NASA Space-based Remote Sensing

National Aeronautics and Space Administration

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SPACE COMMUNICATIONS AND NAVIGATION

Discussion Topics

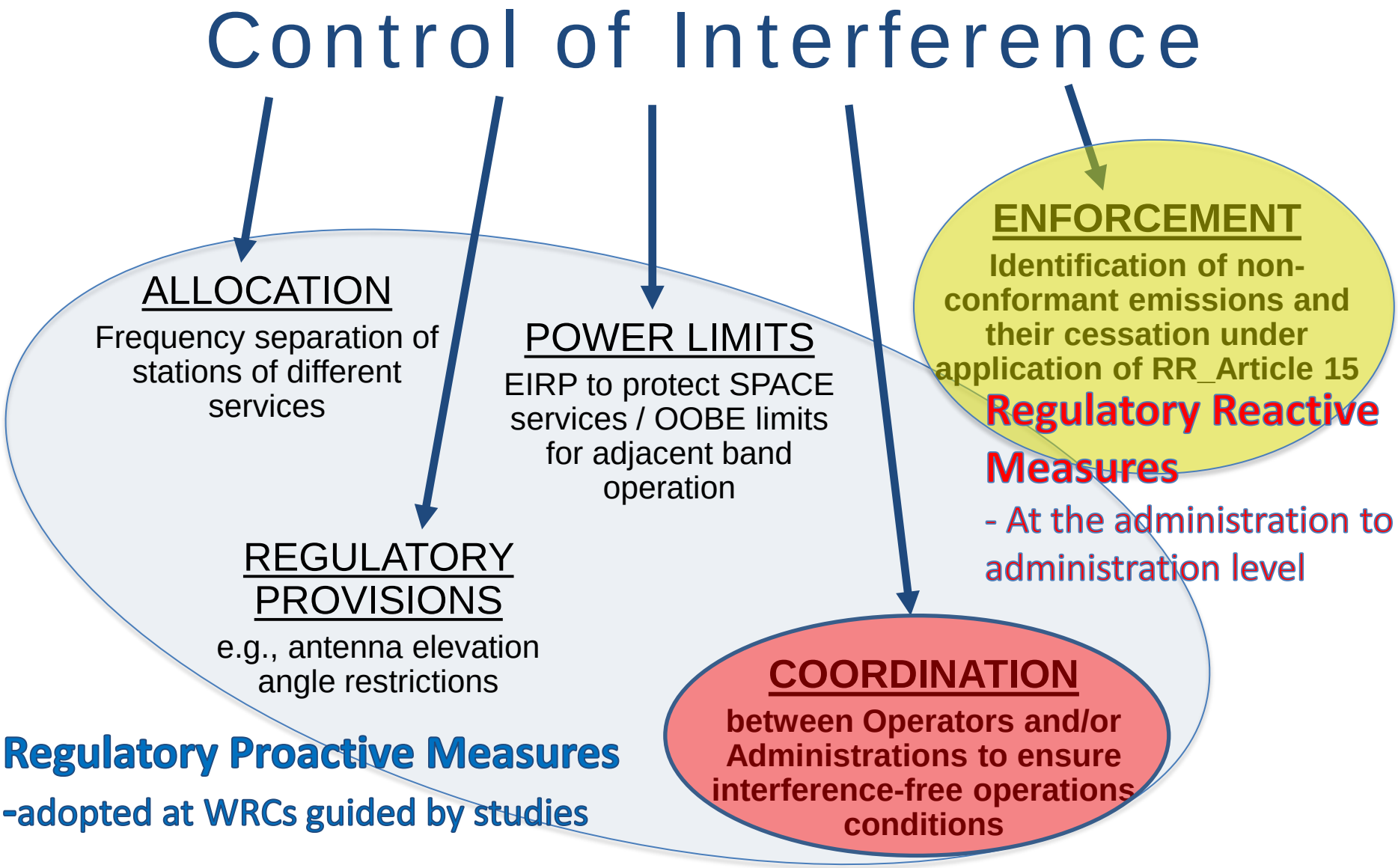
- Spectrum Management Office primary remote sensing functions (review)
- Revision of the ITU-R performance criteria and permissible interference criteria
- Status of the current WRC agenda item studies that most affect remote sensing

AGENCY SMO
Primary Remote Sensing functions

In matters affecting or potentially affecting Remote Sensing operations:

- Respond to FCC actions through the NTIA IRAC
- Participate in ITU-R Working Parties
  - Studies of compatibility
  - Revision of Recommendations used in studies
- Coordinate with international partners
  - Mission operations
  - ITU-R activities
- **International reports of RFI**

Mechanisms for effective control of RFI for EESS sensors



ITU-R Recommendations governing remote sensing

PASSIVE

- **RS.515**: Frequency bands and bandwidths used for satellite passive sensing
- **RS.1813**: Reference antenna pattern for passive sensors operating in the Earth exploration-satellite service (passive) to be used in compatibility analyses in the frequency range 1.4-100 GHz
- **RS.1861**: Technical and operational characteristics of EESS (passive) systems using allocations between 1.4 and 275 GHz
- **RS.2017**: Performance and interference criteria for satellite passive remote sensing

ACTIVE

- **RS.1166**: Performance and interference criteria for active spaceborne sensors
- ITU-R RS.[ACTIVE_CHAR] - Typical technical and operational characteristics of Earth exploration-satellite service (active) systems using allocations between 432 MHz and 238 GHz

Proposed revisions to RS.2017

passive sensor criteria

Measurement Area*

– Currently, it's a 2 million sq km area (MSKA) with 99.99% availability or 10 MSKA with 99.9% availability; in the shape of square.

– We are proposing to change it to 10,000 measurement samples (99.99% availability) or 1,000 measurement samples (99.9% availability); in the shape of a circle.

Result of proposed change:

This will directly tie the interference criteria to the allowable number of measurement sample corruptions instead of the currently used percentage of time.

*Used in calculating data availability criteria violations.

Proposed revisions to RS.2017 (cont.)

passive sensor criteria

RR No. 5.340 OOB

- RR No. **5.340** states that no intentional emissions are allowed in the identified frequency bands.
- However, studies looking at adjacent band OOB emissions use the data availability and measurement area criteria of RS.2017; ***in other words,*** **OOB emissions into 5.340 bands are treated the same as in-band emissions are for non-5.340 bands.**
- NASA proposes that aggregate OOB emissions into the RR No. **5.340** bands meet the RS.2017 interference threshold criteria 100% of the time.

Result of proposed change:

Control of OOB emissions to this extent would be in keeping with the spirit of RR No. **5.340** which, IMO, is the un-impacted operation of passive services.

Proposed revisions to RS.2017 (cont.)

passive sensor criteria

Review of Sensor sensitivities on a band-by-band basis

– The protection criteria should reflect the anticipated state of the art in regards to sensor sensitivities and usage of the data in downstream applications.

Result of proposed change:

Studies examining the impact of RFI will be more reflective of the true impact to sensor operations and applications using the data.

Proposed revisions to RS.1166

active sensor criteria

Measurement Area*

Currently the measurement area is not defined for the various active sensors. As a result, analysis of RFI is done on a percentage of time for measurements taken over the entire globe. This approach underestimates the impact of RFI since polar regions and unpopulated areas (e.g. oceans) are represented disproportionally.

- NASA proposes to define measurement areas for the sensors for use in studies and where that is not possible define correction factors to account for polar regions.

Result of proposed change:

The analysis will more accurately reflect the impact of RFI to active sensor operations.

*Used in calculating data availability criteria violations.

Proposed revisions to RS.1166 (cont.)

active sensor criteria

Peak power of RFI impact to altimeters

The detectors in altimeters respond to the peak power of the emission rather than to the average power that other sensors respond to. Modulated RF have a peak power many dB higher than the average power. However, studies use the average power to assess impact. As a result, the studies underestimate the impact of RFI to altimeters.

– NASA proposes to include information on the peak power of modulated emissions for use in studies.

Proposed revisions to RS.1166 (cont.)

active sensor criteria

TDMA network impact (two aspects)

1. To simplify analysis, TDMA networks have been represented by a single continuously transmitting carrier. However, a comparison analysis has shown that TDMA networks have a greater impact to active sensors than that of this simplification.
2. TDMA OOB emissions are greater than non-TDMA OOB emissions due to the fast rise and fall times associated with TDMA.

NASA proposes to include information on the nature of TDMA emissions for use in studies.

WRC-19 Agenda Items of Interest

- **AI 1.6** - NGSO FSS in (s-to-E): 37.5-39.5 GHz/39.5-42.5 GHz and (E-to-s): 47.2-50.2 GHz/50.4-51.4 GHz – WP 4A
  - **Impact to 50.2-50.4 GHz atmospheric passive sensing**
- **AI 1.13** – Identification of bands for the future development of IMT – WP 5D/TG-5/1
- **AI 1.14** – Broadband delivered by high-altitude platform stations (HAPS) – WP 5C
  - Ground to HAPS TDMA OOBE into 22.21-22.5 GHz EESS passive
- **AI 1.15** – Freq. identification for land-mobile and fixed services applications in the range 275-450 GHz – WP 1A
  - **Potential impact from FS operation to LEO passive sensors**
- **AI 1.16** - RLANs in bands between 5 150 MHz and 5 925 MHz – WP 5A

WRC-19 AI 1.6

NGSO FSS (E-to-s): 47.2-50.2 GHz/50.4-51.4 GHz; adjacent to the 50.2 -50.4 GHz band

- Current RR Res. 750 OOBE limits apply to FSS earth stations
  - Static analysis shows that these current limits could result in a **70 dB** exceedance of the protection level criteria at regions near the equator. Non-GSO earth stations could achieve this exceedance *over the entire face of the earth.*
  - Current dynamic analysis results don't match previous study results which were used to establish the current RR Res. 750 limits.
  - GSO FSS operators are unwilling to accept additional constraints on existing systems or those which are in progress as an outcome of this agenda item.

WRC-19 AI 1.6 (cont.)

50.2 – 50.4 GHz is a RR No. 5.340 band where no emissions are allowed.

- Under current interpretation of RS.2017, 70 dB exceedances from OOBE *are allowed* as long as the protection criteria level in a 2 MSKA is not exceeded more than 99.99% of the time (and the sensor is not damaged).
  - Because the beamwidths are narrow the probability of alignment between EESS sensors and the FSS ESs is low AND *dynamic simulations can be constructed that demonstrate compatibility*.

WRC-19 AI 1.6 (cont.)

***Optimal* Future studies**

- Construct a worst case dynamic simulation over 2 MSKA to establish what the revised RR Resolution 750 OOBE limits should be.

To construct this worst case simulation the following information, and possibly more, is needed:

- The manner and time frame by which sensor measurements are obtained over *any* 2 MSKA.
- The maximum density of non-GSO FSS spacecraft.
- The maximum density of non-GSO FSS ESs in a 2 MSKA.

RESULTS

Compatibility would be proven when non-GSO FSS ES OOBE do not ever exceed the 99.99% availability criteria. A key principle is that although EESS passive is allowed 99.99% availability, they are entitled to having that level of availability met **100% of the time**.

This would be achieved by:

- Adjusting the minimum ES antenna size
- Adjusting the maximum ES OOBE into 50.2-50.4 GHz
- Imposing some sort of ES antenna pointing constraint
- Another method that is TBD

WRC-19 AI 1.15

Freq. identification for land-mobile and fixed services applications in the range 275-450 GHz

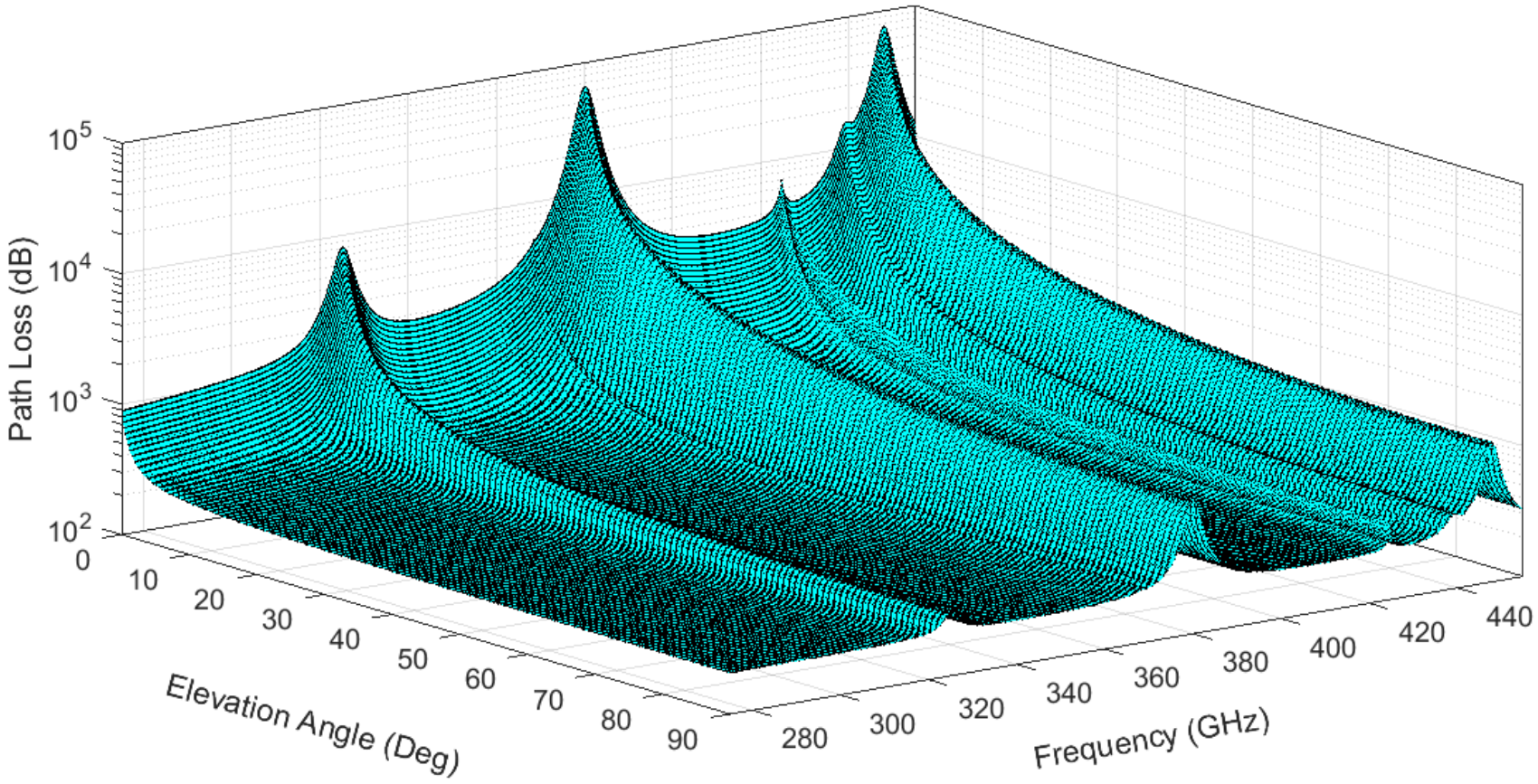
- RR No. **5.565** identifies bands within the 275 - 1 000 GHz frequency range where EESS (passive) operates or may operate. Frequencies are not allocated to EESS (passive).
- Land-mobile and fixed service are seeking frequency ranges and/or rules by which they can operate in the 275 – 450 GHz range. Terrestrial only.

Caveat: the land-mobile and fixed service applications are not well defined at this point!

- Land-mobile applications identified to date are extremely short range, indoor, or within equipment enclosures. *These applications may not be a concern to EESS passive.*
- Proposed Fixed service applications are outdoor, short range (<2 km), and include rooftop-to-rooftop deployments. FS elevation angles in excess of ~37 degrees can align with conical or nadir scanning sensors and exceed the protection criteria.

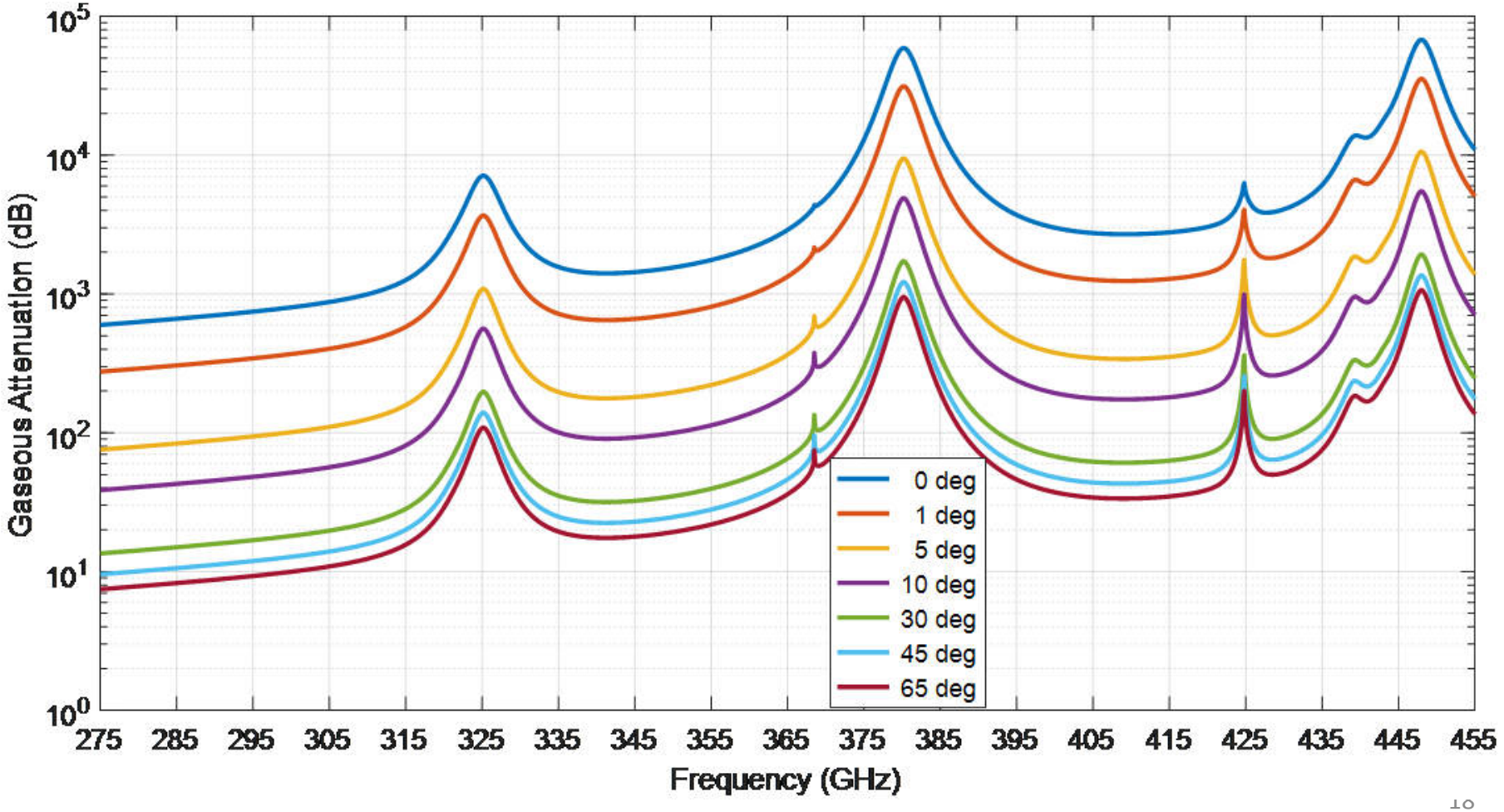
WRC-19 AI 1.15 (cont)

Average Path loss from a terrestrial point to a Satellite (H= 817km) as a Function of Elevation Angle (3D); 1 km altitude



WRC-19 AI 1.15 (cont)

Average Path loss from a terrestrial point to a Satellite (H= 817km) as a Function of Elevation Angle (2D); 1 km altitude



WRC-19 AI 1.15 (cont)

FS compatibility with EESS (passive) hinges on *minimum* atmospheric loss, FS antenna elevation angle statistics and FS deployment characteristics.

- The previous graphs, based on Rec. ITU-R P.676-11, depict the *average* atm. loss to a EESS sensor at a typical orbital altitude. *The max and min atm. loss is not known.*
- *The loss is calculated from a 1 km altitude but other altitudes should be considered as well.*
- The FS characteristics, particularly deployment density and elevation angle statistics are not well known.

WRC-19 AI 1.15 (cont)

FINDING A SOLUTION

- Some of the bands are identified by WP 7C as having only limb sounder operations. *FS operations in those bands will not be an issue to EESS passive due to the atmospheric attenuation at any terrestrial altitude and low degree of coupling at any FS antenna elevation angle.*

- Use of the other EESS passive bands by FS would be feasible if a suitable elevation angle was imposed, *and enforced*, in the regulations.
  - **However, enforcement of this regulation could default to the honor system; that is, the administration's regulatory body sets the rule for FS maximum antenna angle but then does not verify that the installer followed the rule.**
    - **This would be a big risk to EESS (passive) operations as it would never be fixable once it occurred.**

WRC-23 Agenda Items of interest

AI 2.2 – … studies for a possible new allocation to the Earth exploration-satellite (active) service for **spaceborne radar sounders** within the range of frequencies around **45 MHz**…

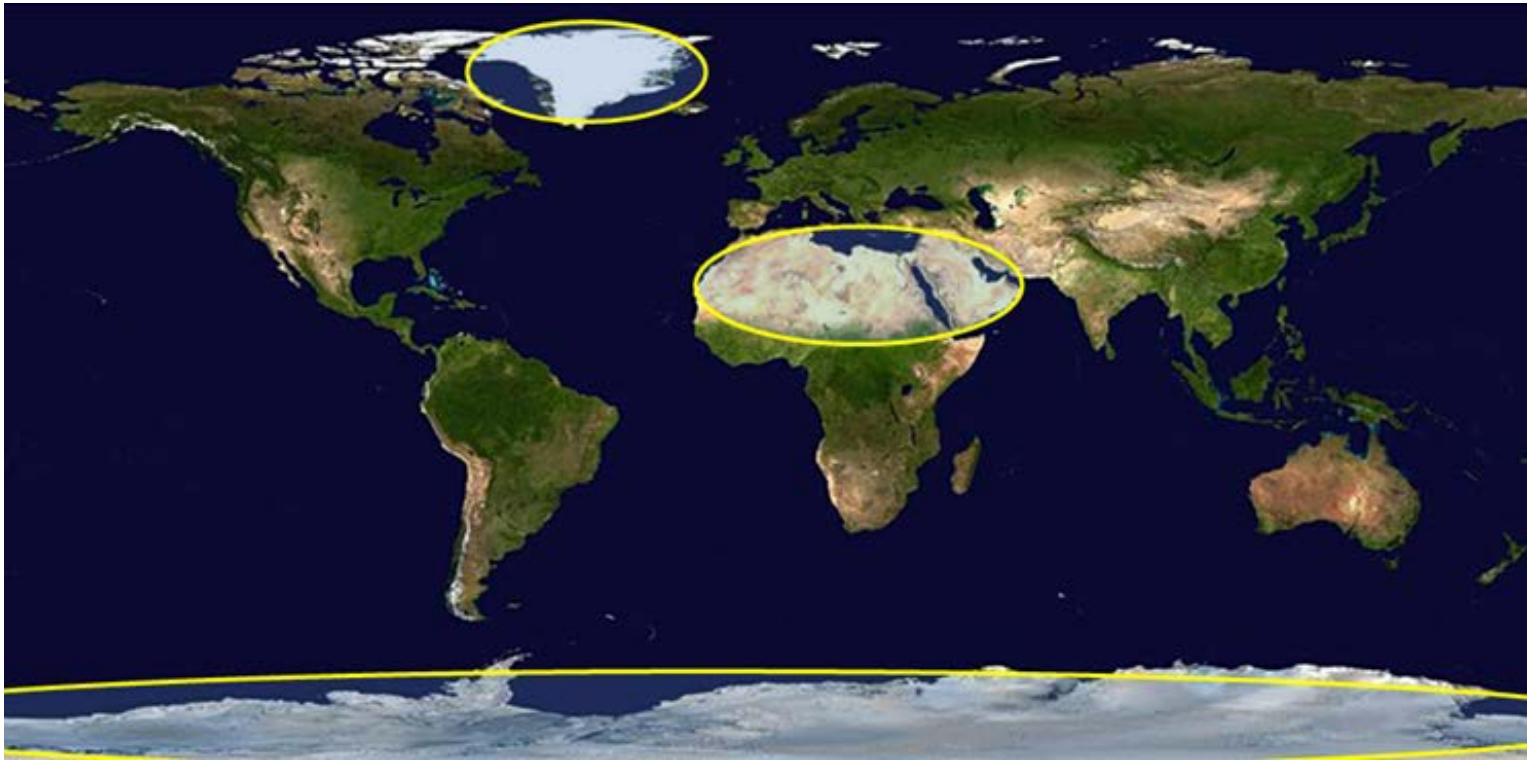
- **Space based ground penetration radar, heavily used RF region**

- The radar sounder missions are to catalog and track over decades the desertic aquifers and glacier dynamics.
- Mission duration will be 18 months repeated about every decade.
- Measurements will be taken from 3 a.m. to 6 a.m. local time over Greenland, Northern Africa, Arabian Penisula, and Antarctica.

WRC-23 Agenda Items of interest

AI 2.2 – … **spaceborne radar sounders** within the range of frequencies around **45 MHz**…

Spaceborne Radar Sounder Coverage



WRC-23 Agenda Items of interest

AI 2.2 – … **spaceborne radar sounders** within the range of frequencies around **45 MHz**…

GOALS

- Complete static analysis of interference impact and duration to affected incumbent services in time for consideration by WRC-19
- Persuade the affected working parties of the ITU-R that this radar sounder application will not appreciably impact their operations.
- Have this proposed agenda item adopted by WRC-19 for the WRC-23 agenda.

WRC-23 Agenda Items of interest

AI 2.3 - …review the results of studies relating to the technical and operational characteristics, spectrum requirements and appropriate radio service designations for **space weather sensors**…

- **SW sensors are not recognized Regulatory and, therefore, are afforded no protections from RF transmitter emissions.**
  - With this AI the NOAA and NASA offices intend to remedy this.

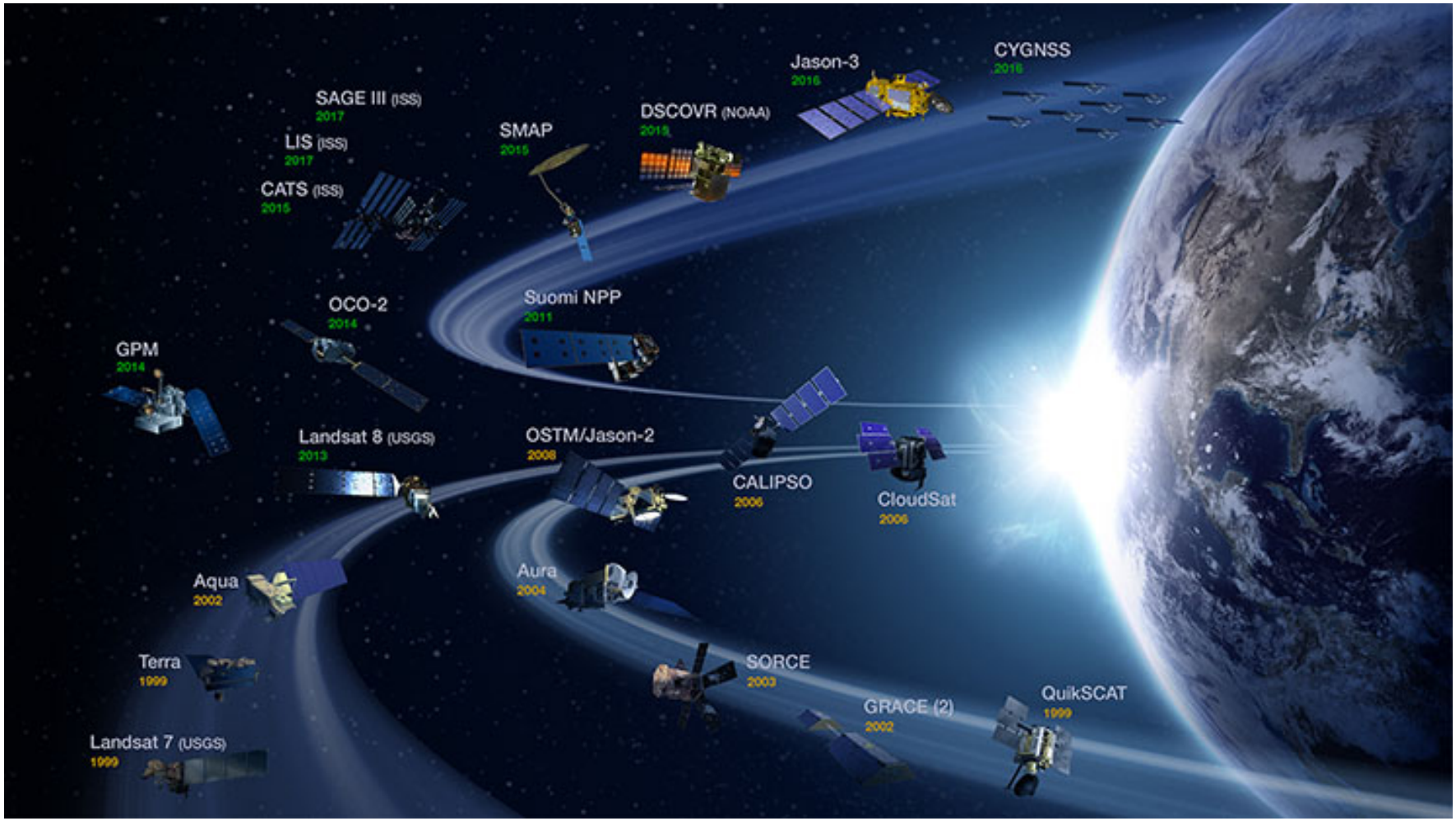
However, we are not finding the SW sensor RF characteristics without which our success is **not feasible**.

The End

Acronyms

Acronym	Description	Acronym	Description
AI	Agenda Item	MMSS	Maritime Mobile Satellite Service
BIPM	Bureau International des Poids et Mesures	NGSO	Non-Geostationary Orbit
BLOS	Beyond Line of Sight	OOBE	Out-of-Band Emissions
CITEL	Inter-American Telecommunications Commission	PFD	Power Flux Density
CPM	Conference Preparatory Meeting	RA	Radio Assembly
dBW	Power in Decibels relative to a Watt	RR	Radio Regulations
EESS	Earth Exploration-Satellite Service	S-to-E	Space-to-Earth
E-to-S	Earth-to-Space	SRS	Space Research Service
FSS	Fixed Satellite Service	TT&C	Telemetry, Tracking, and Command
IAP	Inter-American Proposal	WG	Working Group
IMT	International Mobile Telecommunications	WP	Working Party
ITU	International Telecommunication Union	WRC	World Radiocommunicatons Conference

NASA Remote Sensing Missions



Detailed summary provided in this embedded pdf →

Adobe Acrobat

Observation Fleet Frequency Usage

Freq. Range (GHz)		Pass/ Act/ Comm	Mission	Instrument	Use
1.176	1.575	A	GPS	GPS	land, atmosphere
1.215	1.300	A	ERS-1, GEOSAT, SEASAT,ALOS, ALOS-2, SRTM, SMAP, Aquarius/SAC-D, ADEOS-2	SAR, PALSAR.	land, ocean, atmosphere
1.400	1.427	P	SMAP, SMOS, Aquarius/ SAC-D	Radiometer	land
2.025	2.110	C	Many	TT&C forward	Comm
2.200	2.290	C	Many	TT&C Return	Comm
2.290	2.300	C	Many	comm – return	Comm
3.100	3.300	A	ENVISAT	Radar Altimeter	ocean
5.250	5.570	A	Topex/ Poseidon, JASON Series, ETOPO via SRTM, ENVISAT, TARADSAT, ERS-1, RADARSAT, etc	Radar Altimeter, SAR	ocean
6.425	7.250	P	SeaSat, Nimbus-7, AQUA, ADEOS-2	SMMR, AMSR-E,	land, ocean, atmosphere
7.145	7.235	C	MSL, MERA. MERB, MRO; EXOMARS, MEX, JUNO, Cassini, VEX, Messenger, etc.	comm – forward	Comm
7.750	7.850	C	METOP-#, JPSS, NPP, GOES-#, NOAA-#,	comm – return	Comm
8.020	8.400	C	Many Near Earth	comm-return	Comm
8.400	8.450	C	Many Deep space	comm – return	Comm
9.300	9.800	A	ETOPO via SRTM, TerraSAR-X, COSMO-SkyMed	SAR	land, ocean, atmosphere
10.600	10.700	P	AQUA, TRMM, SeaSat, Nimbus-7, DMSP, ADEOS-2	AMSR-E	land, ocean, atmosphere
13.250	14.000	A	Topex/ Poseidon, JASON Series, ERS-1, ERS-2, GEOSAT, SEASAT, ADEOS-2; QuikSCAT, TRMM, GPM	Radar Altimeter, SAR, Precip. Radar, Scatt.	land, ocean, atmosphere
18.600	18.800	P	Topex/ Poseidon, JASON Series, DMSP, AQUA, TRMM, ADEOS-2	TMR, JMR, SSM/I, AMSR-E	land, ocean, atmosphere
21.100	21.500	P	SeaSat, Nimbus-7, TRMM, DMSP, GFO	SMMR, TMI, SSM/I,	land, ocean, atmosphere
22.550	23.150	C	Altair, Orion	TT&C Forward	comm
23.600	24.000	P	Topex/ Poseidon, JASON Series, AQUA, NOAA-#, ADEOS-2	TMR, JMR	land, ocean, atmosphere

Observation Fleet Frequency Usage

Freq. Range (GHz)		Pass/ Act/ Comm	Mission	Instrument	Use
24.050	24.250	A	GRACE	KBR	land
25.500	27.500	C	Altair, Orion, LRO, ALOS-2, ADEOS-2, SDO, JPSS, ENVISAT	comm – return	Comm
31.300	31.800	P	NOAA Series	AMSU	land, atmosphere
31.800	32.300	C	MRO, Cassini	comm – return	Comm
32.000	32.300	C	GRAIL, JUNO, Bepicolo (MPO)	comm – return	Comm
34.200	34.700	C	GRAIL, JUNO, Bepicolo (MPO)	comm – forward	Comm
36.000	37.000	P	Topex/ Poseidon, JASON Series, DMSP, AQUA, TRMM, ADEOS-2, NOAA-#, GFO	TMR, JMR, SSM/I, AMSR-E, TMI,	land, ocean
50.200	50.400	P	NOAA Series	AMSU	land, atmosphere
52.600	59.300	P	NOAA-#	AMSU	land, atmosphere
86.000	92.000	P	DMSP-series; AQUA, TRMM, NOAA-#	SSM/I; AMSR-E, TMI, AMSU, MHS	land, ocean, atmosphere
94.000	94.100	A	Cloudsat	Cloud radar	atmosphere
148.500	151.500	P	NOAA Series	AMSU	land, atmosphere
155.500	158.800	P	MetOp-#	MHS	atmosphere
174.800	191.800	P(3)	NOAA Series, NPP, JPSS, DMSP, MetOp, METEOR-3M	AMSU, ATMS, SSM/T-2, SSMIS, MHS, MTVZA	atmosphere

Additional Resources

- Committee on Radio Frequencies (CORF) of the National Research Council: sites.nationalacademies.org/BPA/BPA_048819
- International Telecommunication Union: www.itu.int
- Scientific Committee on Frequency Allocations for Radio Astronomy and Space Science (IUCAF) of the International Council for Science: www.iucaf.org
- U.S. Federal Communications Commission: www.fcc.gov
- U.S. National Telecommunications and Information Administration: www.ntia.doc.gov/osmhome/redbook/redbook.html
- U.S. National Radio Astronomy Observatory Spectrum Management: www.cv.nrao.edu/~hliszt/RFI/RFI.htm
- Institute of Electrical and Electronics Engineers (IEEE) Geoscience and Remote Sensing Society (GRSS) Frequency Allocations in Remote Sensing (FARS) Committee: www.grss-ieee.org/community/technical-committees/frequency-allocations-in-remote-sensing/
- Committee on Radio Astronomy Frequencies (CRAF) of the European Science Foundation: www.craf.eu
- U.S. National Science Foundation Electromagnetic Spectrum Management (ESM): http://nsf.gov/funding/pgm_summ.jsp?pims_id=5654