodic surface illuminated by a Gaussian beam. The virtual source of each of the scattered beams is determined for arbitrary distances between the reflecting surface and the receiver or transmitter. A modeling experiment for measuring the reflection coefficients of periodic surfaces at millimeter wavelengths is described. The experimental results show good agreement with the theoretical expectations.

AUTHOR INDEX

MEETING NOTES

MEETING NOTES

MEETING NOTES

MEETING NOTES

MEETING NOTES

MEETING NOTES

MEETING NOTES

Future USNC-URSI and URSI Meetings

1977 USNC-URSI/IEEE AP-S Meeting
June 19-24, 1977
San Francisco, California

1978 USNC-URSI Meeting
January 9-13, 1978
University of Colorado
Boulder, Colorado

1978 USNC-URSI/IEEE AP-S Meeting
May 15-19, 1978
Washington, D. C.

XIX General Assembly of URSI
August 1-10, 1978
University of Technology of Helsinki
Helsinki, Finland