

**Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554**

In the Matter of)	
)	
Facilitating Opportunities for Flexible, Efficient, And Reliable Spectrum Use Employing Cognitive Radio Technologies)	ET Docket No. 03-108
)	
Authorization and Use of Software Defined Radios)	ET Docket No. 00-47 (Terminated)

**COMMENTS OF THE NATIONAL TELECOMMUNICATIONS
AND INFORMATION ADMINISTRATION**

Michael D. Gallagher
Assistant Secretary for
Communications and Information

Kathy D. Smith
Chief Counsel

Fredrick R. Wentland
Associate Administrator
Office of Spectrum Management

Edward Drocella
Mark Settle
Electronics Engineers

Office of Spectrum Management

National Telecommunications and
Information Administration
U.S. Department of Commerce
Room 4713
1401 Constitution Avenue, N.W.
Washington, DC 20230
(202) 482-1816

February 15, 2005

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
EXECUTIVE SUMMARY	v
I. INTRODUCTION	2
II. COGNITIVE RADIO CAPABILITIES CAN BE USED TO RESOLVE SPECTRUM SCARCITY, DEPLOYMENT, AND TECHNOLOGY TRANSITION PROBLEMS ENCOUNTERED BY GOVERNMENT AND NON-GOVERNMENT WIRELESS SYSTEMS.....	3
III. HIGHER-POWERED UNLICENSED DEVICES EMPLOYING COGNITIVE RADIO TECHNIQUES SHOULD BE PROHIBITED FROM OPERATING IN THE RESTRICTED FREQUENCY BANDS LISTED IN SECTION 15.205 OF THE COMMISSION’S RULES.....	6
IV. THE COMMISSION’S PROPOSAL FOR HIGHER-POWERED UNLICENSED DEVICE OPERATIONS IN THE 5725-5875 MHz BAND IS ADEQUATE TO PROTECT GOVERNMENT RADAR SYSTEMS IF A MINIMUM TRANSMIT BANDWIDTH IS ESTABLISHED.	9
V. THE REDUCTION OF UNWANTED EMISSIONS FOR HIGHER POWER UNLICENSED DEVICES SHOULD BE COMMENSURATE WITH THE INCREASED IN-CHANNEL POWER LEVEL.....	13
VI. GEO-LOCATION TECHNOLOGIES USED IN CONJUNCTION WITH AN ON-LINE DATABASE HOLDS PROMISE FOR SHARING BETWEEN UNLICENSED DEVICES AND RADIO SERVICES USING RECEIVERS AT FIXED LOCATIONS.....	15
VII. TECHNICAL, COST, AND LEGAL ISSUES, NOT THE COMMISSION’S RULES ARE LIMITING THE IMPLEMENTATION OF SOFTWARE DEFINED RADIO AS A POTENTIAL SOLUTION TO THE PUBLIC SAFETY INTEROPERABILITY PROBLEM.....	18
VIII. MESH NETWORKS OPERATING AT HIGHER FREQUENCIES WILL REDUCE INTERFERENCE TO OTHER RADIO SERVICES AND CAN FACILITATE	

	BROADBAND COMMUNICATIONS.....	22
IX.	GEO-ENCRYPTION TECHNIQUES CAN BE USED IN CONJUNCTION WITH EXISTING ENCRYPTION TECHNIQUES TO PROVIDE PROTECTION OF OVER-THE-AIR SOFTWARE DOWNLOADS.....	24
X.	THE INITIAL IMPLEMENTATION OF UNLICENSED COGNITIVE RADIO TECHNOLOGY SHOULD BE LIMITED TO THE INDUSTRIAL, SCIENTIFIC, AND MEDICAL FREQUENCY BANDS AND THE FREQUENCY BANDS TRANSFERRED FROM THE FEDERAL GOVERNMENT.....	26
XI.	SECONDARY SPECTRUM MARKET ACTIVITIES PROMISE TO INCREASE SPECTRUM EFFICENCY BY FOLLOWING CHANGING DEMAND.	29
XII.	HIGH-SPEED DIGITAL-TO-ANALOG CONVERTERS THAT ARE MARKETED AS PART OF RADIO SYSTEMS SHOULD BE REGULATED AS SOFTWARE DEFINED RADIOS OR COGNITIVE RADIOS UNDER THE APPROPRIATE SECTION OF THE COMMISSION’S RULES.....	31
XIII.	THE COMMISSION SHOULD CONSIDER REQUIRING PROTECTION PROFILES AS PART OF THE EQUIPMENT CERTIFICATION PROCESS FOR SOFTWARE DEFINED RADIOS.....	33
XIV.	THE REQUIREMENT FOR APPLICANTS TO PROVIDE A COPY OF THEIR SOFTWARE AS PART OF THE CERTIFICATION PROCESS FOR SOFTWARE DEFINED RADIOS SHOULD BE ELIMINATED.....	36
XV.	MANUFACTURERS SHOULD ONLY BE REQUIRED TO DECLARE THEIR DEVICES AS A SOFTWARE DEFINED RADIO IF THE DEVICE IS REMOTELY PROGRAMMABLE AND HAS HARDWARE CAPABLE OF TRANSMITTING IN THE RESTRICTED FREQUENCY BANDS OR IN FREQUENCY BANDS ALLOCATED TO THE FEDERAL GOVERNMENT ON AN EXCLUSIVE BASIS.	37
XVI.	TECHNICAL ISSUES RELATED TO THE COMPLIANCE MEASUREMENTS OF UNLICENSED DEVICES THAT EMPLOY COGNITIVE RADIO TECHNIQUES MUST BE ADDRESSED PRIOR TO IMPLEMENTATION.....	39
XVII.	A NEW SUBPART UNDER PART 15 OF THE COMMISSION’S RULES	

SHOULD BE ESTABLISHED FOR UNLICENSED DEVICES EMPLOYING COGNITIVE RADIO TECHNIQUES.....	43
XVIII. UNLICENSED DEVICES CAPABLE OF OPERATING ON NON-PART 15 FREQUENCIES MUST INCORPORATE FREQUENCY SENSING OR GEO- LOCATIOIN CAPABILITIES.....	44
XIX. CONCLUSION.....	46
ASSESSMENT OF POTENTIAL INTERFERENCE TO RADAR SYSTEMS IN THE 5725-5875 MHz BAND FROM HIGHER-POWERED UNLICENSED DEVICES EMPLOYING DYNAMIC FREQUENCY SELECTION.....	APPENDIX A
PART 15 UNWANTED EMISSION SEPARATION DISTANCE ANALYSIS.....	APPENDIX B
ISSUES RELATED TO GEO-LOCATION COGNITIVE RADIO TECHNIQUES.....	APPENDIX C
ISSUES RELATED TO DEVICES EMPLOYING MESH NETWORKING.....	APPENDIX D
GEO-LOCATION TECHNIQUES AS A METHOD TO PROTECT OVER-THE-AIR SOFTWARE DOWNLOADS.....	APPENDIX E

EXECUTIVE SUMMARY

The National Telecommunications and Information Administration (NTIA) commends the Federal Communications Commission (Commission) for initiating this proceeding to examine issues related to the development and deployment of cognitive radio (CR) technology. NTIA believes that CR technology has the potential to provide more innovative, flexible, and comprehensive use of the radio frequency spectrum, while at the same time minimizing the risk of interference to other spectrum users. CRs can be developed that have the technical capability to adapt their use of the spectrum in response to information external to the radio. As a result of this technical and operational flexibility, CR technologies may also make it possible to use spectrum that may be available in a particular geographic location or during a particular period of time and would otherwise go unused. At this time, there is not a clear boundary between CR and software defined radio (SDR) technologies. In many instances, SDR will be used as the basic platform on which to build CR technology. For this reason, the comments will in certain cases address SDR issues as well as CR, since certain aspects of the SDR regulatory framework could influence the transition from SDR to CR. NTIA offers the following comments in response to the specific issues raised by the Commission in the Notice of Proposed Rulemaking (NPRM).

There is little information given in the NPRM on what CR technologies and techniques are viable today, or in the near future, and what techniques or technologies may only be achievable with advances in technology. NTIA believes that given the relative maturity of the sensing and geo-location techniques proposed in the NPRM, employing them to facilitate sharing in the restricted frequency bands is not practical. Therefore, NTIA agrees with the Commission's tentative conclusion that unlicensed devices employing CR techniques should be

prohibited from operating in the restricted frequency bands listed in Section 15.205 of the Commission's Rules.

NTIA analysis indicates that when the transmit bandwidth of the unlicensed device is greater than 6 MHz, the power levels and detection threshold proposed by the Commission are adequate to protect government radar systems operating in the 5725-5875 MHz band. For transmit bandwidths less than 6 MHz, NTIA analysis indicates that the power levels of the unlicensed device would have to be reduced below the level proposed by the Commission to protect these government radar systems. Since there were many technical parameters that were not included in the Commission's proposal, NTIA considers this a preliminary assessment of the potential interference to government radar systems operating in the 5725-5875 MHz band. If service rules are eventually adopted for higher-powered unlicensed devices operating in the 5725-5875 MHz band that are significantly different than those considered in the assessment in Appendix A, NTIA would have to reassess the sharing situation.

When the level of unwanted emissions are independent of the in-channel power, NTIA recommends that the limits specified in Sections 15.247 and 15.249 of the Commission's Rules be applied for the higher-powered unlicensed devices as proposed by the Commission. For higher-powered unlicensed devices where the unwanted emissions are dependent on the in-channel power level, the unwanted emission limit should be reduced commensurate with the increase in the in-channel power level.

NTIA believes that geo-location technology used in conjunction with an on-line database of sites that require protection holds promise for facilitating sharing between unlicensed devices and radio services using receivers at fixed locations. However, there are many issues related to the accuracy and integrity of the on-line database as well as the integrity of the data downloaded

to the unlicensed device that must be addressed.

The lack of interoperability is the most significant problem contained in after action reports from major public safety incidents. Arguably, SDR and eventually CR promise to be the best long-term interoperability solution. The Commission's Rules are not limiting the use of SDR to facilitate the interoperability between public safety systems. However, there still remain technical, legal, and cost issues that need to be resolved before the full benefits of SDR can be realized as a solution for public safety interoperability.

Mesh networks allow nodes or access points to communicate with other nodes without being routed through a central switch point, eliminating centralized failure, and providing self-healing and self-organization. NTIA believes that the short range characteristics of mesh networks lend themselves to using higher frequencies. NTIA also believes that mesh networks have the capability to increase capacity as the number of nodes increases, enabling them to deliver broadband data rates to support high-speed data, video and voice applications.

Geo-encryption is an approach to location-based encryption that builds on established cryptographic algorithms and protocols. Geo-encryption techniques can support both fixed and mobile applications and a variety of data-sharing and distribution policies. NTIA believes that geo-encryption techniques can be used in conjunction with existing encryption techniques to provide protection of over-the-air software downloads and should be considered in future rulemakings on CR and SDR technologies.

If the Commission contemplates expanding the implementation of higher-powered unlicensed device operations employing CR techniques, NTIA recommends that the frequency bands transferred from federal government to private sector use be considered, because, at this time, these bands have limited government or commercial use or have not been transferred for

private sector use.

NTIA supports the actions taken by the Commission to remove regulatory barriers to the development of secondary markets. These flexible policies will continue the evolution toward greater reliance on the marketplace to expand the scope of available wireless services. Because CRs can play an enabling role in the establishment of secondary markets, the development of CR technology should also have similar, minimum regulatory constraints.

There is no reason to regulate component parts such as digital-to-analog converter (DAC) integrated circuits and the Commission should avoid any regulation that would likely stifle their use. A DAC add-in card alone does not possess the capability to act as a transmitter, and thus should not be subject to regulation as a radio transmitter under the Commission's Rules. If a DAC is coupled with an amplifier and antenna, it should be considered a SDR or CR and regulated under the applicable section of the Commission's Rules. NTIA also recommends that as potential consumer applications of DAC based radio frequency signal sources become better understood, the Commission consider revisiting its regulation.

NTIA is concerned about the regulatory implications associated with downloaded software that can reconfigure the radio functionality, which includes frequency, power, and modulation. NTIA understands the Commission's reluctance to adopt specific security requirements because this may constrain the development SDR technology. However, NTIA believes that the acceptance of SDR and eventually CR technologies hinges on assurances that the operating parameters that can impact electromagnetic compatibility with other systems are protected from malicious attacks. NTIA recommends that as a long-term goal of addressing security concerns for devices that employ SDR and CR technologies, the Commission should consider requiring Protection Profiles as part of the equipment certification.

NTIA agrees with the Commission that examination of software is not an effective means of identifying where unauthorized software changes have been made in an SDR. NTIA believes that the Commission's requirement that certified devices must comply with their applicable technical rules is sufficient to safeguard against unauthorized equipment modifications. Thus, NTIA agrees with the Commission's proposal to eliminate the existing requirement for applicants to provide copies of their software as part of the certification process for SDRs.

NTIA believes that it would be appropriate for the Commission to require manufacturers to declare their devices as SDRs if the device is remotely programmable and has hardware that is capable of transmitting in the restricted frequency bands or in frequency bands allocated to the federal government on an exclusive basis. This would eliminate the problems associated with incorrectly classifying commercial devices such as land mobile radio and personal communication service as SDRs.

CR devices that are capable of changing their electromagnetic characteristics on a near real-time basis will make the compliance measurements more complex. NTIA believes that technological approaches that cannot be verified in the Telecommunication Certification Bodies' laboratories should not be relied upon for successful spectrum sharing. NTIA recommends that the Commission resolve all of the technical issues related to performing the compliance measurements prior to implementing CR techniques in any frequency band. NTIA further recommends that the compliance measurement procedures for devices employing CR technologies be developed in an open forum, and government and non-government parties should participate.

NTIA recommends that a new subpart within Part 15 of the Commission's Rules be established for unlicensed devices that employ CR techniques. This is similar to the approach

used for unlicensed UWB devices, which also did not fit into the existing Part 15 Rules. NTIA also recommends that the Commission adopt a definition for CR in order to provide regulatory certainty to manufacturers seeking industry investment in devices based on these new technologies.

If the Commission adopts its proposal to certify unlicensed devices that are capable of using non-Part 15 frequencies then it should limit this to devices where the central controllers can control the transmit frequencies of the client devices. As part of the device certification process it is imperative that it be ensured that the central controllers can only operate in the bands authorized for Part 15 operations. For unlicensed devices that operate without a central controller, the device should be required to incorporate geo-location capabilities, such as the Global Positioning System, in conjunction with a database, to determine its geographic location. The location information would then be used to control the authorized frequencies that the unlicensed device can use. Furthermore, if the unlicensed device is not capable of determining its geographic location, the device must be restricted from transmitting.

NTIA agrees with the Commission regarding the significant benefits that could be gained by employing CR technologies. The NPRM identifies several areas where technical and regulatory issues must be addressed. NTIA supports the Commission's initial implementation approach, limiting CR technologies to a few frequency bands primarily used by unlicensed devices. NTIA believes that the experience gained in these frequency bands will help facilitate a much broader implementation of CR technologies while ensuring that government and non-government spectrum users are adequately protected from interference. NTIA will continue to work with the Commission and industry to resolve the technical and regulatory issues surrounding the successful implementation of CR technologies.

**Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554**

In the Matter of)	
)	
Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies)	ET Docket No. 03-108
)	
Authorization and Use of Software Defined Radios)	ET Docket No. 00-47 (Terminated)

**COMMENTS OF THE NATIONAL TELECOMMUNICATIONS
AND INFORMATION ADMINISTRATION**

The National Telecommunications and Information Administration (NTIA), an Executive Branch agency within the Department of Commerce, is the President’s principal adviser on domestic and international telecommunications policy, including policies relating to the Nation’s economic and technological advancement in telecommunications. Accordingly, NTIA makes recommendations regarding telecommunications policies and presents Executive Branch views on telecommunications matters to the Congress, the Federal Communications Commission (Commission), and the public. NTIA, through the Office of Spectrum Management (OSM), is also responsible for managing the federal government’s use of the radio frequency spectrum. NTIA respectfully submits the following comments in response to the Commission’s Notice of Proposed Rulemaking (NPRM) in the above-captioned proceeding.¹

1. *Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies*, Notice of Proposed Rulemaking, ET Docket No. 03-108, 18 F.C.C. Rcd. 26859 (2003) (“Cognitive Radio NPRM”).

I. INTRODUCTION

In the NPRM, the Commission seeks comments on ways to encourage and remove regulatory impediments to the continued development and deployment of cognitive radio (CR) technologies. For example, facilitating the ability of licensed spectrum users to deploy CR for their own use to increase spectrum efficiency, and to facilitate secondary markets, allowing licensees to lease their spectrum access to third parties using such technologies. The Commission seeks comment on ways in which CR can facilitate opportunistic use of the spectrum by unlicensed devices, while protecting incumbent licensed spectrum users from interference; rules permitting additional flexibility, including allowing unlicensed devices, in limited frequency bands to use higher transmit power in rural and underserved areas; a specific technical approach that would provide licensees, such as public safety entities, with the ability to retain real-time access to spectrum they lease to third parties; how CR can enhance the ability of different public safety entities using different frequencies and formats to communicate with one another in the event of an emergency; and specific applications of CR, such as mesh networks and real-time frequency coordination between non-geostationary orbit satellite systems and other services. The Commission also proposes changes to its equipment authorization processes to better accommodate software defined radio (SDR) and CR systems.

At this time, there is not a clear boundary between CR and SDR technologies. In many instances, SDR will be used as the basic platform on which to build CR technology. For this reason, NTIA's comments will in certain cases address SDR issues as well as CR, since certain aspects of the SDR regulatory framework could influence the transition from SDR to CR. For example, SDR could support interoperability by providing the capability where the user selects the required radio configuration based on knowledge of the users and communication content for

a given region. This SDR could evolve into a CR that senses the radio frequency (RF) environment and automatically selects the desired radio configuration or might even have the capability to recognize that another band is not being used in the area of interest and thus could direct certain users in a congested band to this alternative frequency band.

NTIA commends the Commission for initiating this proceeding to examine issues related to the development and deployment of CR technology. NTIA believes that CR technology has the potential to provide more innovative, flexible, and comprehensive use of the RF spectrum, while at the same time minimizing the risk of interference to other spectrum users. However, there are technical and regulatory issues related to implementing CR as well as concerns regarding potential interference to federal spectrum users that must first be addressed. NTIA offers the following comments in response to the specific issues raised by the Commission in the NPRM.

II. COGNITIVE RADIO CAPABILITIES CAN BE USED TO RESOLVE SPECTRUM SCARCITY, DEPLOYMENT, AND TECHNOLOGY TRANSITION PROBLEMS ENCOUNTERED BY GOVERNMENT AND NON-GOVERNMENT WIRELESS SYSTEMS.

There are a number of capabilities, such as frequency agility, adaptive modulation, transmitter power control (TPC), location of itself and other transmitters, and mechanisms to enable sharing on an ad-hoc or real-time basis, that can be incorporated in CRs. The Commission seeks comment on what other features and capabilities a CR could incorporate.²

There are several problems confronting both government and non-government wireless communications users with respect to spectrum use: scarcity of spectrum, deployment difficulties, and transitioning to different technologies. The federal government agencies are

2. Cognitive Radio NPRM at ¶ 22.

placing an increasing emphasis on SDR and using SDR as the basic platform on which to build CR technology to resolve these problems. For example, through research projects such as the Defense Advanced Research Projects Agency (DARPA) neXt Generation (XG) program, the Department of Defense (DOD) is investigating how advanced sensing, modulation, and multiple access technologies can be used with a machine-intelligible spectrum policy framework to enable cognitive spectrum sharing that could improve spectrum usage efficiency by a factor of ten or more.³ As the Commission points out, SDRs are likely to be the best platforms for implementing CR, and the tactical military SDRs being developed under the Joint Tactical Radio System (JTRS) may well be the beneficiaries of the XG technology. The application of XG technology to JTRS has the potential to address the spectrum scarcity and deployment issues that could limit the military's broadband wireless end-to-end connectivity. Like DARPA's early work on the Internet, XG-based technology will become applicable to both military and civilian applications. The National Science Foundation (NSF) is also exploring the technology developments needed for enhancing spectral efficiencies of wireless networks in support of expanding opportunities for new services in the wireless industry. NSF's Networking Technology Systems (NeTS) program is addressing the challenges associated with these networks.⁴

Over the years, the development of better electronic equipment has allowed the channel spacing employed by many radio services to be decreased. For example, many radio services have changed channel spacing from 100 kHz to 50 kHz, then to 25 kHz, and now radio services

3. XG Working Group, *The XG Vision*, Request for Comments, Version 2.0, BBN Technologies, Cambridge Massachusetts. This document and other information about the DARPA XG program are available at http://www.darpa.mil/ato/programs/xg/rfc_vision.pdf

4. National Science Foundation, Directorate for Computer and Information Science Engineering, Division of Computer and Network Systems, Research in Networking Technology and Systems (NeTS). More information on the NeTS program is available at <http://www.cise.nsf.gov>.

are instituting even narrower channels (e.g., 12.5 kHz and 6.25 kHz in some land mobile frequency bands). Because of the need for backward compatibility, however, most of the radio services cannot take full, immediate advantage of the increased spectrum use of narrower channels. For example, legacy equipment does not have the capability to tune to the interstitial channels. Moreover, transition of these services from analog to digital modulation techniques, which can support a more flexible and efficient use of the spectrum, has been difficult because of the backward compatibility requirement. CRs could facilitate this transition in channelization and modulation schemes. By being able to switch modulation/detection schemes, to switch frequencies and bandwidths of operation, and possibly, to sense the characteristics of received signals and to institute actions based on these characteristics, CR could operate in this transitional environment. Since the particular service in question is largely under the control of a single user group or entity, the transition can be planned and implemented in an orderly fashion, possibly segmenting the band for different operations to provide support for newer equipment (new channelization and modulation) as well as legacy systems (old channelization and modulation). This band segmentation would gradually be phased-out, however, during and after the transition, the CR would be capable of operating across the band. Because of the planned transition of the band, the CR requirements would be fairly well defined. For example, the Federal Aviation Administration's Next-Generation Air/Ground Radio Communications System (NEXCOM) will be employing some of these techniques to meet the growing need for voice services while also providing a robust data link.⁵

The federal government is developing CR technologies that are able to sense, characterize, identify, distribute, and allocate spectrum use opportunities. These CR capabilities

5. Federal Aviation Administration, *Radio Spectrum Plan*, at Section 1.7 (January 26, 2004).

may eventually be used to resolve the spectrum scarcity and deployment problems encountered by government and non-government wireless systems. CR capabilities can also be used to resolve problems encountered when transitioning from one technology or another within a frequency band or radio service.

III. HIGHER-POWERED UNLICENSED DEVICES EMPLOYING COGNITIVE RADIO TECHNIQUES SHOULD BE PROHIBITED FROM OPERATING IN THE RESTRICTED FREQUENCY BANDS LISTED IN SECTION 15.205 OF THE COMMISSION'S RULES.

The Commission concluded that it should continue to prohibit unlicensed devices from emitting in the designated restricted frequency bands, which includes many bands used by the federal government. The Commission seeks comment on this tentative conclusion.⁶

The restricted frequency bands in Section 15.205 of the Commission's Rules are used to support safety-of-life functions, such as aeronautical radionavigation, military satellite communications, and scientific observations. The federal systems that operate in the restricted frequency bands may be passive, such as radio astronomy, or active, such as satellite downlinks. The NPRM focuses on two types of CR techniques: sensing techniques and geo-location techniques. However, NTIA believes that there are potential problems with effectively implementing either of these CR techniques in the restricted frequency bands.

For CR sensing techniques to be effective in facilitating sharing with other radio services, it must be able to detect a signal that is above a specified threshold. The presence of a signal above the detection threshold indicates that the channel is being used and the CR-enabled device should not transmit. If the signal is below the threshold or the sensitivity of the sensor receiver is not adequate to detect the signal, the CR-enabled device will transmit and potentially cause

6. Cognitive Radio NPRM at ¶ 31.

interference to other receivers operating in the band. It is difficult to envision how CR sensing techniques can be implemented in many of the restricted frequency bands since the detection thresholds would have to be much lower than can be supported by current technology. For example, due to the extremely low power of the cosmic signals studied by the radio astronomy and passive services, these operations are very susceptible to interference. The permissible interference levels in several radio astronomy frequency bands are shown in Table 1.⁷

Table 1.

Frequency Range (MHz)	Permissible Interference Level (dBW)
608-614	-202
1400-1427	-205
4990-5000	-207

These permissible interference levels would be used as the basis for establishing the detection thresholds for CR sensing techniques, and are believed to be outside the range of any practical sensing techniques currently available. Therefore, NTIA does not believe that CR sensing techniques can be implemented in the restricted frequency bands used by the radio astronomy and passive services.

Implementing CR sensing techniques in the restricted frequency bands used to support receive-only operations would face problems similar to those identified for the passive services. This would apply to frequency bands used by military satellite downlink communications or the radionavigation satellite service (RNSS), which are capable of receiving very weak desired signals. For example, the Global Positioning System (GPS), which operates in the frequency bands allocated for RNSS, employs direct sequence spread spectrum (DSSS) and receivers are

7. Recommendation ITU-R RA.769-1, *Protection Criteria Used for Radioastronomical Measurements* (1992-1995).

capable of processing desired signal levels below the noise floor. For an unlicensed device employing CR sensing techniques to protect RNSS receivers the detection threshold would have to be below the thermal noise floor, which NTIA does not believe is feasible using existing technology.⁸

CR sensing techniques would also be difficult to effectively implement in any of the restricted frequency bands where the receivers are mobile and transmissions are non-continuous. This situation occurs in the restricted frequency bands used by the aeronautical radionavigation service (ARNS). In the ARNS, ground-based stations are transmitting and receiving information from aircraft that can be located anywhere. The desired signals at the airborne receiver can vary significantly, making sensing techniques that protect these critical safety-of-life functions difficult to implement. Further complicating the problem is that the transmissions from the ground stations are non-continuous, and it would be very difficult, if not impossible, for CR sensing techniques to predict with any degree of certainty when the primary user activity be initiated or resume on the channel.

When the locations of the licensed systems are known and fixed, CR geo-location techniques hold promise for facilitating sharing with unlicensed devices. However, many designated restricted frequency bands are used for military satellite communications and the locations of these receivers cannot be identified. There are also many restricted frequency bands that are used by mobile receivers, such as those in the ARNS and RNSS. NTIA believes that CR geo-location techniques would not be effective in protecting the critical safety-of-life operations

8. In the NPRM, the Commission describes cyclostationary detectors or feature detectors, which use longer sensing times and internal computation to achieve signal sensitivities below the noise level for signals of known format. Cognitive Radio NPRM at ¶ 25. However, the practical capabilities and limitations of these detectors need to be studied and demonstrated to determine whether or not they can contribute significantly to the implementation of CR sensing techniques.

in these frequency bands. The Commission needs to resolve questions regarding accessing an on-line database on a near real-time basis, the integrity of the data downloading process, and how the database is maintained.

The NPRM provides little information on what technologies and techniques are viable today, or in the near future, and what techniques or technologies may only be achievable with potential advances in technology in the future. NTIA believes that given the relative maturity of the sensing and geo-location techniques proposed in the NPRM, employing them to facilitate sharing in the restricted frequency bands is not practical. Therefore, NTIA agrees with the Commission's tentative conclusion that unlicensed devices employing CR techniques should be prohibited from operating in the restricted frequency bands listed in Section 15.205 of the Commission's Rules.

IV. THE COMMISSION'S PROPOSAL FOR HIGHER-POWERED UNLICENSED DEVICE OPERATIONS IN THE 5725-5875 MHz BAND IS ADEQUATE TO PROTECT GOVERNMENT RADAR SYSTEMS IF A MINIMUM TRANSMIT BANDWIDTH IS ESTABLISHED.

The Commission proposes to allow a transmitter power increase of up to six times the current limits in the frequency bands specified in Sections 15.247 and 15.249 of its Rules.⁹ The Commission proposes to restrict the higher power operation to areas with limited spectrum use and to require the unlicensed devices to sense spectrum use before commencing transmission.¹⁰ The Commission seeks comment on the potential effects of this proposal, including its CR safeguards of federal radio operations in the 5725-5925 MHz band.¹¹

9. Cognitive Radio NPRM at ¶ 38.

10. *Id.* at ¶ 39.

11. *Id.* at ¶ 43.

Federal government users in the 5725-5875 MHz band include fixed, transportable, and mobile radar systems operated by the DOD. These radars are used extensively in support of national and military test range operations in the tracking and control of manned and unmanned airborne vehicles.¹² As pointed out in the NPRM, many of the installations where these radar systems operate are located in rural areas to avoid interference with other systems.¹³ Federal agencies are increasingly concerned regarding potential interference to these radar systems as their role expands in support of homeland defense. This expanded role could result in a requirement to deploy radar systems in areas close to cities and highways, potentially increasing interference to the radar systems from unlicensed devices operating at higher power levels.

Under the Commission's proposal, the higher-powered unlicensed device operations would be limited to rural areas or areas where it is determined that spectrum use is limited.¹⁴ The Commission proposed that the unlicensed devices operating in these rural or unused areas employ sensing techniques with a detection threshold of 30 dB above the thermal noise floor within a measurement bandwidth of 1.25 MHz.¹⁵ The potential interference between military radar systems operating in the 5250-5350 MHz and 5470-5725 MHz bands and Unlicensed National Information Infrastructure (U-NII) devices employing a sensing technique referred to as dynamic frequency selection (DFS)¹⁶ was addressed as part of another rulemaking proceeding.¹⁷

12. The frequency bands from 5250-5925 MHz are allocated on a primary basis to Government radiolocation.

13. Cognitive Radio NPRM at ¶ 43.

14. *Id.* at ¶ 44.

15. *Id.*

16. DFS is a mechanism that dynamically detects signals from other systems and avoids co-channel operation with these systems.

17. *Revision of Parts 2 and 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band*, Report and Order, ET Docket No. 03-122, 18 F.C.C. Rcd. 24484 (2003) ("U-

The analysis performed to develop the detection thresholds for DFS equipped U-NII devices considered specific unlicensed device densities and power levels that are different than those proposed by the Commission in the NPRM. Therefore, NTIA must perform an analysis to assess whether the power levels in conjunction with the detection threshold proposed by the Commission are adequate to protect government radar systems operating in the 5725-5875 MHz band.

In the NPRM, the Commission proposed a transmitter power level of 38 dBm in the 5725-5850 MHz band and 6 dBm in the 5725-5875 MHz band to be used in conjunction with the DFS sensing technique.¹⁸ As discussed earlier, the Commission also proposed a detection threshold of -83 dBm measured in a 1.25 MHz bandwidth.¹⁹ However, the proposal in the NPRM did not identify the unlicensed device application which could have an impact on the device density and antenna heights, the transmit bandwidth of the unlicensed device application (e.g., narrowband or wideband), or the type of antenna (e.g., omnidirectional or directional). All of these parameters can have an impact on the electromagnetic compatibility of the proposed unlicensed devices and the government radar systems.

To assess the potential interference to government radar systems from the unlicensed devices using the higher power levels and the detection threshold proposed by the Commission, NTIA performed an analysis. The analysis provided in Appendix A describes the operational

NII R&O”).

18. Cognitive Radio NPRM at ¶ 38. A power level of 6 watts is proposed in the 5725-5850 MHz band and 125 millivolts per meter at a distance of 3 meters in the 5725-5875 MHz band.

19. *Id.* at ¶ 44. The detection threshold is specified as 30 dB above the calculated thermal noise floor within a measurement bandwidth of 1.25 MHz. The thermal noise floor of a 1.25 MHz bandwidth receiver is -113 dBm. The detection threshold proposed by the Commission is 30 dB above -113 dBm or -83 dBm.

scenario for the unlicensed devices and the military radar systems; technical characteristics of the radar systems and unlicensed devices; and the engineering algorithms used to assess the potential for interference to the radar systems from the higher-powered DFS-equipped unlicensed devices. The parametric analysis performed to assess the potential interference to government radar systems considered different combinations of the number of unlicensed devices, unlicensed device antenna heights, and unlicensed device transmit bandwidths. Monte Carlo techniques were employed for the unlicensed device locations, propagation losses, antenna heights, and other non-terrain specific losses.²⁰

The analysis indicates that when the transmit bandwidth of the unlicensed device is greater than 6 MHz, the power levels and detection threshold proposed by the Commission are adequate to protect government radar systems operating in the 5725-5875 MHz band. For transmit bandwidths less than 6 MHz, the power levels of the unlicensed device would have to be reduced below the level proposed by the Commission to protect these government radar systems. Since there were many technical parameters that were not included in the Commission's proposal, NTIA's analysis is a preliminary assessment of the potential interference to government radar systems operating in the 5725-5875 MHz band. To support 5725-5875 MHz band service rules for unlicensed devices significantly different than those considered in the assessment in Appendix A, NTIA would have to re-evaluate the sharing situation.

In addition to the detection threshold, the following parameters associated with the CR sensing technique must be defined: channel availability check time, channel move time, non-

20. The Monte Carlo method has been used for the simulation of random processes and is based upon the principle of taking samples of random variables from their assumed probability density functions.

occupancy period, detector function (peak or average), and measurement interval.²¹ Since the radar systems operating in the 5725-5875 MHz band are the same as those operating in the 5250-5350 MHz and 5470-5725 MHz U-NII frequency bands, then the values of the radar parameters associated with the detection threshold would be the same.²² The Commission specifies a measurement bandwidth of 1.25 MHz, which is consistent with the channel width of code division multiple access PCS systems. To be consistent with the measurements for the radars operating in other portions of the 5 GHz band where DFS is being implemented, NTIA recommends that a measurement bandwidth for the detection level of 1 MHz be used instead of 1.25 MHz.

V. THE REDUCTION OF UNWANTED EMISSIONS FOR HIGHER POWER UNLICENSED DEVICES SHOULD BE COMMENSURATE WITH THE INCREASED IN-CHANNEL POWER LEVEL.

The Commission proposes that unlicensed devices operating at the higher power levels comply with the same harmonic and out-of-band emission limits as devices operating under Sections 15.247 and 15.249 of its Rules.²³ The Commission seeks comment on whether the out-of-band emission limits for equipment operating at the higher power levels should be adjusted so that they are no greater than those permitted under the current rules.²⁴

The emissions generated by a device can be divided into three categories: necessary emissions generated within the channel of the device (in-channel); out-of-band emissions generated as a result of the modulation process; and spurious emissions such as harmonically

21. For DFS-equipped U-NII devices, these parameters are defined in Section 15.403 of the Commission's Rules.

22. The values for the DFS detection threshold and the additional parameters are provided in Section 15.407(h)(2) of the Commission's Rules.

23. Cognitive Radio NPRM at ¶ 42.

24. *Id.*

generated emissions. The combination of out-of-band and spurious emissions are referred to as unwanted emissions.

The current harmonic emission limits for unlicensed devices operating under Section 15.249 are independent of the in-channel power, while the out-of-band emission limits are a function of the in-channel power. For devices operating under Section 15.247 of the Commission's Rules, the limits on out-of-band emissions that fall within the designated restricted frequency bands are independent of the in-channel power levels. However, under Section 15.247, the limit on out-of-band emissions that fall outside of the restricted frequency bands are a function of the in-channel power level.

As shown in Appendix B, the unwanted emission limits specified in Part 15 of the Commission's Rules are inadequate to protect other authorized radio services unless either a large distance separation or additional attenuation resulting from buildings or terrain are included in the analysis. However, given the large number of Part 15 devices in use today, NTIA is unaware of any reports where a compliant unlicensed device has interfered with another authorized spectrum user. NTIA believes that in part this can be attributed to Part 15 devices generating unwanted emission levels that are well below those specified in the Commission's Rules.²⁵ NTIA has limited data to support this presumption, and thus, cannot comment on whether the actual unwanted emission levels specified in Sections 15.247 and 15.249 of the Commission's Rules adequately protect other radio services.

The harmonic and out-of-band emission limits specified in Sections 15.247 and 15.249 fall into two categories: limits that are dependent on the in-channel power levels, and limits that

25. The power levels of the spurious emissions in many cases are statistical in nature, where the peak levels can vary with time and frequency. Harmonic emissions are more difficult to eliminate, but at non-harmonically related frequencies the levels are also believed to be well below the limits specified in the Commission's Rules.

are independent of the in-channel power levels. For harmonic and unwanted emissions that are independent of the in-channel power (e.g., a fixed field strength level), NTIA recommends that the limits specified in Sections 15.247 and 15.249 be applied for the higher-powered unlicensed devices as proposed by the Commission. For higher-powered unlicensed devices where the unwanted emissions are dependent on the in-channel power level, the unwanted emission limit should be reduced commensurate with the increase in the in-channel power level. In the Commission's proposal, this would result in a reduction of 8 dB in the unwanted emission levels for the higher-powered devices.

VI. GEO-LOCATION TECHNOLOGIES USED IN CONJUNCTION WITH AN ON-LINE DATABASE HOLDS PROMISE FOR SHARING BETWEEN UNLICENSED DEVICES AND RADIO SERVICES USING RECEIVERS AT FIXED LOCATIONS.

The Commission seeks comment on the positional accuracy necessary if geo-location technology such as the Global Positioning System (GPS) were used. Related to CR geo-location techniques, the Commission also requests comment on how a device using geo-location would access a table or database showing where operation is permitted; who would be responsible for maintaining the database; should the geo-location technology be required to be incorporated within the device; and how would the device react if it were unable to determine its position within a specified accuracy limit.²⁶

The positional accuracy of different GPS receiver architectures is discussed in Appendix C. The Commission adopted accuracy and reliability requirements for Automatic Location Identification as part of its Rules for wireless carrier enhanced 911 (E911) service.²⁷ The

26. Cognitive Radio NPRM at ¶ 47.

27. *Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems*, Third Report and Order, CC Docket No. 94-102, 14 F.C.C. Rcd. 17388 (1999).

accuracy and reliability requirements for E911 Phase II operations for handset-based solutions are 50 meters for 67 percent of calls, 150 meters for 95 percent of the calls. NTIA recommends that the Commission adopt positional accuracy requirements for CR devices employing geo-location capabilities that are at least as stringent as the E911 requirements. Many manufacturers are developing GPS chipsets to meet the Commission's December 31, 2005 Phase II deadline, so the technology should be available at a reasonable cost. The Commission's Office of Engineering and Technology has also developed guidelines for testing and verifying these positional accuracy requirements.²⁸

In comments filed in response to another rulemaking proceeding, the Institute of Electrical and Electronics Engineers (IEEE) 820.18 Radio Regulatory Technical Advisory Group stated that embedding GPS technology in unlicensed devices is technically feasible and could be used to limit the device so it does not transmit when located in or near an area where interference to a fixed receiver is likely.²⁹ NTIA agrees with the IEEE that unlicensed devices that employ GPS technology in conjunction with an on-line database of the fixed site locations can be used to prohibit that device from operating in those areas.³⁰ Issues related to the implementation of geo-location techniques and the on-line database are discussed in Appendix C.

NTIA also agrees with the IEEE that it is feasible to incorporate GPS chipsets within unlicensed devices. As discussed earlier, GPS chipsets are being incorporated in handsets to meet the Commission's E911 mandate. Incorporating the geo-location hardware in the

28. Federal Communications Commission, OET Bulletin No. 71, *Guidelines for Testing and Verifying the Accuracy of Wireless E911 Location Systems* (April 12, 2000).

29. Institute of Electrical and Electronics Engineers Comments, ET Docket No. 02-380, at 10 (April 17, 2003).

30. The exclusion areas where unlicensed device operation is prohibited would be determined based on the characteristics and operational scenarios for the licensed service and the unlicensed devices.

unlicensed device is the only practical way from an interference protection standpoint to effectively implement geo-location technology. NTIA recommends that if the Commission permits geo-location technology to facilitate sharing with other fixed receivers, the position location technology should be incorporated within the unlicensed device.

GPS signal failures can occur in urban canyons, indoors, or in shaded areas where the received signals are too noisy, too attenuated or distorted by multipath to be received and used reliably in ranging. Under such conditions, demodulating the navigation data included in the satellite broadcast becomes practically impossible.³¹ Appendix C describes a technology that can be deployed to compensate for losses in the satellite signal. The time between when this momentary loss of satellite signals occurs and when the receiver can no longer provide position information depends on the GPS receiver architecture, application, and manufacturer implementation. Since unlicensed devices that employ geo-location techniques require a position location to control device transmissions, it is important to determine how much time should be permitted after the position location is lost and when the device must cease all transmissions. Appendix C shows that using 60 seconds after position information is no longer available as the upper limit for unlicensed devices employing geo-location techniques to cease transmissions seems reasonable. However, larger separation distances between unlicensed devices and the fixed receivers could accommodate longer periods of time when the geo-location capability is not available.

NTIA believes that geo-location technology used in conjunction with an on-line database of sites that require protection holds promise for facilitating sharing between unlicensed devices and radio services using receivers at fixed locations. NTIA believes that GPS-based technology

31. A minimum of three to four satellites are necessary for a GPS receiver to determine a position location.

incorporated within the unlicensed device is capable of providing position locations with the necessary accuracy. However, many issues related to the accuracy and integrity of the on-line database as well as the integrity of the data downloaded to the unlicensed device must be addressed. If the geo-location device is unable to obtain a location, or the database is not successfully downloaded, the unlicensed device should not be permitted to transmit. In a separate rulemaking, the Commission is proposing to implement geo-location techniques to permit sharing between unlicensed devices and fixed-satellite earth station and radar receivers operating in the 3650-3700 MHz band. NTIA believes that the experience gained with implementing geo-location technology in the 3650-3700 MHz band can be used to address the issues related to the unlicensed device interface with the on-line database.

VII. TECHNICAL, COST, AND LEGAL ISSUES, NOT THE COMMISSION’S RULES ARE LIMITING THE IMPLEMENTATION OF SOFTWARE DEFINED RADIO AS A POTENTIAL SOLUTION TO THE PUBLIC SAFETY INTEROPERABILITY PROBLEM.

The Commission seeks comment on how CR technologies can facilitate interoperability between systems. Specifically, the Commission seeks comment on any rule changes necessary to take advantage of these benefits for interoperability between systems.³²

The Public Safety Wireless Advisory Committee (PSWAC) Final Report defines interoperability as the ability of two or more public safety communications systems to interact with one another and exchange information according to a prescribed manner in order to achieve predictable results.³³ Interoperability between users is divided into three categories with each

32. Cognitive Radio NPRM at ¶ 76.

33. Public Safety Wireless Advisory Committee, *Final Report of the Public Safety Wireless Advisory Committee to the Federal Communications Commission*, Reed E. Hundt, Chairman, Federal Communications Commission and Larry Irving, Assistant Secretary of Commerce for Communications and Information, at 547 (September 1996) (“PSWAC Final Report”).

having specific characteristics: day-to-day interoperability, mutual aid interoperability, and task force interoperability. The SAFECOM Program, managed by the Department of Homeland Security, issued a statement of requirements for public safety wireless communications and interoperability that delineates many public safety wireless operational scenarios.³⁴

There are more than 18,000 law enforcement agencies and over 35,000 fire and emergency medical service agencies across the United States.³⁵ Due to the fragmented nature of this community, most public safety communications systems are individual systems that do not easily communicate with one another or facilitate interoperability. Federal, state, and local public safety communication systems operate in ten discrete bands ranging from 30 MHz to 869 MHz and employ a number of different air-interface protocols.³⁶ As a result of the fragmentation of frequency bands and air-interface standards, multiple agencies converging on a single incident often cannot communicate with each other using their radio systems. SDR and eventually CR promises to be the best long-term interoperability solution. The real need for a public safety officer, when responding to any situation, is to carry a radio that offers the ability to communicate with whomever he or she needs in real-time. That need often must be supported radio-to-radio without the use of infrastructure for on-scene use at many incidents (e.g., the use of portables). As already demonstrated by companies such as Thales and Vanu Inc., SDR offers the potential of providing a multi-band platform that supports a number of different public safety

34. The SAFECOM Program, Department of Homeland Security, *Statement of Requirements for Public Safety Wireless Communications and Interoperability Version 1* (March 10, 2004). SAFECOM was established to serve as the umbrella program within the federal government to help local, tribal, state, and federal public safety agencies improve public safety response through more effective and efficient interoperable wireless communications.

35. National Institute of Justice Journal, *Can We Talk? Public Safety and Interoperability Challenge*, at 18 (April 2000).

36. Air-interface is a radio-to-radio signal path defined in terms of access method, modulation scheme, voice-coding method, channel rate, and channel data format.

waveforms.³⁷ Equipping a field officer with a radio that supports the waveforms of agencies in that geographic area, along with a common national interoperability waveform, would enable that officer to have direct interoperability without the need for enabling infrastructure. SDR also offers the ability to download software of existing waveforms and supports forward migration to new technologies with new waveforms.

SDR is not yet an on-the street reality. Through a contract with DOD, Thales has developed the portable Multiband Inter/Intra Team Radio (MBITR) that is not yet type-certified for public safety use.³⁸ Likewise, Vanu has demonstrated the Universal Communicator, a multi-mode, multi-band radio operating on a Compaq iPAQ platform.³⁹ Both require added waveforms to be of significant benefit to the user community, though they have proven the SDR concept is viable. The SDR Forum⁴⁰ is also in the process of forming a special interest group targeted at public safety users.⁴¹

Even with the progress in SDR technology in satisfying the requirements of public safety users, there are still significant technology hurdles that have yet to be overcome. The development of a public safety portable subscriber set is hindered by a number of technology requirements, including battery capacity, antenna development, and physical form factor. SDR

37. A waveform is the software package that defines the air interface and protocols necessary to enable communications using a particular technology. Project 25 Phase I, M/A-COM, EDACS, and Motorola SmartNet are all examples of waveforms that could be supported on an SDR platform.

38. The MBITR operates in the 30-512 MHz frequency range and supports amplitude and frequency modulation.

39. The Universal Communicator operates in the 100 to 475 MHz frequency range and can interoperate with multiple radio systems by touching various icons on the screen. It is configured to support analog frequency modulation and the Project 25 digital standard.

40. The SDR Forum is an international, non-profit organization dedicated to promoting the development, deployment, and use of SDR technologies.

41. The special interest group is charged with involving vendors and public safety organizations in the SDR forum's

processors and broadband power amplifiers require significant power. Public safety users require a battery that will support a radio for shifts that routinely extend 12 hours. Currently, multi-band antennas are physically too large to carry if they have to support a very wide range of frequency bands. All of the hardware, including an appropriate battery, must fit in an easy-to-carry package with an appropriate form factor that supports ease of use. Finally, the overall product must be affordable. While agencies may be willing to pay a premium for the features provided, all are constrained by today's limited public safety budgets.⁴² Many of these challenges track those identified by the PSWAC when it considered SDR as a possible solution to the public safety interoperability problem.⁴³

In addition to the technical issues identified above, issues related to the licensing of intellectual property (e.g., patents) could be another impediment to fielding a useful SDR product for use by public safety entities. Use of the major public safety waveforms, with the exception of analog frequency modulation, involves technology licensing issues. These issues will require negotiations with the license holders that could introduce major delays in bringing SDR products to the marketplace and involve added cost to the customer.⁴⁴

The communications equipment used by public safety agencies typically operate within one of ten discrete radio frequency bands and use various air-interfaces. The lack of interoperability is the most significant problem contained in after action reports from major

initiatives to promote development of SDR technologies.

42. Mobile Radio Technology, *Software Defined Radio: The interoperability solution?*, at 40 (November 2003) ("MRT Magazine Article").

43. PSWAC Final Report at 239.

44. MRT Magazine Article at 40.

public safety incidents. Arguably, SDR and eventually CR technologies promise to be the best long-term interoperability solution, with the potential to provide the field officer with a belt-worn subscriber unit. As with any new technology, introduction will be slow and the initial products will be expensive. However, the benefits obtained from the technology will eventually drive demand up and cost down. The Commission's Rules are not limiting the use of SDR to facilitate the interoperability between public safety systems. Although a great deal of work has been done since PSWAC identified SDR as a potential solution to the public safety interoperability problem, technical, legal, and cost issues need to be resolved before the full benefits of SDR can be realized.

VIII. MESH NETWORKS OPERATING AT HIGHER FREQUENCIES WILL REDUCE INTERFERENCE TO OTHER RADIO SERVICES AND CAN FACILITATE BROADBAND COMMUNICATIONS.

The Commission seeks comment on the application of mesh networking technology and possible changes needed to facilitate the use of this technology.⁴⁵ Specifically, how mesh network technology might serve the Commission's efforts to facilitate broadband communication services to consumers and any rule changes that might be necessary. The Commission seeks comment on the impact that mesh networks will have on the aggregate interference to licensed services.⁴⁶ The Commission also seeks comment on the ability of mesh network capabilities to "self heal" to improve the reliability of operations.⁴⁷

In mesh networks, sophisticated digital modulation schemes, traffic routing algorithms, and multi-hop architectures are employed that use minimal transmission power to increase data

45. Cognitive Radio NPRM at ¶ 77.

46. *Id.* at ¶ 79.

47. *Id.* at ¶ 80.

throughput over greater distances. With mesh networks, any node within the network can send or receive messages and can relay messages for any one of its neighboring nodes, thus providing a relay process where data packets travel through intermediate nodes toward their final destination. In addition, automatic rerouting provides redundant communication paths through the network should any given node fail. This ability to reroute across other links not only provides increased reliability, but also extends the network's reach. This resilient, self-healing nature stems from mesh networks distributed routing architecture where intelligent nodes make their own routing decisions, avoiding a single point of failure. The self-healing aspects of mesh networks are discussed in more detail in Appendix D.

The IEEE 802.15.4 standard specifies a physical layer that could be used for mesh networking devices. The physical layer defines parameters such as the frequency, bandwidth, transmit power, and receiver sensitivity. Given the large number of transmitters in a mesh network that can be operating simultaneously, there is a potential risk for aggregate interference to authorized radio services. Currently, the IEEE 802.15.4 standard is implemented in the 902-928 MHz and 2400-2483.5 MHz Industrial, Scientific, and Medical (ISM) bands. Because these bands are used primarily by unlicensed devices, there is no impact on federal government operations if mesh network operations are implemented in them. Before mesh networks can be implemented in the 5725-5850 MHz ISM band, however, technical analysis similar to those for the U-NII devices in the 5 GHz band would have to be performed to assess the potential impact to government radars that also operate in this band.

Since the length of communications paths for mesh network devices are short by design, it may be possible to implement this technology at higher frequency bands where propagation losses are greater. Using higher frequencies would limit the range of interfering signals within

the mesh network and substantially increase frequency reuse. This is discussed in more detail in Appendix D.

Another aspect of mesh networks is that the capacity of the mesh increases as more nodes are added. It may also be possible to use technologies for the mesh nodes such as ultrawideband (UWB), which has the potential to support data rates of 100 mega bits per second or more at short distances. The ability of mesh networks to support higher data rates is discussed in greater detail in Appendix D.

A mesh network allows nodes or access points to communicate with other nodes without being routed through a central switch point, eliminating centralized failure, and providing self-healing and self-organization. NTIA believes that the short-range characteristics of mesh networks lend themselves to using higher frequencies. Higher frequencies will become continually more attractive as RF devices become cheaper and better; denser device deployments such as mesh networks reduce the required path length; and demand for wide bandwidths and frequency reuse increases. Operating at higher frequencies will also reduce the potential for aggregate interference to other radio services. NTIA believes mesh networks that have the capability to increase capacity as the number of nodes increases can deliver broadband data rates to support high-speed data, video and voice applications.

IX. GEO-ENCRYPTION TECHNIQUES CAN BE USED IN CONJUNCTION WITH EXISTING ENCRYPTION TECHNIQUES TO PROVIDE PROTECTION OF OVER-THE-AIR SOFTWARE DOWNLOADS.

The Commission seeks comment on whether any modifications are necessary to the security and authentication requirements in the rules. Specifically, the Commission seeks comment on whether the current rules provide adequate safeguards against unauthorized

modifications to SDRs.⁴⁸

Location-based encryption or geo-encryption refers to any method of encryption in which ciphertext can be decrypted only at a specified location.⁴⁹ If someone attempts to decrypt the data at another location, the decryption process fails and reveals no details about the original plaintext information. The device performing the decryption determines its location using some sort of location sensor, such as a GPS receiver. Location-based encryption can be used to ensure that data cannot be decrypted outside of a particular facility (*e.g.*, the headquarters of a government agency or corporation). Alternatively, it may be used to contain access to a broad geographic region. Time and space constraints can also be placed on the decryption location. Appendix E describes one implementation of geo-encryption that builds on established security algorithms and protocols.

Geo-encryption has the potential to support both fixed and mobile applications and a variety of data-sharing and distribution policies. Depending on individual implementations, it can also provide strong protection against location spoofing. NTIA believes that geo-encryption techniques can be used in conjunction with existing encryption techniques to provide protection of over-the-air software downloads. NTIA recommends that the Commission explore the benefits and possible implementation of geo-encryption techniques as part of future rulemaking proceedings on CR and SDR technologies.

48. Cognitive Radio NPRM at ¶ 94.

49. Geo Intelligence, *GPS-Based Geo Encryption*, at 26 (Winter 2003).

X. THE INITIAL IMPLEMENTATION OF UNLICENSED COGNITIVE RADIO TECHNOLOGY SHOULD BE LIMITED TO THE INDUSTRIAL, SCIENTIFIC, AND MEDICAL FREQUENCY BANDS AND THE FREQUENCY BANDS TRANSFERRED FROM THE FEDERAL GOVERNMENT.

The Commission seeks comment on whether higher power operation should be permitted for Part 15 devices. For example, the Commission questions whether higher power unlicensed device operation should be permitted under Section 15.209 of the Commission's Rules.⁵⁰

Section 15.209 of the Commission's Rules permits unlicensed device operation at specified radiated emission levels, in almost any frequency band, other than the television broadcast and certain designated restricted frequency bands.⁵¹ The restricted frequency bands include bands used to support safety-of-life functions, such as aeronautical radionavigation, and bands employed by radio services that must function, as a nature of their operation, using extremely low received signal levels. However, there are many frequency bands used by critical government and non-government radiocommunication systems that are not included in the restricted frequency band list but also require protection. Examples of these critical systems include the Federal Aviation Administration's Terminal Doppler Weather Radar;⁵² the DOD systems used to provide tracking, telemetry, and control of all military satellite systems; the National Aeronautics and Space Administration's Tracking and Data Relay Satellite System; the Department of Transportation's Intelligent Transportation System;⁵³ commercial cellular and personal communication service (PCS) systems; point-to-point microwave systems used to

50. Cognitive Radio NPRM at ¶ 41.

51. In the restricted frequency bands, only spurious and unintentional emissions from unlicensed devices are permitted.

52. The Terminal Doppler Weather Radar provides quantitative measurements of gusts fronts, wind shear, microbursts, and other weather hazards for improving the safety operations at major airports.

53. The Intelligent Transportation System Dedicated Short Range Communication Service is used to support public

support the Nation's critical infrastructure;⁵⁴ and land mobile communications systems used to support state, local, and federal public safety. These critical government and non-government systems span the frequency range of 100 MHz to 7000 MHz.

The low radiated emission levels currently permitted under Section 15.209 are the primary factor that facilitates sharing between unlicensed devices and the licensed radiocommunication systems. Before an increase in the power level for unlicensed devices can be considered, operational parameters (including sharing criteria) of both the licensed services and the proposed unlicensed uses are required to adequately determine the necessary technical characteristics of the CR technique to be employed. An example of an appropriate methodology for conducting the analyses to define the characteristics of the CR technique can be seen by examining the U-NII rulemaking proceeding. The analyses used to determine appropriate thresholds for use by U-NII devices employing DFS took into account the technical characteristics of the radar transmitter and receiver (*e.g.*, antenna gain patterns, bandwidth, scan/tracking rate) as well as the technical characteristics of the unlicensed device proposed for the radio local area networks (RLAN). For this specific unlicensed device application, the analysis was used to determine combinations of transmit power, antenna gain, bandwidth, and measurement time interval that would allow successful sharing between unlicensed RLANs and radar systems. Similar analyses would need to be conducted for each frequency band being considered, each higher-powered unlicensed application, and the CR techniques to be employed to facilitate sharing. Each analysis would be unique due to differing technical characteristics of the various licensed and various unlicensed device applications, as well as the differing

safety communications on the Nation's highways.

54. Fixed point-to-point microwave systems are used by public safety, railroads, and the energy and water

propagation characteristics in each frequency band.

The effectiveness of the CR technique employed by the unlicensed device to facilitate sharing with licensed users will be dependent on the licensed service operating in the band. For example, DFS techniques hold promise for sharing with radar systems or with other radio services where the transmitter and receiver are at the same location and where the propagation path from the DFS-equipped unlicensed device back to the transmitter is the same as the path from the transmitter to the DFS-equipped unlicensed device. However, for sharing with point-to-point microwave systems, where the transmitter and receiver are typically separated by tens of kilometers, the hidden transmitter problem can exist.⁵⁵ For sharing with point-to-point microwave systems, geo-location CR techniques used with an on-line location database may be more appropriate. Detection techniques such as DFS are also not very effective when the licensed user's signal operates below the noise floor, for example spread spectrum systems.

The Commission's proposal to permit higher-powered unlicensed device operation when CR sensing techniques are employed includes three ISM frequency bands: 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz. NTIA agrees with the Commission's current proposal to initially limit higher-powered unlicensed device employing CR sensing techniques to the 902-928 MHz and 2400-2483.5 MHz bands. Because these frequency bands are primarily used by unlicensed devices that must accept interference from other unlicensed devices, compatibility analyses with government systems are not necessary. However, in the 5725-5925 MHz frequency band, the DOD operates fixed, transportable, and mobile radar systems and analyses

industries.

55. In the hidden transmitter problem, if a spectrum sensing equipped unlicensed device is blocked from receiving the transmitted point-to-point signal (*e.g.*, shielded by local terrain features) it will be permitted to transmit, possibly causing interference to the point-to-point receiver that is located close to the spectrum sensing equipped unlicensed device.

will have to be performed to assess the potential impact that the Commission's proposal will have on these critical systems.

If the Commission is contemplating expanding the implementation of higher-powered unlicensed device operations employing CR techniques, NTIA recommends that the Commission consider the frequency bands transferred from federal government to private sector use.⁵⁶ The transferred frequency bands represent spectrum that at this time has limited government or commercial use. In an on-going rulemaking proceeding, the Commission is already examining the implementation of CR techniques in the 3650-3700 MHz band to facilitate sharing between higher-powered unlicensed device and licensed radio services (radar systems and satellite earth station receivers).⁵⁷

XI. SECONDARY SPECTRUM MARKET ACTIVITIES PROMISE TO INCREASE SPECTRUM EFFICIENCY BY FOLLOWING CHANGING DEMAND.

The Commission seeks comment on technical methods that might be used to provide information necessary for leasing of spectrum and how a device would enforce the terms of the lease. Specifically, the Commission requests comment on whether they could reduce the uncertainties that may inhibit leasing transactions by encouraging voluntary technical standards for access to a licensee's spectrum. The Commission also requests comments on what approaches to facilitate leasing transactions could best achieve the goals of the flexible and

56. In accordance with the requirements of Title VI of the Omnibus Budget Reconciliation Act of 1993 and the Balanced Budget Act of 1997, 247 MHz of federal government spectrum have been identified for transfer to the private sector.

57. *Additional Spectrum for Unlicensed Services Below 900 MHz and in the 3 GHz Band; Amendment of the Commission's Rules with Regard to the 3650-3700 MHz Government Transfer Band*, Notice of Proposed Rulemaking, ET Docket No. 04-151, ET Docket No. 02-380, ET Docket No. 98-237, FCC 04-100, 2004 FCC LEXIS 2071, at ¶¶ 64-68 (2004).

market-driven policies for spectrum leasing.⁵⁸

NTIA has, for several years, supported the development of secondary markets as a means of promoting efficient use of spectrum.⁵⁹ To promote these secondary markets, it is important to maximize as much as possible the flexibility for accommodating these markets. In permitting secondary market activities, the Commission should not over-regulate the leasing process or require secondary user registration or lessee filings. NTIA advocates that licensees retain ultimate responsibility for any activity under their lease. By making licensees responsible, the Commission will have a mechanism for ensuring its rules are followed. NTIA would suggest, however, that the Commission impose certain minimum criteria for licensees to follow in entering into lease arrangements to ensure appropriate intervention in the event of misuse by the lessee. The Commission should require licensees to maintain on file the lease agreement with availability to the Commission upon request; notify the Commission upon agreement to a lease; maintain on file contact information for any secondary users of their spectrum; have contractual authority to terminate the lease in response to a violation; approve any subsequent sublease; and assist in enforcement of the lease conditions and administrative regulations.

Making the licensee responsible for any use within the scope of its license will provide incentives for the licensee to construct the appropriate covenants, indemnifications and limitations within its contract to ensure appropriate use by the lessee. These basic principles of minimum regulation of secondary markets should be extended to the application of CRs to facilitate the establishment of secondary markets.

58. Cognitive Radio NPRM at ¶ 50.

59. Letter from Nancy J. Victory, Assistant Secretary for Communications and Information, National Telecommunications and Information Administration, to the Honorable Michael K. Powell, Chairman, Federal Communications Commission (March 7, 2002).

The Commission should consider permitting the deployment of beacon signals and control and communication links that would aid CR systems to identify spectrum that is available to the lessee. These beacon signals and communication links would be restricted to the same spectral and geographical constraints as those of the licensee. The Commission should allow preemption of the lessee use of the spectrum by the licensee subject to lease agreements. Licensees in cooperation with lessees operating in the same or similar bands should also be encouraged to develop voluntary standards for lessee equipment and operations as required.

NTIA supports the actions taken by the Commission to remove regulatory barriers to the development of secondary markets. These flexible policies will continue the evolution toward greater reliance on the marketplace to expand the scope of available wireless services. Because CRs can play an enabling role in the establishment of secondary markets, the development of CR technology should also have similar, minimum regulatory constraints.

XII. HIGH-SPEED DIGITAL-TO-ANALOG CONVERTERS THAT ARE MARKETED AS PART OF RADIO SYSTEMS SHOULD BE REGULATED AS SOFTWARE DEFINED RADIOS OR COGNITIVE RADIOS UNDER THE APPROPRIATE SECTION OF THE COMMISSION'S RULES.

The Commission seeks comment on whether there is a need to restrict the mass marketing of high-speed, digital-to-analog converters (DAC) that could be diverted for use as radio transmitters and whether it can do so without adversely affecting other uses of such computer peripherals or the marketing of computer peripherals that cannot be misused.⁶⁰

DACs are finding increased use in modern communication systems and will be a key element in the implementation of SDR and CR technologies. DAC circuits can be used in local oscillators, clock generator blocks, and wideband modulator circuits. The sources of spurious

60. Cognitive Radio NPRM at ¶ 92.

emissions generated by DACs can generally be attributed to the nonlinearities associated with the non-ideal static and dynamic transfer functions of the DAC.⁶¹ Spurious emissions from the DAC can be categorized into three types: spurious emissions caused by direct circuit nonlinearities within the DAC; harmonically related spurious emissions caused by non-ideal switching characteristics of the DAC; and spurious emissions caused by noise coupling effects that can be harmonically or non-harmonically related.⁶²

The marketing of high speed DACs and the software to make them interact could undermine the Commission's present equipment authorization program at the risk of increasing interference to legitimate spectrum users. This could occur because these devices would not be subject to the normal equipment authorization requirements. This is not presently a problem, but the Commission is considering steps that can be implemented now to help ensure that this scenario does not become a serious problem.

NTIA commends the Commission for addressing the potential problems of emitters that could fall outside of the present regulatory structure as part of this proceeding. The issue of the blurring of applicability of specific rule sections as technology advances is but one indicator of the problems facing the regulatory community in trying to keep pace with technology evolution. While trying to avoid undue burden on the introduction of innovative technology, the Commission clearly has the responsibility to regulate spectrum use such that adverse effects to other authorized users does not occur. The Commission has expressed specific concern that high speed DACs might be used with high processing speed personal computers to create software-controlled RF signal sources that can be used as transmitters.

61. RF Design, *Sources of Spurious Components in a DDS/DAC System*, at 28 (April 1998).

62. *Id.*

NTIA believes that there is no reason to regulate component parts such as DAC integrated circuits and any regulation that would likely stifle their use should be avoided. NTIA also believes that a radio transmitter consists of a means to generate, amplify, and radiate a signal into the environment. A DAC add in card alone does not possess this capability, and thus should not be subject to regulation as a radio transmitter under the Commission's rules. If a DAC is coupled with an amplifier and antenna, with intent to radiate into the environment, then it should be considered a SDR or CR and should be regulated under the applicable section of the Commission's rules. NTIA recommends as potential consumer applications of DAC based RF signal sources become better understood, that the Commission should consider revisiting their regulations.

XIII. THE COMMISSION SHOULD CONSIDER REQUIRING PROTECTION PROFILES AS PART OF THE EQUIPMENT CERTIFICATION PROCESS FOR SOFTWARE DEFINED RADIOS.

The Commission seeks comment on whether any modifications are necessary to the security and authentication requirements in their rules. Specifically, the Commission seeks comment on whether the current rules provide adequate safeguards against unauthorized modifications to SDRs. Comments are also sought on what should happen in the event that reasonable security methods are ultimately broken and what responsibilities do the manufacturers have if accepted industry standards for security are followed.⁶³

The Commission's Rules require that manufacturers take steps to ensure that only software that is part of an approved hardware/software combination can be loaded onto an SDR.⁶⁴ The software must not allow the user to operate the transmitter with frequencies, output

63. Cognitive Radio NPRM at ¶ 94.

64. *See* 47 C.F.R. § 2.932(e).

power, modulation types or other parameters outside the range of those that were approved. Manufacturers may use authentication codes or any other means to meet these requirements, and must describe the methods in their application for equipment authorization. In adopting these requirements, the Commission stated that it may have to specify more detailed security requirements at a later date as SDR technology develops.⁶⁵

NTIA shares the concerns raised by the Commission regarding the adequacy of the current software security requirements. Recurring media reports of security flaws in commercial software packages and operating systems indicate that software based security mechanisms in SDR could be vulnerable. Changes to the Commission's Rules that require the use of specific industry standard security measures would help to remove some ambiguity that exists in how security is implemented and how secure these measures must be. To address problems with security, the SDR Forum has written a document on the requirements for software downloads that reconfigure the RF characteristics of a radio.⁶⁶ This document describes the security requirements for commercial wireless systems to ensure that malicious code cannot be downloaded and activated. The security measures are divided into six generic categories: Trusted System Operator, Authentication, Authorization, Integrity, Privacy, Non-Repudiation, and Auditing.⁶⁷ All of these general security requirements are also requirements for the more specific challenges of SDR security. The SDR Forum has also developed security threat scenarios and an SDR security threat model to address the different categories of threats to

65. *Inquiry Regarding Software Defined Radios*, Report and Order, ET Docket No. 00-47, 16 FCC Rcd 17373, 13383 (2001).

66. SDR Forum, Document Number SDRF-02-A-007-C0.00, *Requirements for Radio Software Download for RF Reconfiguration* (November 13, 2002).

67. *Id.* at 29.

downloaded software that reconfigures the RF parameters.⁶⁸

The SDR Forum is also considering Protection Profiles as a requirement for SDRs. A Protection Profile is an implementation independent statement of security requirements that is shown to address threats that exist in a specified environment.⁶⁹ A Protection Profile would be appropriate for a consumer group that wishes to specify security requirements for an application type. Protection Profiles are now becoming a standard requirement for the Common Criteria, which is the international mechanism for certification and accreditation of security devices.⁷⁰

The main security issue that have been identified include who has the authority to control the reconfiguration of the communications equipment, protection of the reconfiguration signaling, privacy of the reconfiguration information,⁷¹ the correctness and availability of information on which the reconfiguration is based, and secure download of software required for reconfiguration, and issues related to the radio emission and associated conformance requirements of radio equipment. NTIA is concerned about the regulatory implications associated with downloaded software that can reconfigure the radio functionality, which includes such parameters as frequency, power, and modulation. The SDR Forum, which represents a large cross section of national and international organizations, has made a great deal of progress in addressing the areas of security, authentication, and protection of unauthorized modifications to SDRs. NTIA understands the Commission's reluctance to adopt specific security requirements because this may constrain the development SDR technology. From the federal

68. *Id.* at Appendix A.

69. Protection Profiles are registered through national processes.

70. More information is available at http://www.commoncriteria.org/protection_profiles/pp.html.

71. For example, information on current configuration of a user's equipment.

agencies' perspective, however, NTIA believes that the acceptance of SDR, and eventually CR technologies, hinges on assurances that the operating parameters that can impact electromagnetic compatibility with other systems are protected from malicious attacks. NTIA recommends that as a long-term goal of addressing security issues related to SDR and CR technologies, the Commission consider requiring Protection Profiles as part of the equipment certification.

XIV. THE REQUIREMENT FOR APPLICANTS TO PROVIDE A COPY OF THEIR SOFTWARE AS PART OF THE CERTIFICATION PROCESS FOR SOFTWARE DEFINED RADIOS SHOULD BE ELIMINATED.

The Commission proposes to delete the requirement that applicants supply a copy of their radio software upon request. In its place the Commission proposes to add a less burdensome requirement that applicants supply a description and flow diagram of the software that controls the radio operating parameters.⁷²

NTIA agrees with the Commission that examination of software is not an effective means of identifying where unauthorized software changes have been made in an SDR. NTIA believes that the Commission's requirement that certified devices must comply with their applicable technical rules is sufficient to safeguard against unauthorized equipment modifications. Thus, NTIA agrees with the Commission's proposal to eliminate the existing requirement for applicants to provide copies of their software as part of the certification process for SDRs.

72. Cognitive Radio NPRM at ¶ 86.

XV. MANUFACTURERS SHOULD ONLY BE REQUIRED TO DECLARE THEIR DEVICES AS A SOFTWARE DEFINED RADIO IF THE DEVICE IS REMOTELY PROGRAMMABLE AND HAS HARDWARE CAPABLE OF TRANSMITTING IN THE RESTRICTED FREQUENCY BANDS OR IN FREQUENCY BANDS ALLOCATED TO THE FEDERAL GOVERNMENT ON AN EXCLUSIVE BASIS.

The Commission requests comments on the need for a requirement that manufacturers declare certain equipment as SDRs, including the benefits of such a requirement in reducing interference and its possible burden on manufacturers. Specifically, the Commission seeks comment on the type of device to which this requirement should apply, including how the rules should distinguish between transmitters that must be identified as SDRs.⁷³

NTIA agrees with the concerns raised by the Commission regarding an SDR's ability to modify its parameters. Operating outside of the parameters approved under the rules for that device, would increase the potential for interference to other authorized radio services.⁷⁴ Issues related to unauthorized users having the capability to modify or reprogram an SDR to operate outside of its allowable parameters continues to be a concern to many of the federal agencies. Requiring manufacturers to declare a device as being an SDR would require that the security mechanisms must be incorporated, which provides some assurance that unauthorized users cannot modify the parameters of SDRs. This would reduce the interference risk to other radio services.

The definition for SDR adopted by the Commission is extremely broad and covers devices in which parameters such as frequency and modulation type are determined by software.⁷⁵ The problem is that the definition of SDR could also apply to non-government

73. Cognitive Radio NPRM at ¶ 88.

74. *Id.* at ¶ 87.

75. A software defined radio is one that includes a transmitter in which the operating parameters of frequency

private land mobile radios and most commercial PCS base stations, which were not intended to be included under the rules for SDR. The Commission's current rules do not require manufacturers of SDRs to declare them as such when applying for equipment authorization. A device that is not declared as an SDR does not have to comply with the software security requirements that are designed to ensure that only authorized software can be loaded.⁷⁶ NTIA recognizes the potential problem that can be encountered by applying the broad definition for SDR. However, there is still a potential problem with an SDR whose transmitter parameters can be changed remotely. In this situation, large numbers of transmitters could be modified simultaneously, thereby increasing the potential interference to federal spectrum users.

NTIA believes that the primary concern to federal operations would come from SDRs that are remotely programmable and have the hardware capability to transmit in the restricted frequency bands or in other frequency bands used by the federal government. NTIA believes that it would be appropriate for the Commission to require manufacturers to declare their devices as SDRs if the device is remotely programmable and has hardware that is capable of transmitting in the restricted frequency bands or in frequency bands allocated to the federal government on an exclusive basis. This would eliminate the problems associated with incorrectly classifying commercial devices, such as land mobile radio and PCS, as SDRs and provide protection to federal users.

range, modulation type or maximum output power (either radiated or conducted) can be altered by making a change in software without making any changes to hardware components that affect the radio frequency emissions.

76. The manufacturers of SDR devices are now required under Section 2.932(e) of the Commission's Rules to take steps to ensure that only software that has been approved with a SDR can be loaded into such a radio.

XVI. TECHNICAL ISSUES RELATED TO THE COMPLIANCE MEASUREMENTS OF UNLICENSED DEVICES THAT EMPLOY COGNITIVE RADIO TECHNIQUES MUST BE ADDRESSED PRIOR TO IMPLEMENTATION.

Since devices employing CR techniques can perform functions not envisioned at the time the current Part 15 Rules were developed, the Commission recognizes that it will be necessary to specify additional compliance measurement procedures. In the NPRM, the Commission proposes a number of specific tests applicable to the following CR techniques: interruptible radio,⁷⁷ listen-before talk,⁷⁸ and geo-location.⁷⁹ The Commission seeks comment on its proposed compliance measurement tests and whether additional tests might be necessary. The Commission also solicits public comment on whether it or an industry standards organization, such as the American National Standards Institute (ANSI), should develop the compliance measurement procedures.⁸⁰

Currently, when Part 15 devices are certified, the output of the device is tested in response to a single or limited number of input conditions to verify that it complies with the Commission's Rules. However, for unlicensed devices employing CR techniques, it will be necessary to test the output in response to various inputs or various combinations of inputs. NTIA is currently participating in a government/industry working group that is developing compliance measurement guidelines for U-NII devices that are equipped with DFS.⁸¹ In this case, the compliance measurements must verify the DFS detection threshold, startup and in-

77. Cognitive Radio NPRM at ¶ 103.

78. *Id.* at ¶ 105.

79. *Id.* at ¶ 106.

80. *Id.* at ¶ 102.

81. DFS is the same as the sensing or listen-before-talk techniques described in the NPRM.

service monitoring times, the time to cease transmissions or move to another channel, and the time to revisit a portion of the spectrum to determine whether it is unoccupied.⁸² Even with this relatively simple implementation of a CR technique, developing compliance measurement procedures has proven to be challenging. These procedures must be such that they can be reasonably implemented by the Telecommunication Certification Bodies (TCBs). Furthermore, the procedures need to be comprehensive enough to ensure that the DFS capability adequately protects the radar systems.

NTIA agrees with many of the tests proposed by the Commission in the NPRM for listen-before-talk or sensing CR techniques. However, NTIA believes that there are additional factors that must be included in the compliance measurement procedures. For example, depending on how the listen-before-talk or sensing capability is implemented and the type of data transmissions, the channel loading could have an impact on the compliance measurements. If the listen-before-talk or sensing CR techniques are implemented so that a dedicated period of time is established for spectrum monitoring, the channel loading is not as critical. However, if the spectrum monitoring is performed during the quiet periods between data packet transmissions, the channel loading becomes more critical. This is particularly true if the signal that is to be detected has time-varying characteristics, such as a radar system with an antenna that scans 360 degrees in azimuth. In this situation, the detection process depends on the packet size of the data transmissions. To simulate the channel loading, standard data files should be developed.⁸³ For Internet Protocol-based systems that employ a variable packet length based on the file being transmitted, it should be sufficient to stream a file that will load the system to 40 to 60 percent of

82. U-NII R&O at Appendix C.

83. A standard Moving Picture Experts Group-2 (MPEG-2) file could be used for the channel loading depending on

its throughput capability. For frame-based systems that employ fixed packet lengths, but vary the transmit/listen time, the transmit/listen ratios should be set to a value that represents the setting used during actual system deployment. Additional parameters that need to be defined for measuring the detection level including whether the measurement is based on peak and/or average power and the measurement interval.⁸⁴

For listen-before-talk and sensing CR techniques to be effective, the test signals used in the compliance measurements must be representative of the signals employed by the licensed radio service in the frequency band that is being monitored. The DFS-equipped U-NII devices are sharing with the radiolocation service, so the test signals are defined by representative radar characteristics such as pulse repetition frequency, pulse width, burst length, burst period, and hopping rate (for frequency hopping radar systems).⁸⁵ In frequency bands in which the characteristics of the licensed service are known and not subject to change (*e.g.*, broadcast signals), it may be possible to use these characteristics to assist in signal detection. However, when detecting signals in bands where the characteristics of the licensed service vary over a wide range or can change because of future system developments, the detection should be based solely on received power level exceeding a specified threshold. The actual detection threshold will vary depending on the characteristics of the licensed radio service and the unlicensed device application as well as the operational scenario. The compliance measurements must verify that the signal detection is based on received power level in these situations.

the device application.

84. For DFS-equipped U-NII devices, detection is based on a maximum power level averaged over a 1 microsecond time period.

85. U-NII R&O at Appendix C-13.

The Commission also identified tests to be included in the compliance measurements for unlicensed devices that employ geo-location techniques. These tests address the ability of the device to correctly identify its location, the ability to access an on-line database of other authorized systems, and the unlicensed device response when the position location is lost. NTIA agrees with the Commission's proposal and recommends an additional test to verify what corrective action will be taken (*e.g.*, cease transmitting, reduce power, move to another frequency) when it is determined that the unlicensed device is within the exclusion areas around the fixed site locations in the on-line database.

NTIA believes that the compliance measurement procedures for devices employing CR techniques need to be developed in an open forum, where private and government entities can participate. This approach is being employed by the government/industry working group, chaired by NTIA, that is addressing the compliance measurement procedures for DFS-equipped U-NII devices operating at 5 GHz. These working group meetings are open to the public and include participants from NTIA, the FCC, the DOD, manufacturers, and the TCBs. This working group has been successful in developing consensus positions that are used to provide guidance to the Commission. The Commission suggests ANSI as a possible organization for developing the compliance measurement procedures. NTIA believes the SDR Forum is another possible organization that can be used to develop compliance measurement procedures for devices employing CR techniques. The SDR Forum meetings are open to the public and have participation from both the private sector and the government.

In the past, because of their simplicity, the compliance measurement procedures for unlicensed devices were typically considered after the development of the service rules. However, given that CR devices can change their electromagnetic characteristics on a near real-

time basis, compliance measurements will be more complex. NTIA believes that the compliance measurements are a critical element in ensuring that unlicensed devices employing CR techniques do not interfere with authorized spectrum users. The TCBs are experts in the area of performing the compliance measurements and need to be actively engaged in providing guidance on the technical issues related to device certification for unlicensed devices employing CR techniques. NTIA believes that technological approaches that cannot be verified in the TCB laboratories should not be relied upon for successful spectrum sharing. NTIA recommends that the Commission resolve all of the technical issues related to performing the compliance measurements prior to implementing CR techniques in any frequency band.

XVII. A NEW SUBPART UNDER PART 15 OF THE COMMISSION'S RULES SHOULD BE ESTABLISHED FOR UNLICENSED DEVICES EMPLOYING COGNITIVE RADIO TECHNIQUES.

The ability of CR technologies to adapt a radio's use of the spectrum to the real-time conditions of the operating environment offers regulators, licensees, government agencies, and the public the potential for more flexible, efficient, and comprehensive use of the available RF spectrum. Nevertheless, CR technologies could raise new interference issues that will have to be addressed. Furthermore, unlike conventional unlicensed devices, the compliance measurements for devices employing CR technologies will be much more complicated and will have a greater impact on whether or not a device is compatible with other spectrum users. The NPRM does not address how unlicensed devices that employ CR technologies should be accommodated under the current Part 15 Rules. NTIA recommends that a new subpart within the Commission's Part 15 Rules be established for unlicensed devices that employ CR techniques. This is similar to the approach that was used for unlicensed UWB devices, which also did not fit into the existing Part 15 Rules.

The Commission has adopted a definition for SDRs. NTIA recommends that the Commission consider adopting the following definition for CR:

Cognitive radio: A radio or system that senses its operational electromagnetic environment and can dynamically and autonomously adjust its radio operating parameters to modify system operation, such as maximize throughput, mitigate interference, facilitate interoperability, access secondary markets.

NTIA believes that the Commission should adopt a definition for CR in order to provide regulatory certainty to manufacturers seeking industry investment in these new technologies.

XVIII. UNLICENSED DEVICES CAPABLE OF OPERATING ON NON-PART 15 FREQUENCIES MUST INCORPORATE FREQUENCY SENSING OR GEO-LOCATION CAPABILITIES.

The Commission proposes to allow certification of Part 15 devices that are capable of operating on non-Part 15 frequencies. As part of this proposal, the Commission would require that such devices incorporate DFS to select the appropriate operating frequency based on the country of operation.⁸⁶ The Commission also proposes that these devices must incorporate a means to determine the country of operation.⁸⁷ The Commission seeks comment on these proposals.

Many of the frequency bands where unlicensed device operation is permitted are not harmonized on a worldwide basis. For example, the 902-928 MHz band is limited to the United States in most cases. With the Commission's recent action in the U-NII proceeding additional spectrum in the 5 GHz bands, unlicensed devices operating on the U.S. channels will be using the same frequency bands as most of the world. However, in the United States, unlicensed device operation is permitted in the 2400-2483.5 MHz as opposed to the 2400-2500 MHz band

86. Cognitive Radio NPRM at ¶ 97.

87. *Id.*

used by most countries.⁸⁸ The ability to certify unlicensed devices that could be used on a worldwide basis, or at least in a number of different countries, would eliminate the need for manufacturers to produce multiple versions of a device for use in different countries.

Unlicensed devices can fall into two general categories: devices that are under the control of a central controller (e.g., access point); and devices that are capable of operating without a central control (e.g., peer-to-peer operation). NTIA recognizes the potential benefits of allowing manufacturers to produce one device that can be enabled on a country specific basis to transmit in the authorized spectrum bands of that country. However, the proposal to require DFS technology to be embedded into unlicensed devices capable of operating outside of the Part 15 frequency bands is unnecessary since DFS only looks for an open frequency and has no ability to recognize where it is located. Passive sensing is possible in the case where the central controller is capable of supplying the frequency selection information to the devices, for example, as specified in IEEE 802.11 Task Group (TG)d. However, this does not address devices that can operate without a central controller and it also assumes that the central controller is set to only access frequencies authorized for use in the United States.

If the Commission adopts its proposal to certify unlicensed devices that are capable of using non-Part 15 frequencies, then it should limit this to devices where the central controllers can control the transmit frequencies of the client devices. As part of the device certification process, it is imperative that it be ensured that the central controllers can only operate in the bands authorized for Part 15 operations. For unlicensed devices that operate without a central controller, the device should be required to incorporate geo-location capabilities, such as GPS, in

88. Channels 12 and 13 (2467 MHz and 2472 MHz) of the IEEE 802.11 b/g standard are not used in most cases to avoid problems with out-of-band emissions in the restricted frequency band 2483.5-2500 MHz which is used by the mobile satellite service in the United States.

conjunction with a database, to determine its geographic location. The location information would then be used to control the authorized frequencies that the unlicensed device can use. Furthermore, if the unlicensed device is not capable of determining its geographic location, the device must be restricted from transmitting.

XIX. CONCLUSION

NTIA commends the Commission for initiating this proceeding examining CR technology. NTIA agrees with the Commission regarding the significant benefits that could be gained by employing CR technologies. The NPRM identifies several areas where technical and regulatory issues must be addressed. NTIA supports the Commission's approach, whereby the initial implementation of CR technologies is limited to a few frequency bands primarily used by unlicensed devices. NTIA believes that the experience gained in these frequency bands will help facilitate a much broader implementation of CR technologies while ensuring that existing government and non-government spectrum users are adequately protected from interference. NTIA will continue to work with the Commission and industry to resolve the technical and regulatory issues surrounding the successful implementation of CR technologies.

For the foregoing reasons, NTIA submits these comments

Respectfully submitted,

Michael D. Gallagher
Assistant Secretary for
Communications and Information

Kathy D. Smith
Chief Counsel

Fredrick R. Wentland
Associate Administrator
Office of Spectrum Management

Edward Drocella
Mark Settle
Electronics Engineers
Office of Spectrum Management

National Telecommunications
and Information Administration
U.S. Department of Commerce
Room 4713
1401 Constitution Avenue, N.W.
Washington, DC 20230
(202) 482-1816

February 15, 2005