Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Facilitating Opportunities for Flexible, Efficient,	)	
and Reliable Spectrum Use Employing Cognitive	)	ET Docket No. 03-108
Radio Technologies	)	

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 December 30, 2003, Notice of Proposed Rulemaking in the above-captioned docket (NPRM). In these comments, CORF demonstrates that those aspects of the basic concepts underlying cognitive radios that are intended to protect against interference to other users appear to ignore or are incapable of protecting passive users of the spectrum for scientific observation in bands allocated for such uses. Accordingly, CORF strongly urges the Commission to maintain the current Section 15.205 prohibition against intentional unlicensed transmissions in certain restricted bands. In addition, CORF recommends adoption of certain other measures to protect passive scientific observation of the spectrum, and the critically important data being gathered by such observers.

[1] A roster of the committee is attached.

I. Introduction: The Roles of Radio Astronomy and Remote Sensing, and the Unique Vulnerability of Passive Services to Interference.

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

As the Commission has long recognized, radio astronomy is a vitally important 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 emissions that radio astronomers review are extremely weak--a typical radio telescope receives less than *one-trillionth of a watt*[2] from even the strongest cosmic source. Because radio astronomy receivers are designed to pick up such remarkably weak signals, such facilities are particularly vulnerable to interference from in-band emissions, spurious and out-of-band emissions from

[2] That is, less than .000000000001 watt.

licensed and unlicensed users of neighboring bands, and those that produce harmonic emissions that fall into the RAS bands.

In addition to the gains in scientific knowledge that result from radio astronomy, CORF notes that such research spawns 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 tissues inside the human body;
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> –Increasing abilities to *forecast earthquakes* by the use of very-long-baseline interferometric (VLBI) measurements of fault motions;
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> –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;
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> –Improved *baggage scanners* at airports; and
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> –The study of *ozone depletion* in Earth's atmosphere.[3]

The Commission has also long recognized that remote sensing, including users of the EESS, is a critical and unique resource for monitoring the global atmospheric and surface state. 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 climate

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[3] See, National Telecommunications and Information Administration, U.S. Department of Commerce, NTIA Special Publication 98-35, *Radio Astronomy Spectrum Planning Options* (1998) at Appendix B, available on the World Wide Web at http://www.ntia.doc.gov/osmhome/reports/pub9835/raspexec.htm.

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. Major governmental users of the EESS data include the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation, the National Aeronautics and Space Administration (NASA), and the Department of Defense (especially the U.S. Navy). Applications of the data include weather forecasts for use in military and civilian aviation and sailing; hurricane and severe storm warning and tracking;[4] flood monitoring; seasonal and interannual climate forecasts and monitoring; observation and prediction of El Niño effects on agricultural production; studies of the ocean surface and internal structure; and monitoring of changes in vegetation cover, snow cover, and ozone holes, as well as many other critical areas.

Like radio astronomers, remote sensing scientists have little control over the frequencies at which they must observe in order to fulfill their scientific missions — the specific frequencies of specific elements or molecules are established by the laws of physics and chemistry. Similarly, both radio astronomers and remote sensing scientists observe transmissions as extremely weak deviations in the noise floor. For radio astronomy, the threshold levels of detrimental interference, based on a response that has a 10 % increase of the rms noise fluctuations after 2000-second averaging, are given in ITU Recommendation RA.769. For example, for the 1400-1427 MHz band the

[4] Improved hurricane landfall location forecasts from remote sensing save an estimated $1 million per mile of coastline that does not have to be evacuated.

threshold is 255 $dBWm^{-2}Hz^{-1}$ or 3.16×10^{-26} $Wm^{-2}Hz^{-1}$. Values for other bands are provided in Table 1, which shows the upper limit on variations in antenna temperature that can be allowed without degradation of the accuracy of the measurement of power received by a radio astronomy antenna. Because the slow variations in the received power level of interfering signals are not appreciably reduced by time averaging, this value must be considered to represent the maximum tolerable interference level. It is clearly impractical for cognitive radios to monitor such small temperature values for control of interference to the RAS.

Table 1. Examples of Detrimental Interference Temperatures for the RAS

Frequency (MHz)	Detrimental Interference Level ($dB(Wm^{-2}Hz^{-1})$)	Interference Temperature (K)
608-614	-253	7.0×10^{-5}
1,400-1,427	-255	8.0×10^{-6}
4,990-5,000	-241	1.7×10^{-5}
42,500- 43,500	-227	5.6×10^{-6}

The problem of the weakness of signals from cosmic radio sources, compared with communication signals, can be illustrated by noting that approximately 2 million discrete sources have been individually measured and catalogued from measurements near 1.4 GHz, but their average flux density is so small that their combined effect increases the noise power in an isotropic antenna by only 0.1 K.

For the EESS, the harmful interference level is established in ITU-R SA.1029 and is approximately 10^{-3} K. While that level is higher than the level established for the RAS, the area observed by remote sensing scientists is global --urban, rural, and over sea. The satellite-based receivers look at the entirety of

Earth's surface, and have mean noise temperatures of 300-400 K. The signal observed consists of small changes in this level that are only measurable, as in the RAS, when wide bandwidths are used. ITU-R SA.1029 also states that this interference level cannot be exceeded for more than 1 percent of the sensor's measurement cells either by in-band or by out-of-band emissions.

Table 2. Examples of Detrimental Interference Temperatures for the EESS

Frequency (GHz)	**Detrimental Interference Level ($dB(Wm^{-2}Hz^{-1})$)**	**Interference Temperature (K)**
1.400-1.427	-254	1×10^{-3}
10.6-10.7	-243	16×10^{-3}
24.0	-249	4×10^{-3}

EESS observations are made continually (24 hours per day, 7 days per week), and for a typical location in the United States, an EESS sensor passes over that site approximately 20 times per day.

In sum, the critical science undertaken by the RAS and EESS observers (and the development of new technologies resulting from passive observation) 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 applications from the knowledge gained and the technologies developed.

II. The Operation of Cognitive Radios Would Create a Substantial Risk of Harmful Interference to Authorized Passive Users of the Spectrum.

A core premise of the NPRM is that cognitive radios would promote efficient spectrum use because such radios would "search the radio spectrum, sense the environment, and operate in spectrum not used by others." *Id*. at para. 13. Cognitive radios would result in a "more intense, more efficient use of the spectrum" by transmitting in "unused" so-called "white spaces" of the spectrum. *Id.* at para. 20. Although CORF commends the Commission for seeking more efficient use of the spectrum, it is deeply concerned that the basic vision behind the cognitive radio concept ignores the existence of passive scientific users of the spectrum, and thus overlooks the substantial risk that cognitive radios would transmit on frequencies allocated to passive services. Such transmissions would increase the noise floor and cause harmful interference that would reduce or eliminate the utility of data obtained through scientific observation. This result would be inconsistent with the concept of efficient spectrum use, and contrary to the public interest.

A. Passive Scientific Observation Is a Protected Use of the Spectrum.

From the perspective of scientific users of the spectrum, the major flaw in the cognitive radio concept promoted in the NPRM is that it appears to designate as "unused" spectrum any frequency and location where there is no *active* transmission occurring at the moment. Such an approach improperly ignores the *passive* uses of the spectrum, which include those of receive-only radiocommunication services such as the RAS.[5] However, just because radio astronomers and remote sensing scientists do not make transmissions or control the frequency of the transmitting source, this does not mean that they are not

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[5] *See* Section 2.1 of the Commission's rules, defining the use of the spectrum in the RAS and the EESS.

using the spectrum. *Passive use of the spectrum is not non-use of the spectrum.* Moreover, when radio astronomers and remote sensing scientists make observations on frequencies *allocated to their services on a primary basis*, those observations are a *protected use* of the spectrum.

B. Protected Use of the Spectrum for Scientific Observation Cannot Be Detected by Dynamic Frequency Selection or Frequency Agility.

One of the capabilities of cognitive radios described in the NPRM is frequency agility, which is "the ability of a radio to change its operating frequency, combined with a method to dynamically select the appropriate operating frequency based on the sensing of signals from other transmitters or some other method." *Id.* at para. 22. Similarly, the NPRM describes a capability for dynamic frequency selection (DFS) as "a mechanism that dynamically detects signals from other radio frequency systems and avoids co-channel operation with those systems." *Id*. at para. 24. The NPRM suggests that DFS and frequency agility would be primary capabilities used by cognitive radios to avoid interference to incumbent authorized users of the spectrum. While CORF takes no position on the efficacy of such capabilities to sense the presence of active services, it is greatly concerned that *such capabilities, by definition, cannot sense the presence of passive observation of a frequency*. In the case of passive observation there is no identifiable "transmission" for cognitive radios to sense: the "transmission" being observed by scientists is nothing more than an extremely weak fluctuation in the noise floor.

In sum, CORF does not know of any practical sensing capability at this time that is capable of detecting the presence of passive observation. As a result, cognitive radios that rely on DFS or frequency agility capabilities to prevent interference cannot be expected to protect passive users of the spectrum from interference. Moreover, given their inability to protect passive use of the spectrum with these capabilities, cognitive radios transmitting on bands allocated to scientific use on a primary basis would be in violation of Part 15 principles, and contrary to the public interest.

C. Location-Determination-Enabled Devices Are Not a Solution.

In paragraph 28 of the NPRM, the Commission notes that cognitive radios could incorporate the capability to determine their location and the location of other transmitters, through use of geo-location techniques such as those based on GPS. Such radios could then access a database over a network, in order to select the appropriate transmission parameters, based on the location of the cognitive radio and other transmitters. While such capabilities do not have the flaws of DFS and frequency agility as applied to determination of passive observation, location determination coupled with database access does not appear to be a practical solution to the protection of passive users of the spectrum.

It is conceivable that for the protection of RAS observations, a determination could be made as to the minimum distance from radio astronomy observatories at which cognitive radio transmissions on certain frequencies should be prohibited in order to protect RAS observation. However, there are numerous problems with such an approach. First, as the Commission has acknowledged, there is the substantial possibility that location determination technologies in a cognitive radio could malfunction, or be manipulated by the user. NPRM at paras. 30 and 98. While users in the active services might be able to withstand interference from cognitive radios in such circumstances, passive users are much more vulnerable, due to the tremendous weakness of the signals they observe. Second, location determination would not solve interference problems created by cognitive radio transmission on EESS bands, since remote sensing observations are continuously made of the entire continental United States. Information from data for the entire United States is used in numerous remote sensing applications that are critical to maximizing environmental protection, as well as to the U.S. economy.

It is for all of the above reasons that CORF strongly supports the conclusion in paragraph 31 of the NPRM that the Commission should continue to *prohibit unlicensed devices (including cognitive radios) from emitting on the restricted bands* set forth in Section 15.205 of the Commission's rules. As discussed further below, this prohibition is the only practical and effective way to protect passive users of the spectrum from harmful interference.

D. *Protection of Passive Observation in Rural Areas is Critical.*

One of the major policy objectives stated in the NPRM is facilitation of increased use of spectrum in rural areas. *Id.* at para. 33. The NPRM goes on to state in paragraph 34 that “[b]ecause spectrum is generally not as intensively used in rural areas, it may be possible for unlicensed devices to operate at higher power levels in those areas without causing harmful interference to authorized services.” Such a suggestion may be appropriate as applied to use of active services, but is not correct when applied to passive uses.

As the Commission knows, most radio astronomy observatories are located in rural areas *because* of the lower level of active transmissions in such areas. Such geographic locations help to protect radio astronomy observatories from harmful interference, both from primary transmissions and from out-of-band and spurious emissions. Given the radio astronomy community’s attempt to be good spectrum citizens and place vulnerable observatories “out of harm’s way” in rural locations, it would be an ironic and unsuitable outcome if RAS observatories were to receive *less* protection from Part 15 devices.

Protection of spectrum in rural areas is just as critical for remote sensing scientists. As noted above, such scientists regularly observe the entire continental United States for numerous applications such as climate and flood forecasts, observation and prediction of El Niño effects on agricultural production, study of vegetation cover, and monitoring of changes in soil moisture and other water resources. Such observations are particularly focused on rural areas and are often made on a daily basis.

Thus, while CORF recognizes that there may be potential benefits to other users from promoting unlicensed operations in rural areas, the Commission must recognize that passive users need just as much, if not more, protection in rural areas as elsewhere. These are not areas of "limited" use for passive observers, and thus CORF is quite concerned about the possibility that the Commission might authorize cognitive radios to operate with significantly higher power levels in rural areas than in other areas. CORF's concern will be reduced if the Commission retains the Section 15.205 prohibition on transmissions in certain restricted bands, but it retains a concern about higher power transmissions at 24.0-24.25 GHz because this band segment is immediately adjacent to the EESS-primary band segment at 23.6-24.0 GHz.

A moderately dense[6] network of cognitive radios operating in the 24.0-24.25 GHz band segment operating under the conditions prescribed by Section 15.249 suggests the possibility of out-of-band emissions adversely affecting EESS measurements carried out globally in the adjacent 23.6-24.0 GHz band segment. CORF suggests retaining the lower power level for cognitive radios operating near the 24 GHz band segment, and further, suggests moving the 24.0-24.25 GHz band for operation of cognitive radios to 24.25-24.5 GHz or excluding cognitive radios from this segment altogether to reduce the possibility of harmful interference to EESS observations.

III. The Commission Must Retain Current Protections for Passive Services and Add Others If It Authorizes Use of Cognitive Radios.

As noted above, CORF commends the Commission for attempting to promote more efficient use of the spectrum. However, CORF emphasizes that

[6] The threshold for interference to EESS systems operating in the adjacent band segment may occur with a density as small as 2.6 units when cognitive radios are operated at the higher (based on 650 mV/m field strength at 3 meters) power level suggested for use in rural areas, and otherwise in accordance with Section 15.249. For the original suggested power level (based on 250 mV/m at 3 meters) the similar threshold density of operating radios is increased significantly to ~16 units.

protection of incumbent users must include protection passive observers in bands allocated on a primary basis to science. Protections for passive users are suggested below.

First, as noted above, CORF strongly supports the Commission's proposal to *retain and apply to cognitive radios the existing prohibition* in Section 15.205 against intentional transmissions in certain restricted bands. *See* NPRM at para. 31. Those bands include every band allocated on a primary basis to the RAS, and almost every band allocated on a primary basis to the EESS.[7] Exempting cognitive radios from this prohibition would significantly undercut the purpose of the rule, and indeed the nature of Part 15 protection for all licensed users. CORF recognizes that other incumbent services could make similar "not in my backyard" requests for protection of their bands. Nevertheless, CORF believes that retention of this *currently existing* protection for the RAS and the EESS is particularly warranted since these services are *passive* rather than *active* uses of the spectrum, and thus are more vulnerable to interference as a general matter than are active services. Moreover, in order to make observations, RAS and EESS receivers are substantially more sensitive than receivers in other services–tiny variations in the noise floor constitute the entire RAS or EESS signal. A substantial increase in the noise floor in the bands allocated for RAS and EESS would significantly reduce or eliminate the utility of observations in those bands.

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[7]The presence in Section 15.205(a) of numerous frequencies that are allocated *solely* to the RAS and/or the EESS demonstrates the specific purpose of Section 15.205 to protect receivers in the passive services.

Other existing Part 15 protections must be retained as well. Sections 15.109 and 15.209 set specific radiated emissions limits for intentional and unintentional radiated emissions at various frequency bands. The limitations on levels of out-of-band and spurious emissions in these rules should be applied to cognitive radios, at least for transmissions in the Section 15.205 restricted bands. CORF specifically opposes allowing operations higher in power than those currently authorized under these rules.[8] Similarly, the Commission must retain the requirements in Section 15.5 making all unlicensed devices subject to the condition that they not cause harmful interference and that they cease operation if they do cause such interference. CORF believes that removing or weakening these long-standing protections would significantly increase the likelihood of interference to RAS and EESS observations, and thus CORF strongly supports maintaining these protections and applying them to cognitive radio transmissions.

At paragraph 97 of the NPRM, the Commission proposes to allow certification of either cognitive radios or *all* Part 15 devices on frequencies not authorized for transmission by Part 15 devices in the United States. Regardless of the economic benefits that equipment manufacturers might gain from this flexibility, such a proposal is fraught with dangers for all licensed services, both passive and active. The Commission itself recognizes these dangers at paragraph 98 of the NPRM. CORF strongly urges the Commission not to allow certification of such equipment, or at least equipment that is capable of operating on bands prohibited in Section 15.205.

[8] *See* NPRM at para. 41.

Lastly, CORF notes that the Commission seeks comments on the use of geographic determination capabilities in cognitive radios. As noted above, CORF believes that such capabilities would not remedy interference on EESS bands, and believes further that use of such capabilities to carve out protected zones around radio astronomy observatories would present significant dangers. Accordingly, even if the Commission requires that all cognitive radios have geographic determination capability, it should retain the existing Section 15.205 prohibition on transmissions in certain restricted bands.

IV. Conclusion.

The Commission has long recognized the importance of protecting RAS and EESS observations from unwanted interference, not only generally, but also in the specific context of Part 15. CORF strongly urges the Commission to maintain the current Section 15.205 prohibition against intentional unlicensed transmissions and protection against out-of-band or spurious emissions in certain restricted bands. In addition, CORF recommends adoption of other measures described above to protect passive scientific observation of the spectrum and thus ensure ongoing RAS and EESS access to the critically important data being gathered by such observers.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

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Attachment

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