Before the

FEDERAL COMMUNICATIONS COMMISSION

Washington, D.C. 20554

In the Matter of)

)

Amendment of Parts 27, 25, and 97)

of the Commission's Rules) ET Docket No. 98-142

with Regard to the Mobile)

Satellite Service Above 1 GHz)

MOTION TO ACCEPT LATE-FILED 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"; its membership is listed in Appendix A), hereby submits its comments in response to the Commission's August 4, 1998, Notice of Proposed Rulemaking in the above-captioned docket ("NPRM"). In these Comments, CORF suggests that the Commission forbear from enacting rules allocating for fixed-satellite service space-to-Earth downlinks in the 15.43-15.63 GHz band, because of the apparent infeasibility of sharing that band with radio astronomy observations, and, as a result, the likelihood that such allocation will be deleted on an international basis at the next World Radio Conference in the year 2000 ("WRC-00"). CORF is also concerned about the impact of downlink transmissions in the 6.7-7.075 GHz band.

I. Introduction: The Importance of Radio Astronomy Observations in the 15 and 6.7 GHz Bands, and the Unique Vulnerability of Radio Astronomy to Out-of-Band and Spurious Emissions.

CORF has a substantial interest in this proceeding, as it represents the interests of the Radio Astronomy community, as well as that of other scientific users of the radio spectrum. As the Commission has long recognized, radio astronomy is a vitally important tool used by scientists to study our universe. Through the use of radio astronomy, scientists have 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 witness the creation and distribution of heavy elements essential to the formation of planets like the 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") is used by geophysicists to study small motions of the Earth’s crust. These terrestrial observations include identification of potential earthquake zones through measurement of fault motion. VLBI techniques also make major contributions to accurate navigation, including the tracking of spacecraft. The study of the universe and the above benefits are the product of years of work by scientists and engineers and substantial federal investment in the field. To continue to produce these discoveries and benefits, radio astronomy must be protected.

As passive users of the spectrum, radio astronomers have no control over the frequencies that they need to study or over the character of the signals from cosmic objects. The laws of nature set these parameters. Furthermore, the emissions that radio astronomers review are extremely weak--a typical radio telescope receives only about one-billionth of a billionth of a watt signal from most cosmic sources. Because radio astronomy receivers are designed to pick up such remarkably weak signals, these 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 in the Radio Astronomy Service ("RAS") bands.

Of particular concern in this proceeding is interference to RAS observations in the 15.35-15.40 GHz ("15 GHz") and 6.65-6.70 GHz ("6.7 GHz") bands from satellite downlinks. The 15 GHz band is one of the most important bands used by the RAS for continuum observations, which define the frequency variation of radiation in sufficient detail to enable conclusions to be reached concerning the physical mechanisms responsible for such emissions. For this reason, Table 3 of ITU R.RA 314-8 specifically lists the 15.35-15.4 GHz band as among the bands of greatest importance to radio astronomy for continuum observations. This band is also important for monitoring the intensity variability of quasars. These tremendously distant and enigmatic objects have been found to emit energy that varies in intensity in periods of weeks or months. The energy emitted during any one burst from a quasar is equivalent to converting the mass of a few hundred million stars to energy, yet we do not understand the fundamental physics that can produce such events. RAS observations in this band are critical to the task of unraveling the mystery of quasars.

Similarly, the 6.7 GHz band is important for spectral line observations of methanol. Methanol is a basic organic compound, which plays a role in biogenesis. Since the only other observable emission from methanol would be in the heavily occupied spectrum near 12.178 GHz, observations at 6.7 GHz provide the last remaining portal to quantify the abundance and distribution of methanol on a galactic scale. For that reason, Table 1 of ITU R.RA 314-8 specifically lists spectral line observations of methanol (at the resting frequency of 6.668 GHz) as among the spectral lines of greatest importance to radio astronomy.

In sum, radio astronomy observations in the 15 and 6.7 GHz bands are important, yet, like all radio astronomy observations, are uniquely vulnerable to interference from out-of-band and spurious emissions.

II. The Commission Should Forbear From Enacting Rules Allocating the 15.43-15.63 GHz Bands, In Light of the Infeasibility of Sharing Between Downlinks and RAS in That Band, and the Resulting Likelihood that WRC-00 Will Modify the Allocation to Satellite Downlinks.

In this proceeding, the Commission states that in allocating the 15.43-15.63 GHz bands for satellite downlinks, it is merely enacting on a domestic basis, an allocation made at WRC-97 (NPRM at para. 31). Yet, CORF urges that in this proceeding, the Commission acknowledge that the allocation made at WRC-97 is far from finalized, and that it would be counterproductive for all parties, including satellite operators, to commence allocation and then authorization of transmissions in these frequencies, when in fact this allocation is likely to be modified at WRC-00. A brief review of how we have arrived at this point is instructive.

At WRC-95, the frequency band 15.4-15.7 GHz was allocated to FSS (space-to-Earth) with an added footnote S5.511A in order to protect other services in neighboring bands. Consequentially, WRC-95 called for further studies by the ITU-R on the feasibility of having FSS operations in this band. WRC-97 again changed the allocation and footnote S5.511A, to restrict FSS (space-to-Earth) to the band 15.43-15.63 GHz and to refer to Recommendation ITU-R RA.769-1 with respect to protection of the radio astronomy service in the frequency band 15.35-15.4 GHz. In Resolution 123, WRC-97 has, as a matter or urgency, called for new ITU-R studies on the feasibility of implementing non-GSO MSS feeder links in the band 15.43-15.63 GHz, for studies on the interference potential of these NGSO satellite feeder links to the radio astronomy service in the 15 GHz band, and for the development of recommendations to reduce out-of-band interference. Resolution 123 resolves that WRC-

00 shall review these studies and take appropriate action, including adjustments in spectrum allocations.

The allocation to radio astronomy and other passive services of the frequency band 15.35-15.4 GHz is protected by footnote S5.340, which states that: "All emissions are prohibited...." It should be noted that this allocation to the radio astronomy service is very narrow compared to the relative bandwidth of 2%, which is considered the necessary minimum for radio continuum measurements by the RAS. The interference threshold limits to be used for coordination purposes are given in Recommendation ITU-R RA.769, which are based, inter alia, on the assumption of an antenna gain of 0 dBi toward the interfering transmitter. Article S29 of the Radio Regulations states further that the RAS is extremely susceptible to interference from space and airborne transmitters.

Appendix B attached hereto contains calculations recently performed to investigate the impact of satellite downlink transmissions on RAS observations in the 15.35-15.40 GHz band. As shown therein, it would be extremely difficult for such transmissions to be made in a way that is consistent with the required levels of protection for radio astronomy.

In light of the above, and considering the past experiences of the RAS with satellite (space-to-Earth) operations in adjacent bands, as well as the particular vulnerability of the RAS band at 15.35-15.4 GHz, CORF believes that on operational grounds the FSS (space-to-Earth) allocation in the 15.43-15.63 GHz band is not only not feasible, but that this infeasibility will be recognized and acted upon by WRC-00.

In light of the strong likelihood that the 15 GHz allocation will be modified, CORF asserts that it would not be in the interest of any parties, including that of the Commission and satellite operators, to go through the expense and burden of allocating this band, only to have to revise the allocation in such a short period of time. Accordingly, CORF recommends that the Commission forbear from the proposed 15.43-15.63 GHz downlink allocation, pending action at WRC-00.

On a separate matter, CORF is also concerned that the use of the 6.7-7.075 GHz band for downlink service may place at risk observations of the methanol resonance (resting frequency at 6.68 GHz). As the Commission knows, the 6.650-6.670 GHz band is included under Footnote S5.149, which urges administrations to take all practicable steps to protect RAS observations from harmful interference. Observations of this band are made at numerous observatories in the United States including those at Arecibo, Puerto Rico, and the National Radio Astronomy Observatory's facilities at Green Bank, West Virginia, and Socorro, New Mexico. The potential problems in this band can likely be remedied by coordination between any satellite company operating next to this band and the radio astronomy observatories that use this band. CORF suggests that the Commission could facilitate this process.

III. CONCLUSION.

The Commission should forbear from enacting rules allocating the 15.43-15.63 GHz band for satellite downlinks, in light of the infeasibility of sharing in that band between RAS and satellite downlinks, and the resulting likelihood that WRC-00 will modify the allocation in the international table.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'

COMMITTEE ON RADIO FREQUENCIES

By: /S/Bruce Alberts

President

September 29, 1998

Attachments:

Appendix A: Membership of the Committee on Radio Frequencies

Appendix B: Calculation of Interference to Radio Telescopes from Satellite Downlinks in the 15.35-15.40 GHz Band, adapted from a communication from Tony Reed, Chairman, ITU-R Working Party 4A

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Appendix A

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Appendix B

Calculation of Interference to Radio-Telescopes from Satellite Downlinks in the 15.35-15.40 GHz Band

ITU-R Recommendation RA.769 sets out the protection criteria for radio astronomical measurements, and explains their derivation in its Annex 1. The limit of acceptable interference power (I) at the input to the receiver of a radio telescope is given in watts by

$$I = (0.1)(kT) / [\sqrt{2bt}]\ \mathrm{W} \qquad (1)$$

where k is Boltzmann’s constant (1.38×10^{-23} joules/K), T is the system noise temperature of the radio telescope (K), b is the measurement bandwidth (Hz), and t is the integration time of the measurement (s).

Since the on-axis gain-to-aperture ratio of a reflector antenna is given by $g/a = 4(\pi)/L$, where L is the wavelength = $3 \times 10^8 / (f \times 10^9)$ in meters and f is frequency in GHz, then the aperture in square meters is

$$a = (9g)/[(400(\pi)(f^2)]\ \mathrm{m}^2 \qquad (2)$$

The interference power criterion can be converted to a criterion for power-flux-density (pfd) incident on the antenna of the radio telescope by using the relationship

$$pfd = I/q\ \mathrm{W/m^2} \qquad (3)$$

Combining equations (1), (2), and (3) enables the interference criterion to be expressed as a pfd at the Earth’s surface, i.e.,

$$pfd = 40(\pi)(kT)(f^2)/[(9g)\sqrt{2bt}]\ \mathrm{W/m^2},$$

or expressed in decibels:

$$PFD = 10 \, Log[T (f^2)/ \, sq.rt.(bt)] - G - 218.7 \; dB(W/m^2) \quad (4)$$

Table 1 of ITU-R Recommendation RA.769 indicates that parameters of a typical continuum measurement in the band 15.35-15.4 GHz are T = 45 K, b = 50 MHz, and t = 2000 s, and for a 50 MHz measurement at the upper end of the band, the center frequency (f) would be 15.375 GHz. Substituting these numbers into equation (4) yields

$$pfd = G - 233.4 \; dB(W/m^2) \quad (5)$$

At 15.375 GHz a radio telescope with an antenna of 20-m diameter would have an on-axis gain of around 68 dBi, and far sidelobe peaks of around -10 dBi. Hence, its interference criteria for a 50 MHz, 2000 s measurement would be about -301 dB (W/m^2) in its on-axis direction, and about -223 dB (W/m^2) in most other directions.

Now for the protection of the aeronautical radionavigation service, ITU-R Recommendation S.1341 (referenced in RR S.5.511a) includes a limit on the power-flux-density at the Earth’s surface, from a space station transmitting in the band 15.43 - 15.63 GHz. As indicated in the NPRM, that limit is -127 dB (W/m^2)/MHz, which is equivalent to -110 dB (W/m^2) in a bandwidth of 50 MHz. This would allow each satellite in a non-GSO MSS constellation to generate up to that pfd via its feeder downlink. The number of satellites simultaneously visible to a given radio telescope would depend on its latitude and on the characteristics of the MSS constellation, and would vary with time, but at 15 GHz each satellite would probably deploy multiple spot beams to cover its footprint on the Earth’s surface. In that case, it is probably that only one satellite would illuminate the area surrounding the radio telescope via the main-lobe of one beam at any given time (possibly two beams if dual-polar frequency reuse was employed). Since the number of satellites simultaneously visible is unlikely to reach double figures, and the main beam-to-far sidelobe ratio of each satellite antenna is likely to be at least 30 dB, the interference would be dominated by a single satellite beam at any instant. But, assuming that the MSS system included a feeder-station within the instantaneous coverage of that beam (which might span a diameter of 100 km or more), that interference would be continuously present.

Thus, in this scenario we would have a non-GSO MSS constellation transmitting in a 50 MHz bandwidth centered on 15.455 GHz and illuminating a radio telescope with a pfd of -110 dB (W/m^2). However, in order to protect radio astronomy, the out-of-band pfd from this transmission must be reduced to -223 dB (W/m^2) at 15.375 GHz, requiring that the level of out-of-band emission 80 MHz below the center frequency of a 15 GHz carrier, or 55 MHz below its band edge, was 113 dB below the carrier level. Of course, this would be impractical, and nothing like it has ever been demonstrated on a spaceborne transmitter!

Even worse, interference could be up to 80 dB higher during the small periods of time (typically of the order of 1 second and aggregating to proportions of time of a small fraction of 1%) when a satellite passes through the main beam of the radio telescope. It would not be difficult to set up a computer simulation to verify these estimates, but, at present, it would have to be based on a hypothetical satellite constellation, since we have no information of a non-GSO MSS system using the 15 GHz band for its feeder downlinks. Furthermore, if the above considerations concerning the interference that could obtain for the majority of time (i.e., via the radio telescope’s sidelobes) are broadly correct, then it seems possible to answer the questions posed by Resolution 123 without recourse to computer simulations.