December 16, 1999

Before the
Federal Communications Commission
Washington, DC 20554

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

COMMENTS OF THE NATIONAL RADIO ASTRONOMY OBSERVATORY

The National Radio Astronomy Observatory

The National Radio Astronomy Observatory (NRAO) submits these comments in response to the Commission's November 19, 1999 Public Notice which addresses satellite network unwanted emissions.

NRAO is a research facility of the National Science Foundation. With major facilities in Virginia, West Virginia, New Mexico and Arizona, the NRAO annually provides more than 950 scientists from some 200 institutions with approximately 30,000 hours of radio-telescope observing time. The research performed using NRAO facilities covers a wide range of scientific specialties and is reported in more than 400 scientific papers published each year. NRAO telescopes are vital to a number of astrophysical research areas and have provided the data that formed the basis for hundreds of Ph.D. dissertations.

NRAO is very concerned that any relaxation of the limits on unwanted emissions in Part 25 would have detrimental effects on research in radio astronomy and on the observations conducted with its radio telescopes.

The Radio Astronomy Service

Radio astronomy is one of the cornerstones of modern astrophysics. Through radio telescopes, humans gained their first view of the universe at wavelengths other than those of visible light, and that view has dramatically changed our understanding of the universe. Radio astronomers won Nobel Prizes for the discovery of pulsars, the radio "echo" of the Big Bang, and for finding evidence of the gravitational radiation predicted by Albert Einstein. Today, radio telescopes provide key information about our Sun, the Earth and other planets, and other astronomical bodies -- information that can be obtained from no other facilities.

Radio astronomy also has given society a number of technological benefits. The satellite-communication industry benefitted from technology pioneered by radio astronomy. Other technical areas such as computer science and medical imaging also received important boosts from radio astronomy.

Radio telescopes now are one of the physicist's prime tools for exploring the behavior of matter and energy under extreme conditions such as temperature, pressure, and density, which cannot be duplicated in a laboratory. Because physics in such extreme conditions lies at the frontiers of our understanding, astronomical phenomena with those conditions, such as supernovae, pulsars and gamma-ray bursters, are the key to new knowledge unobtainable except by astronomical observations. This "cosmic laboratory" is a repository of undiscovered knowledge of incalculable value to all humanity.

Radio astronomy thus is indispensable to the continued advancement of science and must be protected in the public interest. Unwanted satellite emissions today are a very serious threat to radio astronomy. Radio telescopes must of necessity be the most sensitive receiving systems that can be deployed. In order to protect our ability to study the universe, the most advanced engineering techniques must be employed to minimize the effect of satellite unwanted emissions on radio telescopes. Just as we ask other industries to apply advanced technology to protect our air, water and soil, we must insist that satellite emissions be as technically "clean" as possible to protect the vital resource of undiscovered scientific knowledge that is the heritage of all humanity. There must, therefore, be no relaxation of standards for unwanted emissions from satellites. Indeed, if anything, such standards should be made more stringent.

Changes in satellite technology

This proceeding notes that many significant changes have occurred in satellite technology subsequent to the introduction of section 25.202(f) into the Commission's Rules. According to the Public Notice, "all of these changes impact the ability to minimize unwanted emissions."

Twenty-five years of advancing technology have brought about a proliferation of spectral usage as well as an associated increase in the aggregate of out-of-band and spurious emissions. Thus the need to minimize unwanted emissions has correspondingly increased with improved technology, not decreased. Broadband and significantly different modulation or frequency-use schemes have expanded the spectral extent and impact of unwanted emissions. However, advancing technology has improved the ability to reduce unwanted emissions from transmitters. The increasing number of satellites in a network as well as the presence of multiple networks which share the same allocated band have added to the impact of the aggregate unwanted emissions on receivers in the same, adjacent, nearby and harmonically related bands. Unwanted emissions, especially from downlinks, detrimentally impact radio astronomy receivers and data. Recommendation ITU-R RA.1237 considers protection of radio astronomy from unwanted emissions produced by wideband digital modulation, which is an increasing concern for the future.

Scope of the proceeding

The scope of the issues to be addressed in this proceeding should include the levels of unwanted (that is, spurious as well as out-of-band) emissions and their impact on victim receivers allocated in adjacent, nearby and harmonically related bands. These victim receivers should include those of the passive services. Radio astronomy receivers are especially sensitive and therefore radio astronomical data are especially susceptible to detrimental interference from unwanted emissions from space (see Recommendations ITU-R RA.769, RA.517 and RA.611). Therefore, it is critical that any changes to FCC Rule 25.202 retain the intent 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.

Question 1.

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

Generic out-of-band (OOB) limit masks in dBc or dBs units give the ratio of OOB levels in a reference bandwidth at a frequency outside the necessary or authorized bandwidth of the transmitter to the in-band level. Such masks for OOB and spurious emissions may be conveniently applied at the output of transmitters operating in the Space Services. They provide a limited safety net of interference protection to other satellite networks in the same allocated band and also to other services sharing the same allocated band. However, they are insufficient to provide protection to sensitive receivers in adjacent, nearby or harmonically related allocated bands. The interference level depends on the unwanted effective radiated power towards the victim receiver and the distance to the victim receiver.

Limits in units of dBc or dBs applied at the output of the transmitter are not easily applicable to unwanted emissions from active-array multi-beam antennas, which have multiple power amplifiers distributed among the antenna elements. Such systems have the potential to direct unwanted intermodulation frequencies far from the intended beams.

PFD limits at the Earth's surface for in-band emissions from satellites do exist for some bands in Radio Regulations (RR) Article S21.16 and in FCC 25.208. These limits were established to protect certain sharing terrestrial services.

Given these considerations, the Commission, under FCC 25.202(f)(4), should apply limits as a PFD in a reference bandwidth at potential victim receivers. It is critical to do so for satellite downlink bands which are adjacent to, nearby, or harmonically related to bands having primary allocations to the passive services, especially to radio astronomy.

Question 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?"

An answer requires some consideration of the details of the systems involved. A multicarrier system should perform like an ensemble of individual transmitters, each handling one carrier and conforming to a spectral mask based on the carrier bandwidth. In practice, however, the signals from several of the carriers may pass through a common final amplifier, resulting in the likelihood of generation of intermodulation products from interaction of the different carriers. This type of design could result in serious unwanted emission. However, a single filter after the amplifier could be used to limit the spectral spread of the unwanted emission. Thus a multicarrier system should not be allowed any level of unwanted emission greater than that of the individual carriers. It should be held to more stringent limits than a single broadband transmitter because the form of the signal as a series of individual carriers allows for greater flexibility in the overall design.

Question 3.

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

The ITU-R definition and application of necessary bandwidth to a variety of modulations is complex and open to interpretation for some emission characteristics. Several ITU-R study groups and working parties are considering revisions. Changes from these studies may not become effective for some time.

Both generic masks for unwanted emissions and masks for special situations, defined as a function of a bandwidth authorized and clearly defined by the Commission in the proceedings to license a satellite network, would be convenient for all concerned operators, including potential victims of interference. However, the authorized bandwidth may be much wider than the necessary bandwidth. For example, the Commission has authorized an NGSO satellite network to downlink in the band 1621.35-1626.5 MHz. The OOB mask of FCC 25.202(f) applied to this 5.15 MHz bandwidth would extend to 1611.05 MHz. This extends across most of the 1610.6-1613.8 MHz primary allocation of radio astronomy, which has the special protection of RR S5.372.

The Commission should take these factors into account when considering special limits on unwanted emissions to protect a radio astronomy primary allocation in bands that are adjacent, nearby or harmonically related to satellite downlinks.

Question 4.

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

Generic OOB masks for the purpose of minimal safety net protection of services sharing the same allocated band could

apply to all space services. However, providing more than minimal protection for sensitive services should depend on the characteristics of their potential victim receivers. Certainly for some space service bands and network characteristics, the OOB masks and spurious limits should be made adequate to protect primary services in adjacent, nearby and harmonically related bands, especially for the safety and passive services, and particularly for radio astronomy.

Question 5.

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

The FCC ruling should take into account both out-of-band and spurious emission limits. Levels of spurious emission have recently been revised in Recommendation ITU-R SA.329. For space services, the limit on spurious emissions, defined as emissions separated from the band center by more than 2.5 times the necessary bandwidth, is broadly specified as -43 dBW in any 4-kHz bandwidth for output powers up to 5W. Such a level, radiated by a low-earth-orbit satellite at a height of 800 km, would produce a level of -208 dBW m^-2 Hz^-1 at the earth's surface. This estimate should be increased by the effective gain of the satellite downlink antenna at the frequency of the spurious emission. In the 1400-1420 MHz radio astronomy band, for example, the -208 dBW m^-2 Hz^-1 level would exceed the detrimental threshold for radio astronomy by 47 dB for continuum observations or 31 dB for spectral line observations (see Recommendation ITU-R RA.769). Such large differences between the predicted level and the detrimental threshold of spectral power flux density indicates that serious interference to radio astronomy could result, even making allowance for any implicit assumptions in this simple, worst-case analysis. Thus, Recommendation ITU-R SM. 329 does not provide meaningful protection for radio astronomy and passive services through the general limits on emissions. Such protection should be addressed by special consideration in individual cases. The NRAO strongly urges that the limits of unwanted emissions within primary radio astronomy bands should be based on the values given in Recommendation ITU-R RA.769.

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