Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Proceeding to Address Satellite	)	RM-9740
Network Unwanted Emissions	)	
	)	

COMMENTS OF THE
COMMITTEE ON RADIO FREQUENCIES

The National Research Council's Committee on Radio Frequencies[1] (hereinafter, CORF), hereby submits comments in response to the Commission's November 19,1999, Public Notice addressing satellite network unwanted emissions ("Notice"). In these comments, CORF expresses its deep concern that any relaxation of the unwanted emission limitations in Part 25 of the Commission's rules would likely have very detrimental effects on important observations by radio astronomers and other passive users of the spectrum. CORF therefore urges the Commission to forbear from issuing a notice of proposed rulemaking on these issues, and to take no other action that would weaken satellite unwanted emission limitation standards.

I. The Unique Vulnerability of Radio Astronomy and Other Scientific Services to Out-of-Band and Spurious Emissions.

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

As the Commission has long recognized, the RAS is a vitally important tool used by scientists to study our universe. Through the use of the RAS, scientists have in recent years discovered the first planets outside the solar system. Measurements of radio spectral line emission have identified and characterized the birth sites of stars in our 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 witness the creation and distribution of heavy elements essential to the formation of planets like Earth and of life itself. Furthermore, in addition to increasing knowledge of our world and the universe, radio astronomy has produced substantial benefits through the development of very-low-noise receivers and many other applications used in a variety of other radio applications. In addition, the technique of very-long-baseline interferometry (VLBI), developed for cosmic observations, is increasingly producing substantial benefits through use in terrestrial observations, including measurements of global distances (e.g., identification of potential earthquake zones through measurement of fault motion), and through major contributions to navigation, including the tracking of spacecraft.

The EESS represents both a critical and a unique resource for monitoring the global atmosphere and surface state, operationally and experimentally. Passive and active satellite-based microwave remote-sensing measurements represent the only practical approach to obtaining

[1]The roster of the CORF membership is listed in the appendix.

uniform quality atmospheric and surface data encompassing the most remote oceans as well as densely populated areas of Earth. EESS data have contributed substantially to the study of meteorology, atmospheric chemistry, oceanography, and global climate change. Currently, instruments operating in the EESS bands provide regular measurements to support an extensive variety of scientific, commercial, and governmental (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, and studies of the ocean surface and internal structure. Ensuring the consistent quality of long-term EESS data requires protecting it from an increasingly degraded receiving environment.

The benefits of this scientific research, obtained through years of work and substantial federal investment, as well as future benefits, must be protected.

As passive users of the spectrum, radio astronomers and Earth scientists have little control over the frequencies that they need to study, or over the character of the "transmitted" signal. These parameters are set by the laws of nature. Furthermore, the emissions that radio astronomers receive are extremely weak—a typical radio telescope receives only about one-trillionth of a watt from even the strongest cosmic source. And the signals that usually yield scientific discoveries are much weaker; these weak signals and signals that require precision measurements need to be free from interference. Similarly, the emissions received by passive EESS radiometers are weak by comparison with emissions from other services. Because RAS and EESS receivers are designed to pick up such remarkably weak signals, their facilities are therefore particularly vulnerable to interference from spurious and out-of-band emissions from licensed and unlicensed users of neighboring bands, and from those that produce harmonic emissions that fall in the RAS and EESS bands.

II. The Reasons Proffered in the Notice for the Relaxation of the Standards for Unwanted Emissions Are Not Justified.

As the Commission knows, satellite transmissions (especially downlink transmissions) in bands adjacent to RAS and other passive allocations have often resulted in harmful interference to, and loss of flexibility and scientific yield from, large numbers of RAS and passive scientific facilities. Numerous FCC documents have recognized this concern and have required strict compliance with Part 25 requirements governing unwanted emissions in order to protect vulnerable RAS observations. See, e.g., Digital Audio Radio Satellite Service Report and Order, 12 FCC Rcd 5754 (1997) at para. 118; cf. Motorola Satellite Communications, Inc., Order and Authorization, 10 FCC Rcd 2268 (Int'l. Bur. 1995). Indeed, only one year ago, in a proceeding on proposed rules for non-geostationary satellite orbit (NGSO) fixed-satellite service (FSS) operations in the Ku-band, the Commission stated that "radio astronomy operations utilize some of the most sensitive instruments ever made and even unwanted emissions through zero dB sidelobes may completely destroy observations" (Notice of Proposed Rulemaking in ET Docket 98-206, 14 FCC Rcd 1131 (1998) at para. 82). Yet, the current Notice seems to ignore these facts, and suggests that relaxation of the Section 25.202(f) standards might be warranted because "significant changes" have occurred in the twenty-five years since the rule was first enacted. CORF agrees that significant changes have occurred, but such changes do not justify liberalizing unwanted emission standards.

Twenty-five years of advancing technology have brought a proliferation of spectral usage as well as an associated increase in out-of-band (OOB) and spurious emissions. While advancing technology has improved the ability of some individual space-borne transmitters to reduce unwanted emissions, the introduction of "broadband and significantly different modulation or frequency-use schemes" has expanded the spectral reach and impact of unwanted emissions. Indeed, the broadband emissions now in use, especially spread-spectrum modulation, to some extent mimic natural emissions and are much harder to distinguish from genuine astronomical

emissions than earlier, relatively narrow-band classes of emissions. While amplifier technology has improved, the requirements of adapting transmitters to operate in satellites, where there are strict limits on weight and available power, necessarily lead to designs that minimize the use of components such as filters, and require power amplifiers to be used at signal levels at which it is difficult to control unwanted emissions. Thus the need to minimize unwanted emissions has correspondingly increased with improved technology, not decreased. Furthermore, the increasing number of satellites in a network, as well as the presence of multiple networks that share the same allocated band, has exacerbated the impact of the aggregate unwanted emissions on receivers in the same, adjacent, nearby, and harmonically related bands. As a result, more than ever, unwanted emissions, especially from downlinks, detrimentally affect scientific receivers located on Earth's surface, in the air, and in space.

Similarly, the expansion of satellite services to higher frequency bands does not alleviate the concern of passive users of the spectrum, but rather presents an additional threat to the passive services since passive scientific users currently make observations in such bands and will do so increasingly over time.[2] Thus, protection from OOB and spurious emissions accompanying the wide-bandwidth satellite downlinks and multicarrier satellite downlinks that will be common in proposed systems is necessary for maintaining our nation's substantial investment in X-, Ku-, K-, Ka-, and V-band radio-telescopic and Earth sensing systems.

CORF is thus highly concerned that the development of complex networks of satellites involving numerous low-Earth orbiters or closely spaced but highly directive geostationary satellites presents a significant risk to a number of scientific services, especially passive ones, unless strict regulation of OOB and spurious emissions from space-borne transmitters is maintained. Because of the dominant position of satellite transmitters in the sky, it is nearly impossible to shield Earth-based receivers from their OOB or spurious emissions. The inherent nature of space-borne transmitters being widely observable over much of our planet thus necessitates the highest level of technological protection against OOB and spurious emissions, not a reduction in protection. Moreover, when large numbers of satellites are included in a network, OOB or spurious emissions from several satellites may interfere with the operation of one or more Earth-based radio telescopes, deep-space research receivers, Earth exploration service satellites, or even Global Positioning System (GPS) receivers used for scientific purposes. This is especially true with regard to protection of passive services such as the RAS, since the receivers in the passive services are sensitive enough to detect OOB and spurious emissions from nearly every satellite above the horizon, regardless of the orientation of their antennas.

In sum, the matters stated in the second paragraph of the Notice do not justify relaxing standards for unwanted emissions from satellites. To the contrary, developments in the past twenty-five years have created a need to increase the protection of passive services in order to protect the multi-billion dollar national investment in systems operating in these services. As discussed above, it is imperative to limit the *aggregate* OOB and spurious emissions from all space-borne transmitters so as to assure protection of their spectral neighbors. And, as CORF has stated in numerous comments filed with the Commission, protection from unwanted emissions should be based on levels specified in International Telecommunication Union Radiocommunication Sector (ITU-R) Recommendation RA.769-1 for RAS bands. Similarly, the basis for protection for bands in the Earth Exploration Satellite Service should be Recommendation ITU-R SA.1029-1 (for passive sensors) and ITU-R SA.1166 (for active space-borne sensors). These ITU criteria have already been used to establish in-band power flux density (PFD) limits in

[2] Numerous bands above 15 GHz are allocated on a primary basis to the RAS. See Appendix 1 to the ITU's Handbook on Radio Astronomy (Geneva, 1995, pages 65-66). In addition, Table 2 (page 13) of that Handbook lists the 47 radio-frequency lines of the greatest importance to the RAS at frequencies below 275 GHz. Thirty-three of those 47 lines are at frequencies above 15 GHz.

several bands between 50 and 60 GHz. The limits protect passive sensor operations from interference due to satellites in the inter-satellite service. Specifically, the PFD produced by a station in the inter-satellite service at altitudes from 0 to 1,000 km above Earth's surface is limited.

More broadly, however, it should also be noted that action by the Commission to update rules related to unwanted emissions is premature in light of the considerable national and international studies currently under way. ITU-R Task Group 1/5 has not completed its work, and band-by-band studies to assess the compatibility between passive services and satellite services in adjacent bands have not even begun. Furthermore, the National Telecommunications and Information Administration (NTIA) has undertaken a major new initiative to examine adjacent band interference and to make appropriate recommendations. Surely industry, passive users, and regulators will all benefit from having the results of these studies available in order to make informed decisions about adoption of appropriate regulations.

III. Responses to Specific Questions in the Notice.

In the fourth paragraph of the Notice, the Commission seeks comments on "how the Commission should proceed with this petition for rulemaking, and the scope of the issues to be addressed in considering unwanted emissions from satellite networks." First, as noted above, CORF suggests that the Commission forbear from issuing a notice of proposed rulemaking in this proceeding. Relaxation of the standards for unwanted emissions is not justified. However, if the proceeding is to advance, then the Commission should seriously consider tightening the standards for unwanted emissions. In such a case, it should consider the levels of unwanted (that is, spurious as well as OOB) emissions and their impact on passive receivers allocated in adjacent, nearby, and harmonically related bands. These protected receivers should include those of the passive services located on the ground, in the air, and in space. It is critical that any changes to Section 25.202 retain the essence of 25.202(f)(4) to allow the Commission, at its discretion, to require lower levels of unwanted emissions than the generic levels for satellite downlinks, uplinks, and inter-satellite links. The Commission should also seriously consider applying stringent limits on unwanted emissions from active-array multi-beam antennas, which have the potential to direct intermodulation frequencies far from the intended beams.

CORF's responses to the questions listed on page 2 of the Notice are as follows:

1. "Should the generic out-of-band (OOB) mask be in dBc, dBs, or PFD units or some combination?"

OOB emission masks based on dBc or dBs compare out-of-band emission levels measured in a reference bandwidth centered at a frequency outside the necessary bandwidth of the transmitted signal to the in-band signal. Specifying emission levels in terms of dBc or dBs masks may be convenient in establishing general limits for unwanted emissions for transmitters in the Space Services. Compliance with dBc or dBs masks can be determined by actual measurements of the emitted spectrum taken at the transmitter, and for satellite transmitters compliance with such masks is, of course, independent of the particular orbit chosen for the spacecraft. Therefore, dBc or dBs masks may be favored by certain satellite operators and may, in fact, be appropriate to establish general limits. They are, however, insufficient to determine interference to services receiving unwanted emissions. Also, it is not clear how to apply these masks to phased-array power-amplifier-antennas, some of which may soon operate above 17 GHz. PFD limits, on the other hand, have the purpose of specifying protection levels to services receiving unwanted emissions. To ensure compatibility between the Space Services and other users of the spectrum, particularly passive service users, if general masks are specified in dBc or dBs, they must always be complemented with specific PFD levels that should be met, at a minimum, in bands allocated to the RAS and/or to the other passive services on a primary basis. Specifying PFD levels that satellite

systems must meet is particularly important for non-geostationary satellite systems, where PFD levels at any particular location on Earth vary, depending on the number of satellites over the radio horizon at any given time, as well as their distance, orientation, and antenna gain with respect to radio astronomy sites. The approach of specifying mandatory PFD levels in some bands is not new. The Radio Regulations (e.g., S21.16) and the FCC (25.208) currently place PFD/bandwidth limits at Earth's surface for authorized satellite emissions in certain bands. In fact, some rules even specify spurious emission levels that must be met by the space-based transmitter (e.g., 25.213 (b)). If the United States is to maintain a viable program in radio astronomy, let alone one at a world leadership level, it is essential that this approach be extended, to specify PFD levels to be met by satellite systems in the primary RAS bands.

2. "Should the emissions of a multi-carrier system with a wideband frequency allocation be treated differently than those of a system with a single broadband carrier?"

Under regulations whereby out-of-band emission limits are based on *absolute* PFD, the need for discrimination between multicarrier and single-carrier emissions is not critical. However, under current regulations, the levels of allowable OOB and spurious emissions are instead related to the transmitted carrier power, and the definitions of spectral masks are based on the bandwidth of the transmitted carrier. Under current FCC rules (section 25.202(f)), each carrier is treated as a separate entity, and each carrier must individually conform to a mask based on its authorized bandwidth. By treating a multicarrier transmitter as the equivalent of a transmitter with a single wide-bandwidth carrier, the amount of OOB and spurious emissions allowed would be dramatically increased, and over a much larger spectral extent. Thus, CORF does not support blanket characterization of multicarrier transmissions as the equivalent of a single carrier broadband transmission, since it would undoubtedly lead to levels of OOB and spurious emissions that would exceed those in Recommendation ITU-R RA.769-1.

3. "Should the mask be defined as a function of authorized bandwidth (FCC approach) or necessary bandwidth (ITU approach)?"

The Commission should consider whether any change to Section 25.202 ought to conform to the ITU-R Radio Regulations and pertinent Recommendations as they exist now and as they may exist in the future. The ITU-R definition and application of necessary bandwidth to a variety of modulations is somewhat open to interpretation. Several ITU-R study groups and working parties are considering revisions, and any resulting changes may not become effective for some time. Certainly a mask for unwanted emissions, both generic masks and masks for special situations, defined as a function of an a priori bandwidth authorized by the Commission in the proceedings to license a satellite network, is clear and convenient for all concerned parties, including potential receivers of interference. However, the authorized bandwidth may be wider than the necessary bandwidth and may be as wide as 500 MHz or more. This would extend the boundary between OOB and spurious emissions as far as 2.5 times 500 MHz = 1.5 GHz from the center of the authorized band, which likely would extend the higher OOB limits into an adjacent and even a nearby allocated band. The Commission should take these factors into account when considering special limits on unwanted emissions to protect services, especially the RAS, with primary allocations in an adjacent or nearby band.

4. "Should a generic mask be used for all space services allocations unless otherwise specified?"

Under current FCC rules (section 25.202(f)), a single mask is specified for the allowable OOB and spurious emissions from transmitters in the Space Services. However, a number of additional restrictions, based on the nature of the sensitivity of spectral neighbors to interference,

are currently part of FCC regulations. A more stringent mask has been proposed in recent studies from ITU Working Party 8D. However, requirements for both out-of-band and spurious emission suppression depend very much on the spectral proximity to susceptible services. As a result, band-by-band studies have been conducted by ITU-R Working Party 8D, and the nature of the mask required to protect passive services at the levels specified by ITU-R RA.769.1 (radio astronomy), SA.1029-1 (passive sensors), and SA.1166 (active spaceborne sensors) varies substantially. As a result, CORF feels that while it would be beneficial to define a nominal mask, it will also be necessary to specify additional limits to the allowable out-of-band and spurious emissions based on recommendations ITU-R RA.769.1, SA.1029-1, and SA.1166.

5. "Should the FCC Rules incorporate out-of-band values agreed to in Recommendations of the ITU-R?"

As discussed above, it is imperative to limit the aggregate OOB and spurious emissions from all space-borne transmitters so as to assure protection of their spectral neighbors. And, as CORF has stated in numerous comments filed with the Commission, rules for protection from unwanted emissions should be based on levels specified in Recommendation ITU-R RA.769-1 for RAS bands. Similarly, the basis for rules to protect bands in the Earth Exploration Satellite Service are found in Recommendation ITU-R SA.1029-1 (passive sensors) and SA.1166 (active space-borne sensors). These ITU criteria have already been used to establish in-band PFD limits in several bands between 50 and 60 GHz.

IV. Conclusion.

CORF is deeply concerned that any relaxation of the limitations on unwanted emissions in Part 25 of the Commission's Rules will likely have very detrimental effects on important observations by radio astronomers and other passive users of the spectrum. *There is no need for the Commission to take such an action at this time, and relaxation of the standards for unwanted emissions is not justified.* CORF therefore urges the Commission to forbear from issuing a notice of proposed rulemaking on these issues and to take no other action that would weaken standards limiting unwanted satellite emissions.

Respectfully submitted,
COMMITTEE ON RADIO FREQUENCIES

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December 20, 1999

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