UNITED STATES DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Washington, D.C. 20230

August 16, 1996

William Caton
Secretary
Federal Communications Commission
Room 222
1919 M Street, N.W.
Washington, D.C. 20554

DOCKET FILE COPY ORIGINAL

Re: Amendment of the Commission's Rules to Provide for Unlicensed NII/SUPERNet Operations in the 5 GHz Frequency Range, ET Docket No. 96-102

Dear Mr. Caton:

Enclosed please find an original and nine copies of a revised version of the Reply Comments filed by the National Telecommunications and Information Administration on August 14, 1996 in the above-captioned proceeding. This revised version is submitted to correct an inadvertant error in the original Reply Comments. Please replace the original Reply Comments with the version enclosed.

Please call me at (202) 482-0012 with any questions.

Sincerely,

Bruce A. Henoch
Attorney-Advisor

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AUG 16 1996
FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY

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

In the Matter of	)	
	)	
Amendment of the Commission's Rules to	)	ET Docket No. 96-102
Provide for Unlicensed NII/SUPERNet	)	RM-8648
Operations in the 5 GHz Frequency Range	)	RM-8653

REPLY 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 and information policy. NTIA respectfully replies to comments submitted in response to the Commission's Notice of Proposed Rulemaking (NPRM) in the above-captioned proceeding.[1]

I. INTRODUCTION

The NPRM seeks comment on the Commission's proposal to make available 350 MHz of spectrum at 5150-5350 MHz and 5725-5875 MHz for use by a new category of non-licensed equipment, called NII/SUPERNet devices. NTIA, as the manager of Federal Government use of radio spectrum -- as well as the President's principal adviser on telecommunication matters and the primary Federal agency working toward the development of the NII -- has a direct

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[1] In re Amendment of the Commission's Rules to Provide for Unlicensed NII/SUPERNet Operations in the 5 GHz Frequency Range, ET Docket No. 96-102, FCC 96-193 (Released May 6, 1996) (Notice of Proposed Rule Making).

interest in the outcome of this proceeding.

NTIA applauds the Commission for initiating this proceeding. Non-licensed wireless technology has the potential to be a major pathway for achieving the Administration's goal of connecting the nation's schools, libraries, and health care providers to the National Information Infrastructure (NII) by the year 2000. While the Commission is also conducting other proceedings to further this important goal, those proceedings primarily address the terms and conditions under which existing services are to be offered by service providers. The new class of non-licensed devices contemplated by the NPRM, on the other hand, could provide an alternative means for educational institutions and other end users to develop innovative, inexpensive, and readily-implemented solutions for meeting their needs for communicating rapidly and efficiently, either within the walls of an organization or across communities.

While NTIA recognizes the great potential offered by this new technology and the importance of making available spectrum for such uses, we wish to emphasize the need to proceed with care in developing appropriate rules permitting widespread use of these non-licensed devices.[2] Such rules would further the

[2] NTIA has long advocated finding ways that spectrum use efficiency may be increased; sharing of bands between Federal Government users and unlicensed users is a promising way of doing so, so long as interference to and from the incumbent Federal users is minimized.

development and availability of the NII/SUPERNet devices, increase spectrum efficiency, and minimize interference to and from incumbent Federal users.[3] The Commission should, as part of these rules, ensure that receiver standards are adopted as well as appropriate spectrum sharing protocols. NTIA believes that, if the Commission implements the suggestions proposed in this pleading, such non-licensed NII/SUPERNet devices can be accommodated in the proposed frequency bands.

And, if the Commission does implement such suggestions, NTIA believes it will be possible to permit broader uses than are now proposed by the Commission. The Commission's current proposal would allow for the development of wireless substitutes for inside wiring within structures. It would, however, effectively preclude the use of non-licensed devices using these frequencies either in campus settings or across longer distances. The Commission should increase the permitted effective ranges for these devices within specified portions of the frequency bands under consideration as described further below and begin further study to determine whether such devices operating over longer distances would be compatible with incumbent users. NTIA does not believe, however, that the Commission should delay

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[3] The type of rules that the Commission develops in this proceeding will undoubtedly play a role in other areas as well. There will surely be other Federal-non Federal spectrum sharing opportunities in the future, and protocols and procedures developed here will serve there as they can here, allowing for maximum sharing while minimizing interference to and from incumbent Federal users.

implementation of initial community networks pending further proceedings.

Such an approach would encourage the development of devices for which many commenters have demonstrated a need.[4] It also would encourage the development of self-regulatory procedures among users of these non-licensed devices.[5] If the Commission's limited proposal is adopted as described in the NPRM, it could preclude any form of community networking and could limit the full potential for these devices. While wireless "inside wiring" is an important application, it is one of a wide range of applications that could and should be supported.

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[4] See, e.g., Comments of The Benton Foundation and Computer Professionals for Social Responsibility, filed July 15, 1996, at 3-4; and Joint Comments of the National School Boards Association, Media Access Project, National Education Association, American Association of School Administrators, and People for the American Way, filed July 15, 1996, at 3-4.

[5] The point-to-point communications links envisioned by some parties as part of community networking appear to be technically feasible within existing microwave allocations. Providers of community networks, however, may be unfamiliar with the regulatory process for obtaining, and intimidated by the cost of, such links. At the same time, many services provided today via licensed point-to-point microwave systems might migrate to the 5 GHz band if the Commission adopts a non-licensed regulatory scheme for that band. Although NTIA supports an allocation of spectrum on a non-licensed basis for community networking, a large scale migration by other users could lead to congestion and interference. This allocation cannot and should not become a substitute for other types of point-to-point microwave communications. NTIA encourages the Commission to streamline its regulatory processes to encourage greater use of all fixed point-to-point microwave bands.

II. NII/SUPERNET DEVICES HAVE GREAT POTENTIAL TO SERVE THE NEEDS OF SCHOOLS, LIBRARIES, HEALTH CARE PROVIDERS, AND OTHER COMMUNITY SERVICE ORGANIZATIONS.

The Administration has established a national goal to connect all of the nation's classrooms, libraries, hospitals, and clinics to the NII by the year 2000.[6] This initiative, which promotes expanded access to computers, teacher training, and the development of compelling educational applications, has the potential to revolutionize our educational system, changing the way teachers teach and students learn. Students will be able to collaborate with their peers around the world, search digital libraries, use remote scientific instruments, and take "field trips" to on-line museums.

As NTIA stated in its letter to the Commission in response

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[6] To this end, NTIA's Telecommunications and Information Infrastructure Assistance Program (TIIAP) provides matching funds to more than 200 projects throughout the United States to promote community-based network infrastructure development. Moreover, NTIA envisions using schools, libraries, and other "community access centers" (CACs) as a way of furthering universal access to advanced telecommunications and information services. See Reply Comments of the National Telecommunications and Information Administration, CC Docket No. 95-115, filed March 29, 1996, at 23. Other Executive Branch departments and agencies also have programs to advance this goal. The U.S. Department of Education, for example, has a number of programs including National Challenge Grants for Technology in Education (which awards grants to promote the integration of acquired technology in to curriculum), the Star Schools Program (which supports telecommunications partnerships to provide telecommunication equipment and programming to underserved students), and the Public Library Construction and Technology Enhancement program (which provides grants to States for facilities and technology enhancements to improve public libraries).

to the Apple/WINForum petitions for a rulemaking proceeding, NTIA believes that NII/SUPERNet devices could provide an important means of access to the NII, as wireless networks provide important advantages relative to wired networks, including greater affordability, ease of implementation, and mobility.[7] Schools, hospitals, small businesses, and others would thus have convenient access to communications networks with voice, video, data, and graphics capabilities without the expense and disruption that installing wired systems would require. NTIA has long sought to advance telecommunications and information services for all Americans, and NII/SUPERNet devices would further these goals. They could provide maximum flexibility and choice for users in meeting a wide variety of needs. Use of such devices can be supported while avoiding harmful interference and promoting spectrum efficiency. The Commission should seek to advance that potential to the fullest extent possible.

In addition to connecting schools and other existing public institutions, non-licensed NII/SUPERNet devices have the potential to support new types of services within communities. They could provide a new and vital link within and among individuals, families, social clubs, and community support groups. Except for necessary technical and operational standards, the use of these devices would be unmediated by

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[7] See Letter from Larry Irving, Assistant Secretary of Commerce for Communications and Information, to Chairman Reed Hundt, RM 8648 and RM 8653, November 2, 1995.

service providers and thus would allow free rein to the imaginations and needs of user communities.

III. THE COMMISSION IS PROPERLY CONCERNED ABOUT INTERFERENCE IN THE 5 GHZ BAND BUT CAN ADDRESS THESE CONCERNS THROUGH AN APPROPRIATE TECHNICAL SCHEME

A. The Commission Should Limit the Extreme Upper and Lower Portions of the Proposed Bands to Low-Powered Non-Licensed Wireless Network Devices But Should Permit Longer Range Community Network Applications in the 5250-5350 and 5725-5850 MHz Bands.

1. Extreme Upper and Lower Portions of the Band

The 5150-5350 and 5725-5875 MHz bands proposed for NII/SUPERNet devices are allocated and used by the Federal Government for various radiodetermination services on a primary basis.

The lower 5150-5250 MHz portion is allocated on a worldwide primary basis for the aeronautical radionavigation service. Although there is experimental use of potential future next-generation systems in the band, there are at present no aeronautical radionavigation systems in this band used on an operational basis. Continued experimentation and possible development of new operational air traffic control systems in this band is expected to continue, however, and safety-of-life considerations therefore preclude any applications in this band that would cause interference. In addition, the 5850-5875 MHz portion of the band is used for the Department of Defense's transportable earth stations and also is being considered to

support an element of the Intelligent Transportation System. The Commission must therefore retain the 0.1 Watt e.i.r.p. limit in the 5150-5250 MHz and 5850-5875 MHz subbands.[8] This would permit the development of short-range wireless substitutes for inside wiring within structures, but would preclude the development of longer range networks in these bands.[9]

2. The 5250-5350 and 5725-5850 MHz Bands

NTIA believes that community networking should be an integral part of the NII/SUPERNet concept, and that the remaining (5250-5350 and 5725-5850 MHz) bands are well-suited to this application. In these bands, authorizing community networks having a range comparable to the 1 to 2 kilometer to be used by the European-developed HIPERLAN systems is expected to satisfy many of the wireless LAN's and campus-type community network requirements while also promoting international interoperability. As discussed further below, coexistence between NII/SUPERNet devices and incumbent radar devices is expected to be possible in most areas of the country. Successful operation of community network links, however, will depend on geographic separation from the high-powered radar systems operating in the band.

The 5250-5350 and 5725-5850 MHz portions of the proposed

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[8] The acronym "e.i.r.p." stands for "equivalent isotropic radiated power."

[9] This would be compatible with the proposal made by Apple in this proceeding.

bands are allocated for the Federal radiolocation service and are primarily used by military defense radars. These radars are characterized by very high peak power levels with an e.i.r.p. of up to 110 dBW, pulse modulation, and high-gain antennas that sweep 360 degrees in azimuth. These radar systems are used on land, typically near military facilities, on board ships in coastal areas, on airplanes, and on spacecraft. Billions of dollars have been invested in the research and development of radar systems that operate in these bands. Federal radar systems must continue to operate in these bands to meet essential national defense and training requirements. (Further description of those Federal systems is contained in the attachment to this pleading). All efforts should be made to avoid operating community network links near the military test ranges described in the attachment to this pleading.

Even longer range, 10-30 km, unlicensed community networks in the 5 GHz bands have been proposed. Although the 5725-5850 MHz portion of these bands is a potential candidate for such operation, examining compatibility with existing radar is a more complex undertaking, which requires greater study and analysis. Further complicating this situation is the ongoing FCC rulemaking proceeding in ET Docket No. 96-8 to authorize long range unlicensed links using spread spectrum techniques in this same band. Compatibility analyses of long range links with existing radar must still be completed for both NII/SUPERNet and

spread spectrum systems. The Commission has asked that parties report on the experience gained in operating the devices it authorizes in this proceeding. The Commission should permit experimental tests of the 10-30 km community networks to proceed in the 5725-5850 MHz band and should move to adopt final rules allowing such networks as soon as data becomes available demonstrating the feasibility of such uses.

B. The Commission Must Ensure Adoption of Appropriate Receiver Equipment and Spectrum Sharing Rules as Well as Bandwidth Efficiency Rules

1. Appropriate Receiver Equipment and Spectrum Sharing Rules to Protect All Users in the 5 GHz Band

The use of NII/SUPERNet devices in the 5 GHz bands raises issues both in terms of potential interference from incumbent radars to these devices as well as the potential degradation resulting from the aggregate effects from a large number of these devices to radar performance. While these devices will be authorized on a non-interference basis to the primary radio services in the band, practical considerations suggest that the design of these devices must take into account the existing radio environment in which they will operate.[10] NTIA believes that

[10] NTIA's experience has shown that, despite the fact that unlicensed devices operate on a secondary basis and are supposed to accept interference to some extent, consumers do strenuously object when the operation of consumer devices is interfered with by Government operations. There have been many such instances of interference to non-licensed devices, such as garage door openers, cordless telephones, and security devices, that stemmed from a lack of quality in the design of the receiver.

the adoption of robust receiver design, either by Commission rules or via industry-developed standards, is essential to successful operation of these devices in these bands.

Receiver design techniques that have proven effective against high-power, pulse signals include listen-before-talk techniques, spread spectrum techniques, peak signal limiters, high efficiency error correction, bit interleaving, and error detection with retransmission protocols. Experience has also shown that digital systems operating in or adjacent to bands used by radar systems must incorporate adequate receiver selectivity to achieve satisfactory system performance.

NTIA also supports the Commission's proposal to adopt channel monitoring protocols for NII/SUPERNet data transmission. Such protocols, used in conjunction with dynamic channel selection, can be very effective in minimizing interference, both to and from radars, <u>if implemented in such a way as to adequately detect radar signals typical for the band.</u> The combination of effective receiver design and user protocols can help ensure that spectrum is shared successfully between government and other users. Therefore, the Commission should either mandate receiver standards for the non-licensed devices or require that such standards be adopted by the industry. NTIA plans to be an active participant in WINForum's 5 GHz Sharing Rules Drafting Subcommittee to assist in the development of these rules and

protocols.

2. The Commission Should Implement Bandwidth Efficiency Standards

NTIA agrees with the Commission that there should be some value of minimum bandwidth efficiency applicable to the NII/SUPERNet devices. The justification provided by one of the petitioners in this proceeding for the amount of spectrum needed to satisfy the requirement was based on 1 bit per second per Hertz of bandwidth (b/s/Hz). A bandwidth efficiency of 2 b/s/Hz is currently obtainable at a reasonable cost, however. If a modulation scheme that is more bandwidth efficient, such as the $\pi/4$ Differential Quadrature Phase Shift Keying ($\pi/4$ DQPSK) adopted by the cellular industry, were employed, the available spectrum could support larger numbers of users. We recognize, of course, that overall spectrum efficiency is measured in more than just bits/second/Hertz, but includes an area element as well.

Adoption of a strict bandwidth efficiency at the outset of a new service, however, may have a dampening effect on its rapid implementation. A more practical approach would be adoption of effective bandwidth efficiency requirements that would come into effect at some reasonable future date such as three years from the conclusion of this rulemaking. This would help to achieve both goals, that of fostering the rapid development of the NII/SUPERNet devices, while also promoting more spectrum-efficient operation as the technology matures.

IV. CONCLUSION

NTIA applauds the Commission for undertaking this proceeding at this time. The results could have a profound impact on the way individuals, groups and public institutions communicate and on the realization of this nation's goal of universal access for all Americans. NTIA urges the Commission to adopt rules that support a range of in-building and short range community networking configurations (except in the 5150-5250 and 5850-5875 MHz bands, which are suitable for low-power in-building use only), including implementation of rules to ensure receiver standards and protocols to enhance sharing capabilities. Although there may be interference issues, the Commission should not delay unnecessarily development of initial community networks pending further proceedings to study the feasibility of longer range networks in these bands.

Respectfully submitted,

Barbara S. Wellbery (BH)
Barbara S. Wellbery
Chief Counsel

Bruce A. Henoch
Bruce A. Henoch
Attorney

Larry Irving
Assistant Secretary for
Communications and Information

Shirl Kinney
Deputy Assistant Secretary

Kathryn C. Brown
Associate Administrator
Joseph Gattuso
James McConnaughey
Office of Policy Analysis
and Development

Gerald F. Hurt
Chief
Edward F. Drocella
Spectrum Engineering and
Analysis Division

Charles W. Franz
Office of Policy
Coordination and Management

National Telecommunicationsand
Information Administration
U.S. Dept. of Commerce, Rm 4713
Washington, D.C. 20230
(202) 482-1816

August 14, 1996

ATTACHMENT

DISCUSSION OF TECHNICAL ISSUES INVOLVING THE PROPOSED NII/SUPERNet DEVICES IN THE 5 GHz BAND

By
E. Drocella
NTIA/SEAD

This paper discusses the technical issues related to the Notice. The following paragraphs will give an overview of each issue, with the supporting technical discussion provided in Appendices A through D.

FEDERAL SPECTRUM USAGE

The 5150-5350 MHz and 5725-5875 MHz bands are allocated on a primary basis for radiodetermination services and are used primarily by the Federal Government for high-powered radar systems. The frequency assignment distribution plot in Appendix A indicates that the 5725-5875 MHz band is more heavily used than the 5150-5350 MHz band. This is supported by the spectrum use measurements, which show that the NII/SUPERNet devices will encounter significantly higher signal levels in the 5725-5875 MHz band as compared with the 5150-5350 MHz band. A more detailed discussion of the Federal spectrum usage is provided in Appendix A.

Radar transmitters that operate in the 5 GHz frequency range are characterized by very high peak EIRP levels of up to 110 dBW (100 billion Watts), pulse modulation, and high-gain antennas that sweep 360 degrees in azimuth. The high emission levels can increase the bit error rate of the digital NII/SUPERNet receivers. In the case of radar interference from a rotating antenna, the degradation of NII/SUPERNet receiver performance will appear in the form of regular bursts of bit errors that correspond to the scan rate of the radar antenna. Because of the higher concentration of radars in the 5725-5875 MHz band, the effects of radar transmitter emissions and burst interference will be more significant than in the 5150-5350 MHz band.

The FAA has a radionavigation system that operate in the band adjacent to the lower band proposed for NII/SUPERNet operation. The FAA's Microwave Landing System (MLS) operates in the 5000-5150 MHz band. Although there are currently no aeronautical radionavigation systems operating in the 5150-5250 MHz band segment, the FAA maintains that this spectrum is needed to satisfy future requirements for air traffic control systems. The 5000-5250 MHz band is allocated on a primary basis for aeronautical radionavigation and it should be understood that since the NII/SUPERNet devices are unlicensed, they cannot cause interference to and will not receive any protection from harmful interference created by future aeronautical radionavigation systems.

NII/SUPERNet INTERFERENCE MITIGATION CAPABILITY

The technique of monitoring a channel prior to transmitting data and searching for an available channel can be very effective techniques for avoiding mutual interference with radars, if implemented to adequately consider typical radar signal characteristics. In the Notice, the proposed spectrum etiquette procedure identifies a listen-before-talk and a spectrum search feature. The listen-before-talk feature requires the system to monitor the spectrum window (channel) for 50 microseconds with a reaction time (integration time) on the order of 40 microseconds. If these same parameters are employed for the spectrum search feature, it will fail to detect radar signals present in the channel. In searching for an available channel that is free of co-channel radar signals, a monitoring period of at least 1 millisecond and a reaction time on the order of 1 microsecond would be required. Because of the duration of the radar antenna scan rate and narrow beamwidth it is unlikely that the channel monitoring scheme will detect a mainbeam radar signal. When radar signals are detected in a channel, an effective method of switching to an alternate frequency should also be implemented to reduce the likelihood of mutual interference. A more detailed discussion of the NII/SUPERNet spectrum monitoring function is provided in Appendix B.

Manufacturers of NII/SUPERNet devices should consider the radar characteristics described above in the design of their equipment to reduce the possibility of interference. Implementation of a robust receiver design to reduce the vulnerability of interference from high power radar systems is essential. Features such as spread spectrum modulation, peak signal limiters, high efficiency error correction, and bit interleaving have proven useful in a number of similar situations. Experience has shown that digital systems operating in or adjacent to bands used by high power radar systems must employ adequate radio frequency (RF) receiver selectivity to achieve satisfactory system performance. Receiver standards, either regulatory or industry developed, would be appropriate. Such technical considerations, as described above, incorporated early in the design of the NII/SUPERNet receivers would make them more compatible with high power radar transmitters.

AGGREGATE EFFECTS ON RADIODETERMINATION SYSTEM PERFORMANCE

In general the emissions of a single NII/SUPERNet device will not degrade radiodetermination system performance. The results of the analysis in Appendix C indicate that as the NII/SUPERNet devices proliferate, the power-sum aggregation of emissions from co-channel NII/SUPERNet transmitters can degrade the operational performance of a ground-based radar system. However, if the NII/SUPERNet devices employ listen-before-transmit and spectrum search procedures as discussed earlier, co-frequency use with radars can be minimized reducing the effects of aggregate interference. The results of the analysis also indicate that the aggregate effect of NII/SUPERNet transmitters will not cause interference to radionavigation systems operating in the adjacent 5000-5150 MHz band. The results of the aggregate interference analysis are based on a maximum equivalent isotopically radiated power (EIRP) limit for the NII/SUPERNet devices of -10 dBW. If higher EIRP levels are used by the NII/SUPERNet devices, the aggregate interference levels given in Appendix C will increase. Furthermore, depending on the extent of outdoor community network use, the aggregate interference levels computed in this analysis could increase

significantly.

The out-of-band emission limit of 50 dB proposed by the Commission for the NII/SUPERNet transmitters appears to be a reasonable value and should be sufficient to preclude interference to adjacent band radionavigation systems. This limit for out-of-band emissions is consistent with other digital and unlicensed device standards.

PROPOSED BANDS FOR NII/SUPERNet OPERATIONS

The justification for the requirement for 350 MHz of spectrum for the NII/SUPERNet devices appears to be based on a spectrum efficiency of 1 b/s/Hz. If a more spectrum efficient modulation scheme, such as B/4 DQPSK with a theoretical bandwidth efficiency of 2 b/s/Hz, were employed in the design of the NII/SUPERNet devices the stated spectrum requirements could be satisfied in less than 200 MHz. Employing spectrum efficient modulation techniques in the NII/SUPERNet design would benefit all users by allowing more devices to operate in the same geographic area. The European HIPERLAN standard has 150 MHz allocated in the 5150-5300 MHz band. To maintain global compatibility an allocation of 5150-5350 MHz for U.S. NII/SUPERNet operations would seem appropriate. However, to protect the development of the next generation of air traffic control systems it is recommended that community network operations should not be permitted in the 5150-5250 MHz band segment. Similarly, to reduce the potential impact on communication systems supporting the Intelligent Transportation System and the military's transportable satellite terminals, it is recommended that community network operations should not be permitted in the 5850-5875 MHz band segment. In the 5250-5350 MHz and 5725-5850 MHz bands community network operations having communication ranges of 1 to 2 km comparable to those allowed by the European HIPERLAN system should be permitted. Successful operation of community network links will depend on geographic separation from the high-power radar systems operating in the band. All efforts should be made to avoid operating community network links near the military test ranges specified in Appendix D.

The emphasis has been on unlicensed equipment to support community networking operation. However, the compatibility of the longer range community network operations in the 5 GHz frequency range has not been addresses. The longer range community network operations could be supported by licensed equipment in the 18, 23, or 38 GHz bands, where spectrum and equipment are readily available.

APPENDIX A
FEDERAL SPECTRUM USAGE

The radaiodetermination service has two parts: the radiolocation service and the radionavigation service. The 5150-5350 MHz and 5725-5875 MHz bands are proposed in the Notice for NII/SUPERNet device operation. As stated in a recent NTIA report, the spectrum requirements for radiolocation systems operating in the 5250-5925 MHz frequency range and future radionavigation systems in the 5000-5250 MHz band are expected to continue.[1] In order to gain a better understanding of the potential interference problems that may be encountered by NII/SUPERNet devices, the Federal radiodetermination environment is discussed in greater detail.

RADIOLOCATION ASSIGNMENT DISTRIBUTION

The 5250-5925 MHz frequency range is allocated to the radiolocation service on a primary or secondary basis in six bands. The Department of Defense (DoD) radiolocation systems operating in these bands can be broadly divided into three categories: ground-based radar stations (fixed and mobile), shipborne radar stations, and airborne radar stations. Ground-based radar systems represent the largest category of radars in the 5 GHz band.

A distribution of the frequency assignments from the Government Master File for the 5150-5350 MHz and 5725-5875 MHz bands are shown in Figure A-1. As it can be seen from Figure A-1, there are many more frequency assignments in the 5725-5875 MHz band. While this information is presented in terms of the number of frequency assignments, it should be noted that the number of actual radio equipment will exceed, and sometimes far exceed the number of assignments in the band.

As documented in an NTIA report[2], in the 5350-5650 MHz band there are also 150 frequency assignments for non-Government weather radars and 190 frequency assignments for Government weather radars deployed throughout the United States. These radars, although not operating in the

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[1] U.S. Department of Commerce, NTIA Special Publication 94-31, *U.S. National Spectrum Requirements: Projections and Trend* (March 1995).

[2] U.S. Department of Commerce, NTIA Report 90-260, *Ground-Based Weather Radar Compatibility with Digital Radio-Relay Microwave Systems* (March 1990).

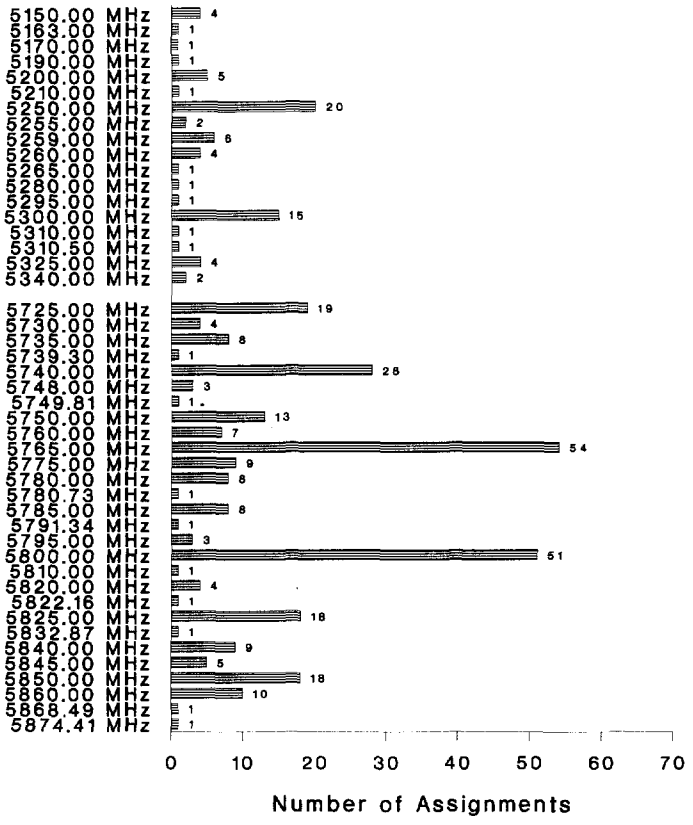


FIGURE A-1. Distribution of Frequency Assignments in the 5150-5350 MHz and 5725-5875 MHz Bands[3]

[3] The actual number of equipment often exceeds the number of frequency assignments.

proposed NII/SUPERNet bands, have relatively high levels of spurious emissions that fall within the proposed NII/SUPERNet bands.

MEASURED RADIOLOCATION SPECTRUM USAGE

Radar spectrum usage in the 5250-5925 MHz bands has been monitored in four major cities.This information is useful to indicate the extent and signal levels likely to be encountered by NII/SUPERNet devices. The results of these measurements are shown in Figures A-2 through A-5. The three curves shown in Figures A-2 through A-5 represent maximum peak, mean peak, and minimum peak signal levels received at each frequency. The measurements show that high signal levels will be encountered from the radars operating in the 5725-5875 MHz band.

RADIOLOCATION EQUIPMENT CHARACTERISTICS

The radars operating in the 5250-5925 MHz frequency range are characterized by high EIRP[4] (50-110 dBW), pulsed emissions, with transmitter spurious emission levels that can be significant. The high EIRP of these radars results in large interference ranges that could exceed several hundred kilometers for airborne and shipborne radars.

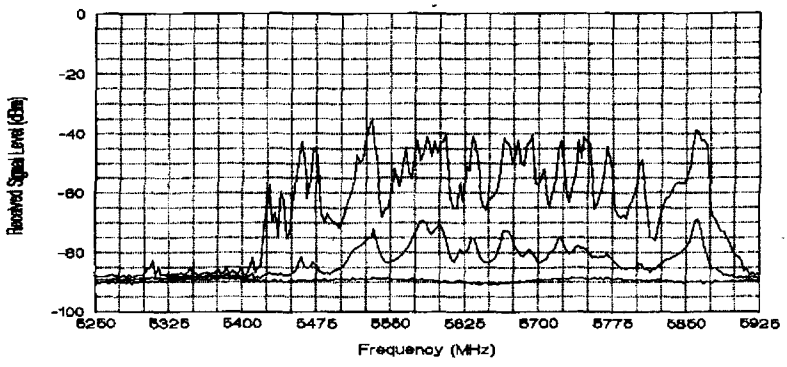
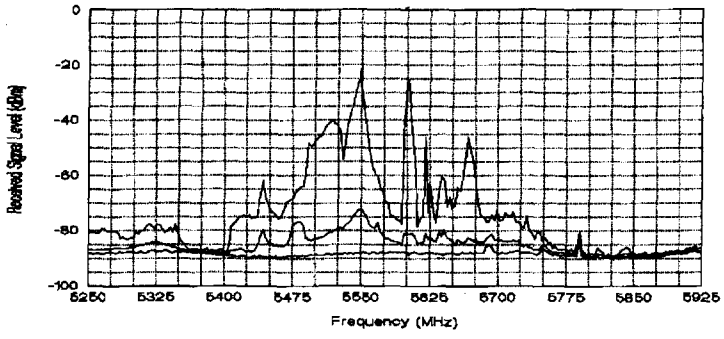


FIGURE A-2. NTIA Spectrum Survey Graph Summarizing the 5250-5925 MHz Frequency Range at Los Angeles, CA, 1995.



[4] Equivalent Isotopically Radiated Power (EIRP) is the gain of a transmitting antenna multiplied by the net power accepted by the antenna from the connected transmitter.

FIGURE A-3. NTIA Spectrum Survey Graph Summarizing the 5250-5925 MHz Frequency Range at San Francisco, CA, 1995.

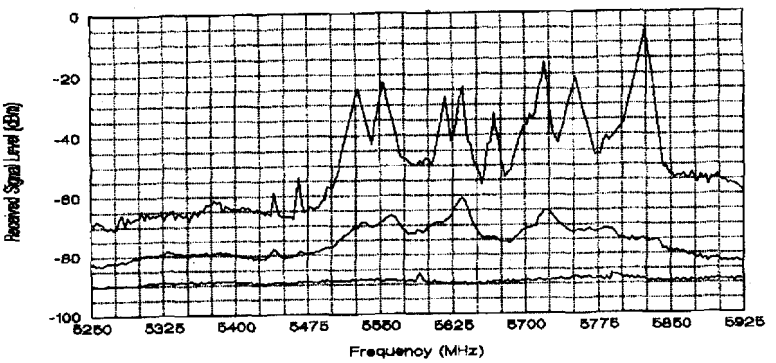


FIGURE A-4. NTIA Spectrum Survey Graph Summarizing the 5250-5925 MHz Frequency Range at San Diego, CA, 1995.

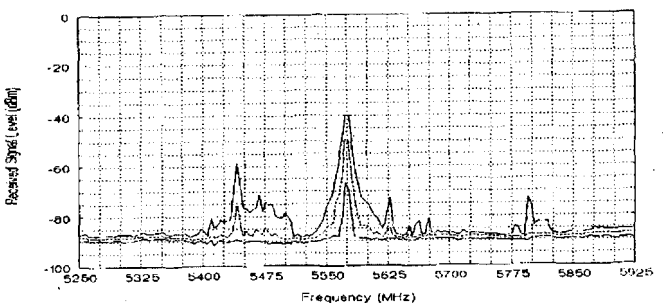


FIGURE A-5. NTIA Spectrum Survey Graph Summarizing the 5250-5925 MHz Frequency Range at Denver, CO, 1993.

Nominal technical characteristics for the radars operating in the 5250-5925 MHz frequency range are provided in Table A-1.

TABLE A-1. Nominal Characteristics for Radars in the 5250-5925 MHz Bands

Radar Type	EIRP (dBW)	Pulse Rate (kpps)	Pulse Width (usec)	Linear FM Chirp (MHz)	Emission Bandwidth (MHz)	Receiver Bandwidth (MHz)	Noise Figure (dB)
Ground	100 74	100 1	1 .2	none none	54 5	25 5	5 5
Airborne	56	4	4	120	130	150	5
Shipborne	75	15	4	none	0.25	0.27	5
Weather	110	2	1.5	none	1.6	0.9	3.5
Space Shuttle	77	2	34	20	20	20	6
Orbital	49	1	100	320	320	15	5

Adjacent Band Issues

One of the inherent characteristics of a radar transmitter is their high level of spurious

emissions. Transmitter spurious emissions are of particular concern because they can extend to frequencies 100 MHz or more from the transmitter fundamental frequency possibly causing interference to several NII/SUPERNet channels at the same time. The predominant factor that governs the level of spurious emissions from a radar transmitter is the output device used in the radar (also referred to as an output tube). Knowledge of the inherent spurious emission characteristics of various types of output tubes used in radar transmitters is essential to assessing the potential for interference from radars utilizing these tubes to digital receivers operating in adjacent bands. The spurious emission levels for the various types of microwave tubes used in radars are given in Table A-2.[5] Radar transmitter spurious emissions can increase the Bit Error Rate (BER[6]) of a digital receiver. Based on the measurements shown in Figures A-2 and A-4, the levels of spurious emissions are significantly higher in the 5725-5875 MHz band. In general, coupling that results from radar transmitter spurious emissions is limited to distances of less than several kilometers depending on the output device.

TABLE A-2. Radar Output Device Spurious Emission Characteristics

Output Device	Spurious Emission Level
CROSSED-FIELD	
Magnetrons (unlocked)	-65 to -80 dBc
Magnetrons (locked)	-75 to -90 dBc
Coaxial Magnetrons	-60 to -75 dBc
LINEAR BEAM	
Coupled Cavity TWT	-105 to -115 dBc
Klystron	-110 to -120 dBc
Twystron	-105 to -115 dBc
SOLID STATE TRANSISTORS	
Si Bipolar	-100 to -110 dBc
GaAs FET	-100 to -110 dBc

Burst Interference

The antennas associated with radar systems operating in the 5 GHz frequency range have the ability to sweep 360 degrees in azimuth. The effect of this type of pulsed interference differs from continuous interference. In the case of continuous analog or digital interference into a digital receiver, the receiver encounters a simple increase of the minimum signal threshold. In the case of

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[5]U.S. Department of Commerce, NTIA Report 94-313, *Analysis of Electromagnetic Compatibility Between Radar Stations and 4 GHz Fixed Satellite Earth Stations* (July 1994); Document Radiocommunication Study Group 9A(draft), *Effects of Unwanted Emissions from Radar Systems in the Radiodetermination Service on Systems in the Fixed Service*, (March 1996).

[6] Bit Error Rate (BER) is a performance measure applied to digital systems and may be defined as the number of erroneous bits received divided by the total number of bits transmitted.

radar interference from a rotating antenna, the effect is to create an additional received signal threshold below which the receiver regularly and periodically may experience error bursts when the radar is operating. The degradation of the digital receiver will appear in the form of regular bursts of bit errors. The repetition rate of these bursts corresponds to the scan rate of the radar antenna, typically every 3 to 20 seconds.

AERONAUTICAL RADIONAVIGATION USAGE

The Microwave Landing System (MLS) is a joint development of Department of Transportation (DOT), DoD, and National Aeronautics and Space Administration (NASA) under Federal Aviation Administration (FAA) management. Its purpose is to provide a civilian/military, Federal/non-Federal standardized airport approach and landing system with improved performance. The MLS is not being phased out by the U.S. in favor of differential Global Positioning System (GPS), as stated by WINForum in their petition for rule making. In fact, there are plans for at least 26 MLS installations and possibly many more at Category II and III runways. In addition, the DoD has a significant number of MLS installations.

In the Notice, the Commission agrees with NTIA and the FAA that air safety services must be protected from harmful interference and therefore are not proposing to allocate the 5100-5150 MHz band for NII/SUPERNet device operation. However, the Commission believes that NII/SUPERNet devices can operate above 5150 MHz without causing harmful interference to aeronautical radionavigation systems if appropriate maximum power and out-of-band emission limits are adopted.

Although there are currently no operational aeronautical radionavigation systems in the 5150-5250 MHz band segment, the FAA maintains that this spectrum is needed to satisfy future requirements for air traffic control systems. The 5000-5250 MHz band is allocated on a primary basis for aeronautical radionavigation and it should be understood that since the NII/SUPERNet devices are unlicensed, they cannot cause interference to and will not receive any protection from harmful interference created by future aeronautical radionavigation systems.

DEPARTMENT OF DEFENSE SATELLITE OPERATIONS

In the Fiscal Year 1992 Defense Appropriation Act, Congress directed DoD to study its long-term communications needs and to determine to what degree and how industry believes these needs could be met by projected commercial systems. In response, DoD carried out the Commercial Satellite Communications Initiative (CSCI) under the executive direction and management of the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (ASD (C3I)) during the period November 1991 to December 1993.

To accomplish the goals established by the CSCI, DoD will require both commercial fixed-satellite and mobile-satellite communications services. The CSCI policy specifically requires that, to the extent practical, all new military transportable earth stations shall have access to the 6/4 GHz

commercial frequency bands. In compliance with the CSCI's policy, DoD has developed the Light-Weight Multi-Band Satellite Terminal (LMST) and the Transportable TROJAN SPIRIT II Satellite Communications Terminal. Both of these satellite terminals operate in the 5850-6425 MHz band. The highly transportable nature of these satellite earth stations will make it difficult to predict interference interactions with co-frequency NII/SUPERNet devices. Nominal characteristics for the DoD's transportable earth stations are provided in Table A-3.

TABLE A-3. Nominal Characteristics for Military Transportable Earth Stations

Equipment	Frequency Range (MHz)	Power (W)	Emission Bandwidth (kHz)	Antenna Gain (dBi)	Azimuth Beamwidth (degrees)	Elevation Beamwidth (degrees)
Earth Station 1	5850-6425	50	512	42	1.3	1.3
Earth Station 2	5850-6425	350	512	42	1.34	1.34

SUMMARY

The frequency assignment distribution plot indicates that the 5725-5875 MHz band is more heavily used than the 5150-5350 MHz band. This is supported by the spectrum use measurements that show NII/SUPERNet devices will encounter significantly higher signal levels in the 5725-5875 MHz band as compared with the 5150-5350 MHz band.

Radar transmitters that operate in the 5 GHz frequency range are characterized by high power levels and antennas that can sweep 360 degrees in azimuth. The high emission levels can increase the BER of the digital NII/SUPERNet receivers. In the case of radar interference from a rotating antenna, the degradation of NII/SUPERNet receiver performance will appear in the form of regular bursts of bit errors that correspond to the scan rate of the radar antenna. Because of the higher concentration of radars in the 5725-5875 MHz band, the effects of radar transmitter spurious emission and burst interference will be significant compared to the 5150-5350 MHz band.

The FAA has a radionavigation system that operates in the band adjacent to the lower band proposed for NII/SUPERNet operation. The FAA's MLS operates in the 5000-5150 MHz. This system performs safety-of-life functions and must be protected from harmful interference. The FAA maintains that the 5150-5250 MHz band is required for future expansion of aeronautical radionavigation systems.

The military also operates their transportable satellite earth station terminals, the LMST and TROJAN SPIRIT II, in the 5850-6425 MHz band.

APPENDIX B
NII/SUPERNet INTERFERENCE MITIGATION CAPABILITY

As stated in the Notice, the NII/SUPERNet devices will employ digital modulation. There has been a significant increase in the number of documented cases of high EIRP radar transmitters interfering with digital receivers. Investigations by NTIA[7] of several interference cases have identified two types of radar transmitter interference into digital receivers: receiver front-end overload caused by the radar transmitter fundamental frequency and radar transmitter spurious emissions into the bandwidth of the digital receiver. Based on these studies it was determined that the effect of radar pulsed emissions into digital receivers are a function of the coupling mechanism (front-end overload or spurious emissions), radar pulse train characteristics (peak amplitude, pulse width and the number of transmitted pulses), and the effect of the environment on the pulsed emissions (multiple coupling paths). In addition, the digital signal format (e.g., modulation type, multi-level signaling) and special signal processing circuitry (e.g., error correction coding, bit interleaving) influence the effects of the radar emissions.

SPECTRUM MONITORING

As stated in the Notice, as part of the spectrum etiquette procedures, the NII/SUPERNet devices must incorporate a listen-before-transmit feature and a search for available spectrum window (channel) feature. The listen-before-transmit feature requires the NII/SUPERNet device to monitor the channel for at least 50 microseconds (μsec) prior to data transmission with a maximum reaction time (integration time) on the order of 40 μsec. Other than starting the available channel search at the band edge, the details of the available channel search feature are not specified.

The technique of searching for an available channel can be a very effective technique in mitigating mutual interference with radar systems. However, to be effective it must be implemented to adequately detect typical radar signal characteristics. If the monitor period and reaction time proposed in the Notice are used in the available channel search, it will be ineffective in detecting radar use of the channel and in avoiding mutual interference with radars. Using the characteristics in Table A-1 of Appendix A, typical radar inter-pulse periods range from 10 to 1000 μsec. To effectively detect the pulsed radar signals in the band, a monitor period of at least 1 millisecond (msec) and a integration time of less than about 1 μsec would be required.

Because of the duration of the antenna scan rate and narrow beamwidth it is unlikely that the available channel search feature will detect a mainbeam radar signal. To be effective in detecting radar signals, the listen-before-talk and available spectrum search features (hereinafter referred to

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[7] NTIA 94-313 *supra* note 5; NTIA Report 90-260 *supra* note 2.