Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Allocations and Service Rules for the 71-76, 81-86, and 92-95 GHz Bands	)	WT Docket No. 02-146
	)	
Loea Communications Corporation Petition for Rulemaking	)	RM-10288

**COMMENTS OF THE
NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES**

The National Academy of Sciences, through the National Research Council's Committee on Radio Frequencies (hereinafter, CORF[1]), hereby submits its Comments in response to the Commission's June 28, 2002, Notice of Proposed Rulemaking in the above-captioned docket (NPRM). In these Comments, CORF supports the full enactment of all the allocations proposed in the NPRM, as these allocations constitute a carefully crafted compromise that balances the interests of numerous radio services. Those allocations should be enacted as designated at various World Radio Administrative Conferences (WARCs) and World Radiocommunication Conferences (WRCs), without shifting primary allocations to secondary or unprotected status. While CORF supports coordination between licensed users of these bands and radio astronomy sites, the coordination requirements should be placed in the service rules for the applicable service, not just in the Part 2 Table of Allocations. CORF also notes that work still remains to be done in setting up such coordination procedures.

I. Introduction: The Importance of Radio Astronomy and Earth Sensing Observations, and the Unique Vulnerability of Passive Services to Interference.

CORF has a substantial interest in this proceeding, as it represents the interests of the scientific users of passive radio spectrum, including users of the Radio Astronomy Service ("RAS") and the Earth Exploration Satellite Service ("EESS") bands. Both RAS and EESS observers perform extremely important yet vulnerable research.

As the Commission has long recognized, radio astronomy is a vitally important

[1]A committee roster is attached.

tool used by scientists to study our universe. It was through the use of radio astronomy that scientists discovered the first planets outside the solar system, circling a distant pulsar. Measurements of radio spectral line emission have identified and characterized the birth sites of stars in our own galaxy and the complex distribution and evolution of galaxies in the universe. Radio astronomy measurements have discovered ripples in the cosmic microwave background, generated in the early universe, which later formed the stars and galaxies we know today. Observations of supernovas have allowed us to witness the creation and distribution of heavy elements essential to the formation of planets like Earth and of life itself.

The EESS is a critical and unique resource for monitoring the state of Earth's global atmosphere and surface. Satellite-based microwave remote sensing represents the only practical method of obtaining uniform-quality atmospheric and surface data encompassing the most remote oceans as well as densely populated areas of Earth. EESS data has contributed substantially to the study of meteorology, atmospheric chemistry, oceanography and global change. Currently, instruments operating in the EESS bands provide regular and reliable quantitative atmospheric, oceanic, and land measurements to support an extensive variety of scientific, commercial, and government (civil and military) data users. Applications of the data include aviation forecasts, hurricane and severe storm warning and tracking, seasonal and interannual climate forecasts, decadal-scale monitoring of climate variability, medium-range forecasting, and studies of the ocean surface and internal structure, as well as many others.

The 90 GHz band offers unique characteristics for EESS. It is sensitive to atmospheric water vapor and clouds as well as surface characteristics. As a consequence, this channel exhibits high (if not the most) general information content of the scene of any channel in multiple channel orbiting radiometers. It is of central importance for hydrological studies.[2]

The emissions that radio astronomers measure are extremely weak—a typical radio telescope receives less than *one-trillionth of a watt* from even the strongest cosmic source. Because radio astronomy receivers are designed to pick up such remarkably weak signals, such facilities are therefore particularly vulnerable to interference from spurious and out-of-band emissions from licensed and unlicensed users of neighboring bands, and those that produce harmonic emissions that fall into the RAS bands. Similarly, the emissions received by passive EESS radiometers in Earth orbit are weak by comparison with emissions from other services.[3]

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[2]For example, the 94-94.1 GHz band is used by EESS for cloud-profiling radars. The band was selected after extensive consultations between the remote sensing and radio astronomy communities because of the small number of lines of astrophysical interest in that band.

[3]The strength of emissions received by the EESS systems operating in this band is approximately 10^{-11} W, based on a 3-GHz observing bandwidth and 250-K scene. The main issue is not the level of signal received, but rather the absence of any

In addition to the gains in scientific knowledge that result from radio astronomy and Earth sensing, CORF notes that such research leads to technological developments that are of direct and tangible benefit to the public. For example, radio astronomy techniques have contributed significantly to major advances in the following areas:

- *Computerized tomography* ("CAT scans"), as well as other technologies for studying and creating images of tissue inside the human body;

- Increasing abilities to *forecast earthquakes* by very-long-baseline interferometric ("VLBI") measurements of fault motions; and

- Use of VLBI techniques in the development of *wireless telephone geographic location technologies*, which can be used in connection with the Commission's "E911" requirements.

Continued development of new critical technologies from passive scientific observation of the spectrum depends on scientists having continued access to interference-free spectrum. More directly, the underlying science undertaken by the observers cannot be performed without access to interference-free spectrum. Loss of such access constitutes a loss for the scientific and cultural heritage of all people, as well as for the practical civil and military applications from the information learned and the technologies developed.

II. CORF Supports the Commission's Proposal to Implement International Allocations in These Bands, and Demonstrates That the RAS Allocations ARE in Fact Necessary.

As the Commission recognizes in the NPRM, the allocations proposed in this proceeding are the result of extensive international negotiations over the course of many years, resulting in allocations adopted at a number of WARCs and WRCs (NPRM at paras. 11-42). The reallocations for the bands at issue in this proceeding represent a carefully crafted compromise that balances the interests of numerous radio services. As part of this compromise, the RAS and the EESS gave up exclusive access to substantial amounts of spectrum, in return for limited access to other regions of the spectrum. This compromise is acceptable to the scientific community, and accordingly,

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contamination of the signal. For instance, recommendation ITU-R 1029-1 limits contamination to on the order of 5×10^{-16} W (or -153 dBW) or less within a bandwidth of 200 MHz. Based on some current systems that operate at ~3 GHz bandwidth, the value of acceptable contamination, based on the criterion that the contamination is a factor of ~10 below the sensitivity of the sensor, is ~(0.05 K)(3 GHz)(1.38×10^{-23}) = ~2×10^{-15} W. This is an extremely small signal.

CORF supports the Commission's proposal to implement the allocations adopted at WRC-92, WRC-97, and WRC-2000 (NPRM at paras. 20, 30 and 40).[4]

CORF is concerned, however, about language in para. 44 of the NPRM. The NPRM will implement allocations that take spectrum away from the RAS, but asks if it should *not* implement allocations giving *primary*-use spectrum back to the RAS in return for that surrendered. CORF is concerned because the allotment plan at issue is one that the U.S. delegation proposed, lobbied for, and supported. No explanation is given in the NPRM as to why the Commission would take action that undercuts the work of the U.S. delegation over so many years. CORF is also greatly concerned about the suggestion in para. 44 that perhaps the allocation of new spectrum to the RAS should be made on a secondary or unprotected basis. As is noted above, the allocation plan at issue constitutes a carefully crafted balance that serves the interests of both passive and active users of the spectrum. That careful balance would be completely overturned if the Commission were to take away exclusive and protected use of the spectrum allocated to the RAS in return for spectrum surrendered by the RAS in the 71-76 GHz band. Such action not only would be unfair to the users of the RAS but also would have a negative impact on the ability of the U.S. delegates to future WRCs to negotiate allocation matters, since there would be no certainty that negotiated agreements would be implemented by the Commission.

A. Molecular Line Studies

Even putting aside the procedural and fairness concerns described above, it is clear that the proposed allocations of 81-86, 92-94, and 94.1-95 GHz are necessary for the RAS on scientific grounds. The molecular spectral lines between 81 and 95 GHz in the 3-millimeter window (67-118 GHz) have the highest value in studies of interstellar clouds that are precursors to the formation of stars and galaxies. Furthermore, millimeter-wave frequencies are also important for studying planets, protoplanetary disks, comets, and quasars.

As astronomers have developed telescopes sensitive at shorter and shorter wavelengths reaching to the millimeter scale, they have found an ever greater density of spectral lines from molecules in space. There are currently 120 known molecular

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[4]There is a primary allocation at 86-92 GHz for EESS. Earth scientists use this band to make critically important measurements of global precipitation and cloud parameters, and for supporting and developing an understanding of the global hydrologic cycles. Because there is a real possibility of out-of-band emissions into EESS satellites observing in that band from satellite uplinks at 84-86 GHz proposed for allocation in this proceeding, CORF suggests that a footnote be added to the Table of Allocations encouraging the assignment of uplink frequencies in the 84-86 GHz band as far away as practicable from 86 GHz.

species in interstellar space.[5] However, at certain millimeter wavelengths, Earth's atmosphere becomes opaque due to spectral lines of emission by oxygen and water molecules. Ground-based observations of molecules in space are thus restricted to "windows" in the spectrum between the terrestrial emission lines. Each molecule conveys unique information about the physical conditions and chemical nature of interstellar clouds, and many important known molecules were discovered via observations within the 3-mm atmospheric window. It should be noted that observations of a single molecular line are not sufficient to determine useful information about the nature of interstellar clouds. Rather, astronomers rely on observations of several molecular transitions to do their work, and most modern millimeter-wave observatories have developed receiver systems that will observe more than one species at a time in order to be efficient. Observations of several transitions of the same molecule are required to determine the total abundance of that molecule in a molecular cloud. Observations of transitions of different molecules are used to provide information about the physical properties (density, temperature, motion) of the clouds themselves. However, the molecular lines that are known to be important are spread over many gigahertz within this range of frequencies. Accordingly, reduction of the millimeter wave frequency range available to radio astronomers on a primary, interference-free basis would significantly limit the opportunity to perform this research.

B. <u>Continuum Studies</u>

The emissions from dust in molecular clouds do not occur at specific frequencies, like spectral lines, but rather over the entire spectral window. To make the most sensitive observations requires measurements with instruments whose bandwidths cover the widest range of frequencies that is available. Consequently, special receivers for this purpose are created to observe with a bandwidth that matches the *entire* atmospheric window.

C. <u>High Redshift Studies</u>

One of the remarkable things about astronomy is that observations of distant objects allow us to see how the universe looked in the distant past. This occurs because electromagnetic radiation takes a finite amount of time to travel any distance. Signals from distant objects give a view of the object as it was earlier in time. For objects that are very far away, astronomers get a view back to the earliest times in the universe, which may provide details about how the universe has evolved with time.

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[5]Eighty-two of them have been discovered at millimeter wavelengths. The list of detected molecules continues to grow. Among the most important molecular lines observed in the frequencies at issue in this proceeding are deuterated water (center frequency of 80.578 GHz), cyanoacetylene (81.881 GHz), cyclopropenylidene (82.966 GHz), methyl acetylene (85.5 f(92.494 GHz), and hydrodinitrogen (93.174 GHz).

Recent observational work at millimeter-wave observatories, such as the Caltech Submillimeter Observatory, the James Clerk Maxwell Telescope in Hawaii, and the University of Arizona's Steward Observatory Telescope (formerly the NRAO Kitt Peak 12-m telescope), has discovered highly redshifted emissions from very distant galaxies, corresponding to looking back through approximately 90 percent of the age of the universe. This has established an exciting possibility for radio astronomy: the study of the evolution of galaxies throughout most of the history of the universe.

The expansion of the universe causes spectral lines that are emitted at short (submillimeter) wavelengths to be shifted to longer wavelengths. The magnitude of this "redshift" is proportional to the distance, and the greatest sensitivity to the most distant objects occurs at the frequency where the intrinsically brightest lines appear. As it happens, the lines of particular importance for studies of distant galaxies are those of carbon monoxide, with a range of isotopes, for which the rest frequencies (i.e., without redshift) lie in the range of 109-116 GHz. However, redshifts bring these lines into the bands at issue in this proceeding. Thus, modern instruments are planned to conduct spectral line observations of the *entire* 3-mm window to measure the spectral lines from distant galaxies in order to determine their redshifts (and hence distances) and physical properties. If the window available to astronomers were reduced, then observations of galaxies at certain redshifts would not be possible within this spectral band. This limitation would make studies of the evolutionary behavior of these galactic systems significantly more difficult.

D. Very Long Baseline Interferometry

CORF also notes that the Very Long Baseline Array (VLBA), with antenna locations stretching from Hawaii to the Virgin Islands, now operates at frequencies up to 86 GHz. At 3-mm wavelengths, the VLBA provides the highest angular resolution currently achieved in astrophysics. This capability is critical to studies of the environs of massive black holes in distant galaxies, as well as maser sources in star-formation regions in our own galaxy and observations of maser sources around evolved stars.

Lastly, CORF noted that the suggestion to allocate these bands to the RAS on a secondary basis is of little use to radio astronomers. The Commission well knows that without a primary allocation, whether and when a passive observer can use the spectrum is completely controlled by the active user. Useful observations cannot be made this way. Similarly, the suggestion in paragraph 44 that an allocation to the RAS be made on an unprotected basis would result in no allocation at all: passive users can already observe at any frequency they want, regardless of the allocation of that frequency. The critical utility of a primary-use allocation is that it gives passive users the protection they need for observations to be productive.

III. CORF Supports Various Means of Protecting Passive Users in These Bands.

In paragraphs 43, 45, and 46, the NPRM discusses various means of protecting

RAS users of the 81-86, 92-94, and 94.1-95 GHz bands. These proposals and related matters are addressed below.

A. Coordination with RAS Sites

The NPRM notes the suggestion of the National Science Foundation that in order to avoid interference with RAS users of the 81-86, 92-94, and 94.1-95 GHz bands, licensees of all other allocated services in these bands be required to coordinate with the relevant RAS observatories. CORF fully supports the proposed coordination requirement, with the revisions discussed below.

Values for the coordination radii should be based on atmospheric attenuation of no more than 0.4 dB/km, and line-of-sight transmission paths, to be consistent with the location of most RAS sites that observe in these higher frequencies, which are usually at high-elevation sites in dry desert areas.[6] The-150 km radius is satisfactory in the general case, but for the 10 Very Long Baseline Array (VLBA) stations, CORF requests that the 25-km figure be increased to 60 km, to provide the required path attenuation. It should be noted that 60 km for the VLBA stations is consistent with the value for the same set of RAS sites in the table in Section 101.31 of the Commission's Rules.

While the Commission proposes to place the coordination requirement in a footnote to the table of allocations, CORF strongly suggests that the requirement also be placed in the sections of the Commission's Rules that regulate the services to be authorized in these bands (i.e., Part 101). As the Commission knows, many operators and frequency coordinators do not consult the table of frequency allocations in Part 2 of the Commission's Rules. However, those parties do regularly consult the operating rules for specific services. Thus, if licensees are to be required to comply with the coordination requirement, they must first be alerted to the existence of the requirement, and accordingly it must be placed in the operating rules. *See, e.g.,* Section 101.31.

In paragraph 45 of the NPRM, the Commission seeks input into factors and procedures that could eliminate any unnecessary coordination burden on licensed users. First, it should be noted that most RAS sites that observe in the high frequencies at issue in this proceeding are, as a rule, located at high altitudes and in dry areas, in order to minimize the effects of atmosphere attenuation. The fact that the site referenced in paragraph 45 of the NPRM is in a valley (Owens Valley), is quite exceptional.[7] Thus, while the typical setting for a radio astronomy observatory is on a

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[6]Note that at the best millimeter-wavelength sites listed in the table in proposed footnote USzzz, the atmospheric absorption, based on water vapor density, can be as low as 0.1-0.2 dB/km under good conditions. The proposed coordination radii may therefore underestimate the protection required in such cases.

[7]In fact, the Owens Valley and BIMA observatories listed in proposed footnote USzzz have recently decided to merge under the name Combined Array for Research in Millimeter-wave Astronomy (CARMA). It is expected that CARMA will be located in a

mountain or high plateau, where interference may be received from all directions, CORF is open to the possibility of factors that would reduce or eliminate the coordination requirement where such a requirement is clearly unnecessary. The general concept of such an approach would seem to be that licensed users (or their frequency coordinator) would be required to first determine if they are within the coordination zones proposed in the NPRM. If so, then they would consult a Web site operated by the relevant observatory, or perhaps a common Web site for relevant U.S. observatories, that would allow evaluation of certain parameters to be entered by a proposed licensee to see if coordination is necessary. Such parameters could include regional topological and climatological data; transmitter antenna characteristics; and transmitter location, azimuth, power, beam width, and frequency. If coordination is required, then a frequency coordination process would occur between the licensee and the observatory. Such a process will need to be further defined by the Commission, in consultation with representatives of the RAS community.

While CORF supports the general concept of coordination, and the use of certain factors to determine if coordination is required, it notes that the software necessary to evaluate factors such as terrain shielding or radio propagation by diffraction at these very high frequencies has not been developed at this time. CORF has no knowledge of such software being currently available on a commercial basis or of its having been developed by radio astronomy observatories.

B. Geographic Scope of RAS Allocations

In paragraph 46 of the NPRM, the Commission seeks comments as to whether the geographic scope of the RAS allocations proposed in this proceeding should be limited to prevent giving protection to RAS sites in major urban areas. The Commission uses footnote US277 as an example of such an approach. CORF does not oppose this proposal, as long as all current RAS sites listed in proposed footnote USzzz are "grandfathered" in and allowed to continue operation.[8]

C. Proposed Service Rules for Unlicensed Bands

In paragraph 62 of the NPRM, the Commission notes the proposal to allow unlicensed use in all of the bands at issue in this proceeding, and seeks comments on rules designed to prevent interference to other users.

First, CORF strongly supports the proposed prohibition on airborne and

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new, high-altitude site at Cedar Flat, California: 118° 09′ 03″ west, 37° 16′ 39″ north. The Commission will be informed when the facilities are moved to the new location. For the time being, OVRO's valley location does not guarantee protection, since communication stations are placed to facilitate north-south transmissions in the valley.

[8]Such grandfathering must also apply to the new site for CARMA, whose current locations are listed in proposed footnote USzzz. *See* note 7, *supra.*

space-borne use of such devices. There is no doubt that such uses would significantly increase the possibility of interference to RAS facilities.

In proposed Section 15.257, the Commission sets out emission-level limits for unlicensed devices operating in the 92-95 GHz band, which presumably would also be used if unlicensed devices are allowed in the 71-76 and 81-86 GHz bands. CORF has substantial concerns about these proposed limits and believes that they are based on an inaccurate assumption. In paragraph 62, the Commission states that the proposed levels are "based on our existing regulations for the 57-64 GHz band" and continues "We believe that power levels for 57-64 GHz unlicensed operation are also appropriate for 92-95 GHz since they were based primarily on safety issues with respect to power densities." While safety is one issue, CORF's concern is with interference to the RAS and the EESS in this case. Interference from transmitters in the 57-64 GHz band is a less serious issue because 57-64 GHz is centered on the strong oxygen absorption line.

An appropriate calculation of power limits for the 81-95 GHz bands based on propagation characteristics would be the following. For unlicensed devices the proposed power level indicated in footnote 92 corresponds to an EIRP of 10 watts. In the absence of a specified figure for the bandwidth over which the transmission would be spread in the case of unlicensed devices, we will use 100 MHz. Since radioastronomy facilities operating in the millimeter wavelength range are generally located at high elevations in dry desert areas, a value of no more than 0.4 dB/km should be used for atmospheric attenuation. This value is based on a water vapor content of 7.5 gm/m^3 (see Recommendation ITU-R P.620). For the conditions assumed above, the transmitter spectral power flux density (SPFD) falls to the detrimental threshold for spectral line observations in Table 2 of Recommendation ITU-R RA.769, -204 dBW/m^2Hz, at a distance of 70 km. For stations of the NRAO Very Long Baseline Array, the corresponding SPFD threshold in Table 4 of Recommendation ITU-R RA.769 is -166 dBW/m^2Hz, which occurs at a distance of 10 km from the transmitter. The EIRP emission limits assumed in this calculation of the coordination radii (55 dBW for licensed users) should not be exceeded unless coordination distances are increased so that the threshold SPFD values at the radio astronomy stations are not exceeded. CORF recommends a reduction of the average power density limit by a factor of 4, to 2 $microW/cm^2$, a level that will reduce the range for harmful interference from a single unit to values acceptable for RAS.

D. Technical and Operational Rules for Licensed Use

In paragraph 93, the Commission proposes regulation of licensed services in the new allocations as fixed operations, under Part 101 of the Commission's rules. CORF supports this proposal.[9] The major concern of passive users here is that it is much more difficult to identify out-of-band and spurious emissions from mobile uses, than

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[9]CORF assumes that the proposed regulation under Part 101 does not apply to services using the new allocations to satellite uplinks and downlinks.

from fixed uses, when such emissions cause interference to radio astronomy.

In paragraph 99, the Commission seeks comments on a proposed frequency tolerance of 0.03 percent. CORF suggests that a more stringent limit on harmonics and the level of harmful out-of-band emissions which specifies tighter filter requirements is appropriate in addition to, not instead of, the proposed frequency tolerance.

IV. Conclusion.

The Commission should enact the allocations as designated at various WRCs, without shifting primary RAS allocations to secondary or unprotected status. The give and take of allocations enacted at the WRCs constituted a carefully crafted compromise that balances the interests of numerous radio services. The RAS gave up allocations at certain frequencies in return for allocations at frequencies that are important to radio astronomy science. While CORF supports coordination between licensed users of these bands and RAS sites, the coordination requirements should be placed in the service rules for the applicable service, not just in the Part 2 Table of Allocations. Furthermore, work still remains to be done in setting up such coordination procedures.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

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