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

FCC 95-499

In the Matter of	)	
	)	
Amendment of Parts 2, 15, and 97 of the	)	
Commission's Rules to Permit Use of Radio	)	ET Docket No. 94-124
Frequencies Above 40 GHz for New Radio	)	RM-8308
Applications	)	

FIRST REPORT AND ORDER
AND
SECOND NOTICE OF PROPOSED RULE MAKING

Adopted: December 15, 1995; ; Released: December 15, 1995

Comments Due: **[60 days from date of publication in the Federal Register]**
Reply Comments Due: **[90 days from date of publication in the Federal Register]**

By the Commission:

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INTRODUCTION

1. By this action, we open for commercial development and use a portion of the "millimeter wave" frequency bands above 40 GHz.[1] The amendments to our rules set forth herein will encourage the development and use of new technology in commercial products and services. In this Report and Order, the first of several that will be forthcoming in this proceeding, we are making available a total of 6.2 GHz of spectrum in the 46.7-46.9, 59-64, and 76-77 GHz bands for unlicensed devices. These new frequency bands and associated standards will permit the development of vehicle radar systems that could be used in conjunction with Intelligent Transportation Systems (ITS)[2] and short-range, high capacity wireless radio systems that could be used for educational and medical applications, wireless access to libraries or other information databases.

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[1] The term "millimeter wave" is taken from the fact that the wavelength of radio signals for frequencies between 30 GHz and 300 GHz ranges from 10 millimeters down to 1 millimeter.

[2] ITS was formerly referred to as Intelligent Vehicle Highway Systems (IVHS).

2. It has been our experience that opening regions of the spectrum to commercial applications and new technology fosters the development and growth of new industries and promotes job creation. We believe that opening portions of the millimeter wave spectrum will similarly stimulate the development of new services for consumers and facilitate technology transfer from the military sector.[3] This action will also promote national competitiveness by enabling development of technology for potential use in other parts of the world.[4]

3. We are also issuing a Second Notice of Proposed Rule Making that addresses several issues relating to use of the 46.7-46.9 GHz, 59-64 GHz, and 76-77 GHz bands. First, we are proposing to restrict temporarily amateur use of the 76-77 GHz band in order to ensure that vehicle radar systems will not receive interference from amateur operations. To balance any perceived harm by amateur operators, we are proposing to upgrade the status of amateur operators in the 77.5-78 GHz band to co-primary with the radiolocation service. We are also proposing limits for emissions in the 200-231 GHz band to protect radio astronomy operations from potential interference. In addition, we are proposing to initiate the development of a spectrum etiquette technique that would minimize interference in the 59-64 GHz band. We view this proceeding as an ongoing process to develop appropriate policies that will ultimately provide new opportunities for businesses, and promote the interests of consumers by making available new communications products and services.

BACKGROUND

4. In the Notice of Proposed Rule Making (Notice) on radio operation above 40 GHz, we proposed to open a total of 18 GHz of spectrum between 40.5 GHz and 153 GHz for commercial development.[5] We specifically proposed thirteen frequency bands for potential use by new millimeter wave technology: 40.5-42.5 GHz, 47.2-48.2 GHz, 59-64 GHz, 71-72 GHz, 76-77 GHz, 84-85 GHz, 94.7-95.7 GHz, 103-104 GHz, 116-117 GHz, 122-123 GHz, 126-127 GHz, 139-140 GHz, and 152-153 GHz. We proposed to divide these bands between licensed services and unlicensed devices, with unlicensed spectrum further divided between unlicensed vehicle radar systems and general unlicensed devices.

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[3] For example, opening spectrum in the 2 GHz range for Personal Communications Services (PCS) has stimulated investment and technological development that promises to bring tremendous benefits to consumers.

[4] We note that other parts of the world, such as Europe and Japan, are also considering commercial uses of millimeter wave technology. Specifically, the Europeans recently adopted the 76-77 GHz band for vehicle radar systems.

[5] See Notice of Proposed Rule Making in ET Docket No. 94-124, 9 FCC Rcd 7078 (1994).

5. In proposing this division of spectrum, we recognized the potential benefits in licensing exclusive access to millimeter wave spectrum for the provision of certain kinds of telecommunication services.[6] Based on the demand for licensed services below 40 GHz, we proposed to designate all of the 40.5-42.5 GHz band and virtually all of the 47.2-48.2 GHz band for licensed use (except for a small portion that would be designated for vehicular radar use, as indicated below). We also proposed to make available for use portions of the bands above 64 GHz that are not designated for vehicular radar or general unlicensed use.

6. We also recognized that there is significant interest in developing millimeter wave technology for vehicle radar systems.[7] We proposed to make the 47.2-47.4 GHz, 76-77 GHz, 94.7-95.7 GHz, and 139-140 GHz bands available for vehicle radar systems operating on an unlicensed basis. We noted that establishing spectrum for vehicle radar systems is seen as an important initiative in the development of Intelligent Transportation Systems which is intended to offer significant benefits to the American public by improving highway safety.[8]

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[6] See Notice, at para. 13. The propagation of millimeter wave radio signals is more limited than that of radio signals at lower frequencies. Signals in the millimeter wave bands are significantly affected by the presence of oxygen and water vapor within the atmosphere. Absorption and scattering caused by oxygen and water vapor limit the range of millimeter wave transmissions to a few kilometers almost regardless of the power used. The amount of signal attenuation due to absorption and scattering varies with frequency and other factors. Attenuation caused by oxygen is significant throughout the millimeter wave spectrum, but increases dramatically at frequencies around 60 GHz and 120 GHz. Attenuation caused by water vapor varies based on temperature and relative humidity but generally increases with frequency. Rain, snow, hail, and fog can all affect the range of millimeter wave transmissions. See "Attenuation by Atmospheric Gases," International Telecommunications Union, Reports of the CCIR, 1990, Vol. V, Report 719-3, at pg. 189, for a more detailed discussion of atmospheric attenuation in the millimeter wave spectrum.

[7] General Motors Research Corporation (GM) submitted a Petition for Rule Making to provide the 76-77 GHz band for vehicle radar systems. Comments responding to GM's petition were filed by Ford Motor Company (Ford), Chrysler Corporation (Chrysler), VORAD Safety Systems, Inc. (VORAD) and the American Automobile Manufacturers Association (AAMA). These parties requested that further bands be made available for vehicle radar systems. For example, AAMA, which is comprised of Ford, Chrysler, and GM, requested use of spectrum in the 24.75-25.25, 37.5-38.5, 76-77, 92-95, 139-141, and 152-154 GHz bands. VORAD requested 200 MHz of spectrum within the 46-50 GHz band.

[8] We are also reviewing spectrum in other bands that could be available for ITS. For example, on February 3, 1995, we adopted a Report and Order to amend Part 90 of our rules by adopting regulations for a location monitoring service. See, Report and Order in PR Docket No. 93-61, 10 FCC Rcd. 4695 (1995).

7. Finally, we recognized that unlicensed use may be preferable for a portion of millimeter wave spectrum in order to meet the demand for a variety of low power communication devices.[9] To address this demand, we proposed to make available 5 GHz of spectrum in the 59-64 GHz band, as well as portions of the bands above 64 GHz, for general unlicensed devices. We noted that the extremely limited propagation range of the 59-64 GHz band, as well as higher millimeter wave frequency bands, suggests that these bands would be appropriate for general unlicensed devices.

DISCUSSION AND DECISIONS

8. In this First Report and Order, we are addressing the use of vehicle radar systems operating below 80 GHz and general purpose, unlicensed devices operating in the 59-64 GHz band. Licensed millimeter wave operation, vehicle radar operations above 80 GHz, and unlicensed operation in other millimeter wave frequency bands will be addressed in future decisions. Several commenters asked that we review spectrum below 40 GHz;[10] however, such requests are beyond the scope of this proceeding.

Vehicle Radar Systems

9. 46.7-46.9 GHz Band. In the Notice, we proposed to make available the 47.2-47.4 GHz band for vehicle radar systems.[11] This proposal was in part motivated by a request by VORAD Safety Systems, Inc. (VORAD) that we establish a 200 MHz band for vehicle radar systems somewhere within the 46-50 GHz band thereby permitting the rapid introduction of low cost millimeter wave vehicle radar systems. Such systems, according to VORAD, would be adapted using existing 24.125 GHz technology with a frequency doubler. Many radar devices, including police radars, operate at 24.125 GHz. The use of frequency doubling circuitry with the existing 24.125 GHz technology could allow the relatively low cost and speedy development of millimeter wave vehicle radar systems operating near 48 GHz.

10. In response to the Notice, the Telecommunications Industry Association (TIA) requests that we move the proposed frequency band for vehicle radar from 47.2-47.4 GHz to any 200 MHz segment in the range of 45-47 GHz to accommodate potential licensed

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[9] See Notice, at para. 14-15.

[10] For example, VORAD requests that we consider the 24.675-24.775 GHz band in this proceeding for use by vehicle radars. Epsilon Lambda requests that we establish bands at 24.0-24.25 GHz and 37.0-39.5 GHz to be used under Part 15 for spread spectrum operations.

[11] This band is currently allocated for Government and non-Government fixed, fixed-satellite, and mobile applications.

operations.[12] Alcatel Network Systems (ANS), the Association of American Railroads (AAR), Digital Microwave Corporation (DMC), Harris, Hewlett-Packard (HP) and the Millimeter Wave Advisory Group (mmWAG) generally support TIA's proposals. VORAD and HP recommend that we use the 46.7-46.9 GHz band for vehicle radar systems.[13] They indicate that this proposal would provide the amount of spectrum VORAD requested for its application and would also permit a small "cushion" of unlicensed spectrum in between the bands to provide added protection against interference.

11. Based on the comments, we now believe that the frequency band 46.7-46.9 GHz proposed by VORAD and HP would be a better choice for vehicle radar operations in this region of the spectrum than our original proposal. The use of this frequency band for vehicle radar systems addresses the concerns of TIA and others, and will provide additional flexibility in our decisions regarding licensed operations. Accordingly, we are making the 46.7-46.9 GHz band available for vehicle radar systems.[14]

12. 60-61 GHz Band. In response to the Notice, the Association for the Promotion of Millimeter-Wave Development and Utilization (APMDU), Fujitsu Ltd., Fujitsu Ten Ltd., Honda, Mitsubishi, the Research and Development Center for Radio Systems (RCR), and Toyota request that we authorize use of the 60-61 GHz band for vehicle radar systems. The APMDU indicates that the 60-61 GHz band is being considered by the Japanese Ministry of Posts and Telecommunications for vehicle radars and adds that the severe propagation losses in this band will reduce potential interference or crosstalk to other radio systems even when there is a high concentration of users in an area. Fujitsu Ltd. requests that the 60-61 GHz band be employed exclusively for vehicle radar. Fujitsu Ten Ltd. adds that this band would

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[12] For example, TIA requests that the 48.5-51.4 GHz band be allocated for fixed point-to-point use. TIA indicates that the European Conference of Post and Telecommunications Administrations (CEPT), which is responsible for setting European telecommunications standards, has made an interim allocation for fixed, point-to-point use of the 48.5-51.4 GHz and 55.2-58.2 GHz bands in Europe. TIA also requests that the 47.2-48.0 GHz band be allocated for licensed use.

[13] See VORAD and HP joint letter of August 18, 1995. VORAD and HP also suggest that the 45.6-46.6 GHz band should be reserved for general unlicensed operation. We are not addressing the 45.6-46.6 GHz band in this Report and Order. We intend to address in the future this proposal, along with the TIA proposals discussed in this paragraph. VORAD's and HP's request was not accompanied by a timely filed motion under Section 1.46 of our rules. However, no parties opposed or were prejudiced by the late-filed letter. Therefore, the Commission accepts VORAD's and HP's filing into the record of the proceeding as informal comments.

[14] Although we did not propose in the Notice to use this specific frequency band, we did invite comments on alternative bands and indicated that frequency bands may be altered in our final rules. See Notice, at para. 12 and n. 19.

provide a balance between the more costly components and materials necessary for higher frequencies and the smaller aperture of the antenna. The American Radio Relay League (ARRL) supports the use of 60-61 GHz for vehicle radars and indicates that the use of this band would avoid potential interference to amateur operations in the 76-77 GHz band. In addition, the AAMA indicates that it would not oppose also permitting vehicle radars in the 60-61 GHz band, provided the addition of this band would not cause us to eliminate any of the vehicle radar bands proposed in the Notice.

13. AT&T, HP, and mmWAG oppose the proposal to set aside the 60-61 GHz band for vehicle radar. AT&T expresses concern about the potential for interference from vehicle radar systems operating at 60-61 GHz to general unlicensed devices operating in the 59-64 GHz band.[15] Moreover, AT&T argues that the exclusive use of the 60-61 GHz band for vehicle radar would break up the 5 GHz of spectrum proposed for use by general unlicensed devices into two smaller bands that would be less useful. HP concurs, pointing out that vehicle radars would interfere with broadband communications devices unless given an exclusive band of their own. It further states that allowing vehicle radar use in the 60-61 GHz band would destroy the only contiguous 5 GHz of bandwidth available, or ever likely to be available, for short range broadband communications.[16] HP adds that spectrum sharing with radars is impossible, and that if the Commission were to set aside the 60-61 GHz band for vehicle radars, efforts to develop broadband communications systems in the 59-64 GHz would probably be abandoned. Both HP and mmWAG point out that the oxygen absorption band is ideally suited to short-range communications links, but confers no benefit to vehicle radar. AAMA points out that, from the perspective of the U.S. auto interests, the proposed 60-61 GHz band is not a viable alternative to the AAMA requested bands, nor is it being considered in Europe.[17]

14. An important goal of this proceeding is to foster the development of novel broadband communications systems. We believe that the 59-64 GHz band offers the greatest potential for allowing the development of short-range wireless radio systems with communications capabilities approaching those now achievable only with coaxial and optical fiber cable. Breaking up this band by providing an exclusive vehicle radar band at 60-61 GHz could potentially interfere with the development of important new applications. As discussed below, we believe that the sharing of vehicle radar spectrum with other services is not feasible. Accordingly, we will not authorize the use of the 60-61 GHz band for vehicle radar systems. We also note that, in this action, we are already making available 1.2 GHz of spectrum for vehicle radar systems, which we believe will satisfy the near-term spectrum requirements for these systems.

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15 See AT&T Comments at n. 5.

16 See HP Reply Comments.

17 See AAMA Reply Comments at 2.

15. 76-77 GHz Band. In the Notice, we also proposed to make the 76-77 GHz band available for vehicle radar systems. This band is allocated for Government/non-Government radiolocation systems and, on a secondary basis, to the Amateur Radio Service under Part 97 of our rules. We also asked for specific information regarding whether the entire 76-77 GHz band would be needed for vehicle radar systems.

16. The AAMA, the Federal Highway Administration (FHA), Ford, GM, GM-North American Operations, HP, the Intelligent Transportation Society of America (ITS America), and mmWAG support the use of the entire 76-77 GHz band for vehicle radar systems. The AAMA notes that typical systems currently under development require operating bandwidths of 200-500 MHz, with some requiring as much as 1 gigahertz of spectrum. The AAMA adds that more information can be extracted from the return signal when a wider bandwidth is used.[18] Specifically, the AAMA notes that for a vehicle radar to be able to locate the edge of a road to an accuracy of 1/10th of a lane width, a minimum bandwidth of 416 MHz is required. It further states that sufficient additional spectrum must be available to account for short-term and long-term frequency drift. GM concurs with AAMA's position, adding that the entire 76-77 GHz band is needed to reduce the probabilities of interference between units and decrease the manufacturing costs.[19] GM also submits that the 76-77 GHz band is desirable for product development because it offers an excellent trade-off between antenna size and component costs. GM further notes the additional benefit of enhancing the possibility of exporting units to the European market, since the 76-77 GHz band has already been chosen as a vehicular radar band in Europe.[20] ARRL states that it has no objections to the shared use of this band between amateurs and vehicle radar systems. However, it expresses concern regarding potential problems with sharing and indicates that it prefers that the 60-61 GHz band be used for vehicle radars.[21]

17. As demonstrated by the comments, there is significant industry support for use of the entire 76-77 GHz band for vehicle radar systems. Indeed, the three major U.S. automobile manufacturers have targeted this band in their efforts to develop collision avoidance radars. Furthermore, testing of vehicle radar systems operating in the 76-77 GHz range has already commenced. We also foresee economic benefits, such as economies of

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[18] AAMA notes that range resolution is inversely related to bandwidth. For example, they argue that for automatic cruise control systems, typical resolution requirements are 0.5 meters to 2 meters, translating into a bandwidth of 75 to 300 MHz. See AAMA comments, at 9-11.

[19] See GM Comments at 16-21.

[20] See GM Comments, at 3.

[21] The proposal from ARRL, as well as similar proposals from APMDU, Fujitsu Ltd., Fujitsu Ten Ltd., Honda, Mitsubishi, RCR, and Toyota, to employ the 60-61 GHz band for vehicle radar is discussed above.

scale and broader marketplace demand, that may be attained if both the U.S. and European markets use the 76-77 GHz band for vehicle radar systems. Accordingly, we are making this band available for use by vehicle radar systems.

18. Sharing Between Vehicle Radars and Other Applications. Due to the safety nature of vehicle radar systems and the lack of experience of such systems sharing with totally different technologies, we tentatively concluded in the Notice that bands should be made available for exclusive use by vehicle radar systems until spectrum sharing criteria were developed.[22] AAMA, Epsilon Lambda, Ford, HP, mmWAG, and VORAD support this proposal. VORAD points out that vehicle radar systems will be used for collision warning, automatic cruise control, automatic braking plus other longitudinal and lateral vehicle control applications. In such applications, VORAD stresses the necessity of preventing false alarms that could result from shared use of the spectrum. VORAD adds that vehicle radar manufacturers can develop interference avoidance systems to cope with other vehicle radar systems on the road, but if the band is shared with unlimited emitters and users, it will be much more difficult, and therefore more costly, to design interference avoidance schemes for all possibilities. HP indicates that it would be impractical for vehicle radar systems to share spectrum with licensed services.

19. ARRL objects to limiting the 76-77 GHz band to vehicle radar systems, noting that it wishes to maintain the existing amateur allocations from 75.8-81 GHz in order to spur development of short-range, high-speed data links. ARRL also recommends that we revise the proposed Table of Frequency Allocations in 47 CFR Section 2.106 to clearly indicate that only the 76-77 GHz portion of the amateur band would be used by vehicle radar systems. In the Notice, we proposed to permit Part 15 vehicle radar systems to operate in the 76-77 GHz band. However, the band of operation referenced in the Table of Frequency Allocations covers 76-81 GHz. Thus, ARRL is concerned that there could be a misunderstanding that our original proposal to amend 47 CFR Section 2.106 would permit unlicensed devices to operate throughout the 76-81 GHz band. Ford, in its reply comments, opposes the continued use of the 76-77 GHz band by amateur operators because of the public safety benefits of vehicle radar systems and the statement in ARRL's comments that "[p]rotection of vehicular radar systems by amateurs would be impossible...."[23] GM generally supports the proposal to limit use of the 76-77 GHz band to vehicle radar systems, but states that such systems would not be adversely affected if we permitted amateurs to continue using the bands. GM states that the anticipated amateur uses would result in power densities on public roads that are well below the levels that would cause any concern to the reliable operation of vehicle radars.

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[22] We did not, however, propose to change the existing allocation that permits Amateur Radio Service use of this band.

[23] See Ford's reply comments at para. 2 and ARRL's comments at n. 2.

20. Because of safety considerations, we agree with commenters that unlicensed use of the 76-77 GHz band should be limited for the time being to vehicle radar systems. In addition, as discussed below in the Second Notice of Proposed Rule Making, we also propose to temporarily restrict amateur use of the band until sharing criteria can be developed. We anticipate that vehicle radar systems may eventually be used for vehicle control, and this heightens our safety concerns regarding possible interference to these systems. Because the development of vehicle radar systems is still ongoing, it is difficult at this time to develop appropriate sharing criteria. While we are concerned about safety considerations, unlicensed bands are generally allocated to uses which can co-exist without causing detrimental interference. In the future, we expect that there will be non-vehicle radar systems which can successfully operate in these bands without causing interference. However, we wish to ensure that vehicle radar systems will have sufficient spectrum and design flexibility to develop their systems successfully, so that at this time we are restricting use of the band to vehicle radar systems. Even though there may be multiple vehicle radar systems, we feel the number of systems and their method of operation will permit them more easily to coordinate non-interfering sharing criteria than if we were to allow any type of system into the band. In the future, we expect other types of systems to operate in this band and wish to encourage the design of vehicle radar systems that will facilitate such sharing. Finally, in order to avoid confusion, we are amending Section 2.106 of the Rules, as requested by ARRL, to clarify that vehicle radar systems may only operate in the 76-77 GHz band and not in the remainder of the 77-81 GHz band.

21. In-band Power Density Limits. For vehicle radar systems, we proposed in the Notice a power density of 30 $\mu W/cm^2$ at 3 meters from the radiating source. We also proposed that the vehicle radar systems be limited to a power density of 200 nW/cm^2 at 3 meters when the vehicle was moving less than 1 km/hr. We invited comments on whether alternative approaches other than reducing power when not in motion could be implemented to ensure that vehicle radar devices are used safely. We indicated that one approach could be to permit devices with higher power density levels, provided they have design features that preclude human exposure to excessive RF signals.[24] We noted that we currently have a proceeding pending to consider the appropriate RF safety standard for radio transmitters, including millimeter wave band operations.[25] Our current rules specify the use of the American National Standard ANSI C95.1-1982, "Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300 kHz to 100 GHz" for evaluating the environmental effects of RF radiation.[26] We proposed to use a newly-developed standard,

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[24] These design features could include circuitry to automatically turn off the transmitter if a person comes too near to the antenna, or physical protective enclosures to keep people at least a certain distance from the antenna.

[25] See Notice of Proposed Rule Making in ET Docket No. 93-62, 8 FCC Rcd 2849 (1993).

[26] See 47 CFR Section 1.1302 et seq.

IEEE C95.1-1991 (ANSI/IEEE C95.1-1992), "Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz." For frequencies above 15 GHz, ANSI C95.1-1982 is generally more restrictive than IEEE C95.1-1991. We also note that comments were filed by the Environmental Protection Agency in response to this proposal urging us to adopt the health-safety guidelines approved by the National Council on Radiation Protection (NCRP). The NCRP standards are more restrictive on millimeter wave frequencies in terms of power density than those contained in ANSI C95.1-1982 or IEEE C95.1-1991.

22. Epsilon Lambda states that the proposed power density of 30 $\mu W/cm^2$ at 3 meters is adequate for vehicle collision warning systems having a range of about 500 feet. VORAD also indicates that effective vehicle radar systems can be produced at the proposed power density limit, stressing that the power density limit should be low to provide as great a margin for RF safety as possible.[27] AAMA, however, suggests that effective vehicle radar systems meeting the proposed power density limit cannot be produced. AAMA proposes a power density of 60 $\mu W/cm^2$ at 3 meters, average, and 300 $\mu W/cm^2$ at 3 meters, peak, which will provide a range of 300 meters. The AAMA states that researchers investigating collision avoidance systems typically reference a 100 m maximum range. However, AAMA adds that future systems will require maximum ranges on the order of 150 m to 300 m. GM agrees with AAMA, adding that it must design units with power densities at least 3 dB below the allowed limit due to a 1 dB variation each for transmitter power and antenna gain, and an additional 1 dB tolerance on the measurement. GM suggests that without an increase in allowed power density at 76 GHz, its current vehicle radar system would be forced to reduce range to an unacceptable value.[28]

23. Several companies express concerns regarding our proposal to require that power density be reduced when the vehicle is stationary or moving at less than 1 km/hr. Epsilon Lambda states that the proposed power density reduction when the vehicle is stationary would add major costs to vehicle radar equipment. GM indicates that it is sometimes desirable to operate a vehicle radar system at full power when the vehicle is stopped; GM therefore requests that we not require the power density of vehicle radar systems to be reduced when the vehicle is stationary. GM provides information on the distance at which the RF safety standard would be met, based on the power density levels, and concludes that this power reduction is not needed to protect public safety. GM adds that building a speedometer that can accurately determine when a vehicle's speed crosses 1 km/hr is difficult. Thus, if we continue to require a reduction in the power density when the vehicle is stationary, GM requests that we adopt an "in motion" or "in drive gear" criterion instead of the 1 km/hr criteria. AAMA recommends against requiring that power density be reduced for stationary

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[27] VORAD also requests that the transmitter output limits be expressed in terms of volts/meter at a distance of 3 meters, similar to the limits for other Part 15 transmitters.

[28] See GM Comments, at 24.

vehicles or that special interlocks be used to control RF exposure, stating that vehicle radars will be designed to comply with IEEE C95.1 or its equivalent. Ford concurs noting that "in motion" interlocks would defeat the purpose of rear and side looking vehicle radars by failing to alert drivers to potential collisions while at rest. Ford recommends allowing manufacturers sufficient technical flexibility to determine how best to meet the applicable radiation limits. VORAD recommends against allowing higher power densities even if special design features or safety interlocks to preclude human exposure above the standard are required. VORAD states that it is difficult to design human safety devices or mechanisms that will not fail or cannot be defeated, adding that vehicle radar systems could occasionally expose maintenance personnel to radiation hazards during equipment repairs if the safety features were deactivated. For these reasons, VORAD argues that the safest approach is for the vehicle radar emissions to be at safe levels at all times without relying on special safety features.[29]

24. We agree with AAMA and GM that the maximum power density for forward-looking vehicle radar systems should be raised to 60 $\mu W/cm^2$ at a distance of 3 meters. This increased power density should not cause excessive RF safety problems, especially since the emissions would be facing forward on a moving vehicle. With a power density of 60 $\mu W/cm^2$ at 3 meters, compliance with the stricter NCRP safety standard should occur at distances of greater than 0.75 meters from the transmitting antenna. Obviously, anyone in danger of excessive RF exposure would be in greater danger of being struck by the vehicle. We recognize that toll-takers, officers directing traffic and others may, at times, be in front of moving vehicles. However, we also note that these persons should not be within the 0.75 meters in which it is necessary to exceed the RF safety standards. This limit should also be sufficient to provide the greater range AAMA indicates will be needed for future systems. While we recognize the need for greater range for forward-looking vehicle radar systems, we do not believe that additional operating range is required for side-looking or rear-looking vehicle radar systems. Accordingly, we are adopting a power density limit of 60 $\mu W/cm^2$ at a distance of 3 meters for forward-looking vehicle radars and the originally proposed power density limit of 30 $\mu W/cm^2$ at a distance of 3 meters for side-looking and rear-looking radars operating in the 46.7-46.9 GHz band or the 76-77 GHz band when the vehicle is in motion.

25. As indicated in the Notice, it is our intention to ensure that millimeter wave systems meet the relevant RF safety standards. As such, it is important that we limit the power density of vehicle radar systems to levels that ensure safe operation at distances where people are likely to be located. Because people are more likely to be located nearer to a stationary vehicle as opposed to a moving vehicle, we are adopting our proposal to require that the power density of vehicle radar systems be reduced when the vehicle is stationary. However, as suggested by GM, we are substituting the "in motion" criteria in lieu of the 1 kilometer/hour critical speed criteria previously proposed. We are sympathetic to the concerns of industry that the 1 kilometer/hour criteria may be too burdensome because, for example, of the difficulties of interfacing the sensor to the speedometer. The "in motion"

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[29] See VORAD Comments at 2-3.

criterion should suffice to ensure that when the vehicle is not in motion, harmful human exposure will not occur. We believe that GM's recommendation that an "in drive gear" standard should be applied is inappropriate because there are many situations, such as when a pedestrian is crossing a street, that a vehicle may be in drive gear with persons in close proximity to the vehicle.

26. We continue to believe that our proposed stationary vehicle power density limit of 200 nW/cm^2 at 3 meters is appropriate. This value will generally ensure compliance with our proposed RF safety standards at all distances greater than 2-4 cm from the antenna. This limit is consistent with our existing and proposed RF safety standard at distances of 2 cm from the antenna. It is also consistent with the more stringent NCRP standard at a distance of 4 cm. The NCRP RF safety standard over the frequency range 1.5-100 GHz is 1 mW/cm^2. Accordingly, we believe the application of this power density limit will ensure that vehicle radar systems operating in stationary vehicles will be inherently safe in almost all situations. If, however, vehicle manufacturers place vehicle radar systems where persons may routinely be located, where the RF fields exceed the levels permitted in the RF safety standards, we will require them to take steps to ensure compliance with the RF safety standards, such as reducing power density, using warning labels, or installing protective covers. Finally, we believe industry should be responsible for designing effective safety systems that are not prone to failure or intentional override. Accordingly, we will review compliance with the RF safety standards in the equipment authorization process.

27. Antenna Side Lobe Attenuation. In the Notice, we proposed to require that the power density of the fundamental emissions from vehicular radar systems that are outside the main lobe of the radiation pattern be limited to 200 nW/cm^2 at a distance of 3 meters. AAMA, Epsilon Lambda, GM and VORAD express concern that this proposed limit is too stringent. In addition, GM argues that there is no need for a special restriction on the side lobe power density of vehicle radars since manufacturers will limit this level without Commission regulation. GM indicates that good side lobe suppression is crucial to limiting false responses, i.e., interference, from out-of-lane vehicles. VORAD adds that some vehicle radars may require hemispherical coverage, which could be prohibited by sidelobe specifications. VORAD also states that a standard is difficult to define because of the great variation in antenna beam patterns. Based on the information provided in these comments, we conclude that our proposal to require antenna sidelobe specifications for vehicle radars would be inappropriately restrictive on product design and unnecessary to avoid interference. Accordingly, we are not adopting this proposal.

General Unlicensed Bands

28. 59-64 GHz Band. In the Notice, we proposed to make available the entire 59-64 GHz band for general use by unlicensed devices based on the severe propagation losses in this frequency band. In making our proposal, we noted that the National Oceanic and Atmospheric Administration (NOAA) had indicated that it plans to use the 60.4-61.2 GHz

band for weather satellite passive sensing.[30] Parties were requested to provide detailed analysis and comments on whether terrestrial use of the 60.4-61.2 GHz band would interfere with NOAA's planned operations in that band and, in particular, whether this portion of the band should be excluded from the frequency bands made available under this proceeding.

29. The commenting parties broadly support our proposal to make the 59-64 GHz band available for general unlicensed devices. HP notes that the 59-64 GHz band will support "premises communication" such as wireless local area networks, campus-wide links, roadway communications, and the like.[31] AT&T is interested in using the band for computer-to-computer communications, which is already provisionally recommended in Europe.[32] mmWAG also notes its support for our proposal to open the 59-64 GHz band for general unlicensed devices, but suggests that licensed services and radio physics systems should also be provided access to the spectrum. Apple supports the unlicensed use of the 59-64 GHz band, noting that the exclusivity and protection from interference that would normally be secured by licensing are provided by the very limited distances that signals at those frequencies are able to travel.[33]

30. Hughes Aircraft Company, Communications Products Business Unit (HCP) expresses the need for a 2.5 GHz band to support high power, licensed point-to-point links that could provide the high data rate capabilities used by asynchronous transfer mode (ATM) networks. HCP suggests that the proposed 71.0-71.5 GHz band be expanded to 71.0-73.5 GHz to address this need. As an alternative, HCP proposes that the power density limit for devices in the 59-64 GHz band be raised to allow for longer point-to-point connections. It proposes that, as a third option, the 59-64 GHz band could be subdivided into a general unlicensed band from 59-61.5 GHz and a licensed point-to-point band from 61.5-64 GHz, in which a higher power density level would be permitted. However, several respondents, including AT&T, HP and mmWAG, express strong support for keeping licensed and unlicensed services on separate frequencies. In particular, AT&T notes that the difficulty of resolving interference problems between licensed services and the potentially large number

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[30] See Notice, at n. 17 and 18.

[31] See HP Reply Comments.

[32] See AT&T Reply Comments, at 7.

[33] See Apple Comments, at 3. On January 31, 1995, Apple filed a request for acceptance of its late-filed comments, stating that its filing was one day beyond the due date but that the brief delay would not prejudice the interests of other parties. Apple's comments were not accompanied by a timely filed motion under Section 1.46 of our rules. However, no parties opposed or were prejudiced by the late-filed letter. Therefore, the Commission accepts Apple's filing into the record of the proceeding as informal comments.

of unlicensed devices operating in the millimeter wave spectrum makes separation advisable.[34]

31. The National Research Council, Committee on Radio Frequencies (CORF) expresses concern regarding the potential for spurious and out-of-band emissions from some general unlicensed devices to interfere with terrestrial radio astronomy observations in adjacent bands.[35] CORF indicates that it is primarily concerned about transmitters on satellites and aircraft. Regarding terrestrial use of the 59-64 GHz band, CORF argues that, taking into consideration the small number and isolated locations of observatory sites, the propagation characteristics of millimeter waves, and the proposed low power density of unlicensed transmitters, protection zones around the sites represent an attractive method to limit interference without significant impact on commercial development above 40 GHz.[36] CORF notes that the size of a protection zone at a particular frequency can be determined by using the specific screening characteristics of the site. CORF states that it has begun calculating the parameters of the proposed zones, and will make the results available as soon as the analysis is complete. Finally, CORF recommends that we modify US211 to include the 59-64 GHz band noting that the 58.2-59 GHz and the 64-65 GHz bands are allocated to the passive services.[37]

32. Regarding the potential for interference to satellite passive sensing, the National Aeronautics and Space Administration (NASA) states that its analysis of the sharing potential demonstrates that sharing between terrestrial users in the 59-64 GHz band and space based passive sensors in the 60.3-61.3 GHz band is feasible. HP concurs with NASA's position regarding interference, noting that it will not be possible for the proposed unlicensed devices in this band to interfere with satellites. NASA requests that we allocate the 60.3-61.3 GHz band for earth exploration-satellite service.

33. We are therefore making the 59-64 GHz band available for use by general unlicensed devices under Part 15 of our rules. Our decision is primarily motivated by the physical characteristics of the spectrum and the widespread support for this aspect of our proposal. We believe that licensing is not necessary because of the limited potential for interference due to oxygen absorption (see n. 6, supra) and the narrow beamwidth of point-to-point antennas likely to be operating in this range. Moreover, we believe that by providing a full 5 GHz bandwidth we will be making the spectrum more attractive for novel broadband applications such as wireless computer-to-computer communications.

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[34] See AT&T Comments, at 2-3.

[35] The bands 58.2-59.0 GHz and 64.0-65.0 GHz are allocated to radio astronomy.

[36] See CORF Comments, at 4.

[37] See 47 CFR Section 2.106, United States Footnote US211. This footnote states that applicants for airborne or space station assignments are urged to take all practical steps to protect radio astronomy operations in adjacent bands.

34. We note HCP's interest in obtaining access to a band with a 2.5 GHz bandwidth for higher powered, broadband, two-way links. We continue to believe that the sharing of spectrum by unlicensed and licensed users would not be workable because of the difficulty of resolving interference problems involving unlicensed devices. Given the current availability of other millimeter wave spectrum for licensed services, we believe sharing of spectrum by unlicensed and licensed operators is also unnecessary. Thus, we are not adopting rules to provide for licensed services in the 59-64 GHz band. Regarding HCP's alternative proposals, the proposed increase in the equivalent isotropically radiated power (EIRP) for the 61.5-64 GHz band is discussed below. HCP's other proposal for expanding the 71-71.5 GHz band will be considered in a future decision on licensed millimeter wave operations.

35. In response to CORF's concerns about potential interference to radio astronomy operations, we are adopting rules that will prohibit the use of 59-64 GHz unlicensed devices aboard aircraft and satellites. We believe that this prohibition will provide sufficient protection to radio astronomy services.[38] If future filings indicate a need for use of these devices on aircraft and demonstrate how such devices can be designed to avoid potential interference to radio astronomy operations, then we may ultimately allow such use. As suggested by CORF, protection zones around radio astronomy observatories may be necessary. However, we will consider such protection zones if and when CORF presents us with its proposals.

36. We also agree, based upon the information presented by both NASA and HP, that interference to satellite-based passive sensors will not be a problem. On this issue there seems to be a consensus that operations in the 59-64 GHz band will not pose an interference threat to space-based sensors and NOAA's proposed system in particular. We defer consideration of NASA's request to allocate the 60.3-61.3 GHz band for earth exploration-satellite service until such time as this proposed allocation has been approved by the International Telecommunications Union and we are presented with a formal request from the National Telecommunications and Information Administration (NTIA) to allocate the band for such use.

37. In-band Power Density Limits. In the Notice, we proposed to limit the power density of unlicensed Part 15 millimeter wave transmitters, except those used in vehicle radar systems, to 200 nW/cm^2 at a distance of 3 meters from the antenna.[39] We indicated that this limit would accommodate the needs of low-power, unlicensed users and would help ensure

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[38] Prohibiting the use of 59-64 GHz devices aboard aircraft and satellites also will provide even greater protection to radio astronomy operations than the application of US211 in 47 CFR 2.106 requested by CORF.

[39] This is comparable to 0.23 watts EIRP.

that unlicensed millimeter wave devices comply with the relevant RF safety standards.[40] We invited comment on the appropriateness of our proposed power density limit and on alternative approaches that could be implemented to ensure that Part 15 millimeter wave technology devices are used safely. One approach that we suggested would be to approve devices with higher power density levels, provided they have design features that preclude excessive human exposure to radio frequency signals.[41]

38. The commenting parties generally request that we permit higher power density levels than were proposed in the Notice. HP and mmWAG both submit that the power density limit should be raised to 9 $\mu W/cm^2$ at 3 meters[42] to provide a greater communications range for systems in the 59-64 GHz band. NASA notes that a power density level of 9 $\mu W/cm^2$ at 3 meters in the 59-64 GHz band would not interfere with passive space-based measurements. Apple supports our proposal, stating that the 200 nW/cm^2 at 3 meters standard is reasonable for applications in "uncontrolled" environments, but suggests permitting significantly higher power density levels of 9 mW/cm^2 at 3 meters to 88 mW/cm^2 at 3 meters[43] for professionally installed point-to-point systems in "controlled" environments.[44] Similarly, Southwest Microwave requests a power density limit of 30 $\mu W/cm^2$ at 3 meters for outdoor, point-to-point, fixed systems. HCP proposes permitting higher power density levels for devices installed in locations where people will not be "close" to the main beam of the

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[40] The 200 nW/cm^2 at 3 meters power density limit generally provides compliance with both the existing ANSI C95.1-1982 standard and the proposed IEEE C95.1-1991 standard for human exposure to RF fields at distances greater than 2 cm from the transmitting antenna.

[41] Such design features could include circuitry to automatically turn off the transmitter if a person comes too near to the antenna, or physical protective enclosures to keep people at least a certain distance from the antenna.

[42] HP and mmWAG request that the system output levels be raised to an EIRP of 10 dBW. Where we discuss various power levels throughout this proceeding, we have converted the specification into W/cm^2 for consistency and to allow direct comparison.

[43] 9 mW/cm^2 at 3 meters corresponds to an Equivalent Isotropically Radiated Power (EIRP) of 10,000 watts, and 88 mW/cm^2 at 3 meters corresponds to an EIRP of 100,000 watts.

[44] The new ANSI standards define limits for both "controlled" and "uncontrolled" environments. "Controlled environments are locations where there is exposure that may be incurred by persons who are aware of the potential for exposure as a concomitant of employment, by other cognizant persons, or as the incidental result of transient passage through areas..." "Uncontrolled environments are locations where there is the exposure of individuals who have no knowledge or control of their exposure." See IEEE C95.1-1991, supra, at pgs. 9 and 12.

device for a substantial part of a minute or more.[45] HCP notes that many of the general unlicensed millimeter devices will be custom installed and not simply "bought off the shelf" by consumers. HCP recommends that we allow a power density of as much as 88 mW/cm^2 at 3 meters for professionally installed devices with appropriate warning labels.[46] Under this scenario, the installer would be responsible for ensuring that the installation is such that people will not be within the critical distance of the device's antenna.

39. HP requests that we replace our proposed power density limits with EIRP limits. Metricom opposes the use of EIRP limits, and suggests that we adopt limits on RF transmitter output power with the flexibility to use high gain antennas. Epsilon Lambda requests that we employ a transmitter output limit of 1 watt, without specifying a limit on maximum antenna gain, for systems using spread spectrum modulation techniques. HP states that the RF safety standard in IEEE C95.1-1991 is reasonable, indicating that this standard would not be a constraining factor in the design of Part 15 transmitters. However, HP also recommends against permitting the use of active interlocks on Part 15 transmitters as a means of complying with the RF safety standards. Instead, HP contends that all devices should comply with the safety standard at a distance of 2 cm from the transmitter.

40. We are adopting the higher power density level for unlicensed devices requested by HP and mmWAG, i.e., 9 μW/cm^2 at 3 meters. This would seem to be a reasonable approach in allowing manufacturers the necessary power density to be able to communicate effectively while still generally ensuring that the public would not be exposed to RF fields in excess of the safety standards. We again remind manufacturers that we will require millimeter wave equipment to meet the relevant RF safety standards, which may be changed as a result of further consideration under ET Docket No. 93-62.[47] Manufacturers will be required to take appropriate steps to comply with the RF safety standards, such as reducing power, using warning labels, or installing protective covers, if persons could routinely be located in places where the RF fields exceed the levels permitted in the RF safety standards. This will be particularly necessary for handheld devices. Compliance with the RF safety standards will be reviewed as part of the equipment authorization process.

41. We do not find it acceptable to permit operation of unlicensed millimeter wave systems at the levels requested by HCP and Apple. Such levels would result in a relatively

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[45] See HCP Comments, at 5.

[46] See HCP Comments, at 6.

[47] HP requests that we work with EPA to develop a more appropriate safety criteria, contending that scientific data does not exist for health effects of power density levels at these frequencies. We intend to continue our work in ET Docket No. 93-62 to develop appropriate RF safety standards. However, we also recognize that the resolution of an appropriate limit may take some time. At such time as formal RF safety standards are adopted by the Commission, we may revise the limits adopted in this proceeding.

large area near the millimeter wave system in which people may be present and the RF fields would exceed the safety standards.[48] As indicated in the Notice and discussed above, it is our intention to ensure that millimeter wave equipment meets the relevant RF safety standards. Unlicensed devices are often sold directly to consumers who have little knowledge of RF safety issues. Because of this, we must, in most cases, require that unlicensed millimeter wave systems be limited in power density to levels that ensure safe operation in places and at distances where people are likely to be located. Furthermore, we do not agree with HCP and Apple that a "professional installation" could reasonably be expected to ensure that persons would not be located in the large area in which the RF safety standards would be exceeded. We note that for licensed transmitters, the licensee is accountable for the installation and appropriate operation of the device. A significantly more detailed plan for protecting against RF exposure would be needed before we could adopt this approach for unlicensed devices.

42. Regarding HP's proposal to replace power density limits with EIRP limits and the other proposals to limit only transmitter output power, we do not believe that such changes are appropriate. Power density limits are used already in the RF safety standards. Furthermore, power density most clearly regulates the interference potential that might be encountered by other users of the frequency band. Accordingly, we will specify the limit in units of power density as proposed.

Other Requirements

43. Out-of-band Emission Limits. In the Notice, we proposed to protect other radio services from harmful interference by limiting all spurious and out-of-band emissions from unlicensed millimeter wave devices, including vehicle radar systems, to 2 pW/cm^2 measured at 3 meters.[49] This is equivalent to an out-of-band suppression requirement of 50 dB for general unlicensed devices and 72 dB for vehicle radar systems.[50] In addition, we proposed to apply the general limits in 47 CFR Section 15.209 to all radiated emissions below

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[48] If we were to adopt the levels suggested by HCP and Apple, compliance with the RF safety standards would only be ensured at distances of 9 to 28 meters from the device, depending upon whether the existing standard, the proposed standard, or the more restrictive NCRP standard is used.

[49] Notice, at para. 41.

[50] These suppression limits are based on the in-band power density levels proposed in the Notice: 200 nW/cm^2 at 3 meters and 30 μW/cm^2 at 3 meters. At the in-band power density level being adopted for general operation in the 60 GHz band, 9 μW/cm^2 at 3 meters, this attenuation requirement would be 66 dB. At the power density limit being adopted in this proceeding for forward-looking vehicle radar systems, 60 μW/cm^2 at 3 meters, this attenuation would be 75 dB.

47.2 GHz.[51]

44. Eight parties filed comments regarding our proposal on spurious emission levels.[52] Generally, the commenting parties express their concern that the power density limits proposed in the Notice would be: 1) difficult to meet and could undermine the development of low cost commercial products; 2) difficult to measure; and 3) unnecessary to protect other communications users. GM indicates that the high intrinsic signal losses in the millimeter wave region, the highly directional transmit and receive antennas that will be used with vehicle radar systems, and the fact that other systems will be located away from the highway limit the impact of out-of-band signals from vehicle radar systems. GM and AAMA therefore suggest an out-of-band suppression requirement of 25 dB for vehicle radar systems. VORAD recommends a 40 dB attenuation requirement for harmonic emissions and a 50 dB attenuation for spurious emissions other than harmonics. HP recommends a maximum attenuation of 50 dB below the in-band power density limit proposed for vehicular radars, i.e., a limit on spurious emissions of 350 pW/cm^2 at 3 meters, to be applied to all millimeter wave transmitters. However, in its reply comments HP supported a more relaxed spurious emission power density limit of 35 nW/cm^2 at 3 meters for spurious emissions that fall within the licensed frequency bands.

45. NTIA expresses concern about relaxing the proposed out-of-band emission limit for vehicle radar systems operating at 46.7-46.9 GHz.[53] NTIA states that there is a potential for second and third harmonic emissions from transmitters operating in the band 46.7-46.9 GHz to interfere with present and future Government operations near 94 GHz and 140 GHz.[54] Thus, NTIA requests that the proposed out-of-band emission limit of 2 pW/cm^2, measured at 3 meters, be adopted.

46. In establishing limits for out-of-band emissions, we must particularly consider where harmonics of the transmitted signals will fall as well as adjacent frequencies. All transmitting devices generate some level of energy on harmonic frequencies and in frequency bands immediately adjacent to the operating frequency. Based on consideration of the current

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[51] See 47 CFR Section 15.209.

[52] Comments of AAMA, Epsilon Lambda, GM, HP, HCP, CORF, NTIA and VORAD.

[53] See letter from Richard D. Parlow to Richard M. Smith, dated November 2, 1995.

[54] NTIA also expresses concern about potential interference from third harmonic emissions from vehicle radar systems operating in the 76-77 GHz band. Because the initial Notice did not propose out-of-band emission limits above 200 GHz, we are proposing, in the Second Notice of Proposed Rule Making section of this document, to limit the third harmonic emissions from transmitters operating in the 76-77 GHz band.

and expected future use of the harmonic bands and NTIA's comments, we do not believe that the limit on the power density of spurious emissions from vehicular radar systems operating in the 46.7-46.9 GHz band should be relaxed from our proposal of 2 pW/cm^2 at 3 meters. The 94 GHz band is employed for radio astronomy, U.S. Government passive imaging and Department of Defense classified applications. The 140 GHz band is used for radio astronomy and Government military passive imaging. The 94 GHz and the 140 GHz bands share many potential uses since these bands are in the only two atmospheric transmission windows between 60 and 300 GHz.[55] In particular, we note the Advanced Research Projects Agency's MIMIC program to develop lower-cost millimeter wave components has involved technology in the 94 GHz area and is likely to increase the use of this and other millimeter wave bands.[56] The resolution capabilities of passive imaging systems in the harmonic bands are directly related to the amount of RF signal noise in the band. Thus, if we permit excessive spurious emissions to be generated by millimeter wave products, the usefulness of these bands will be degraded for passive imaging and other possible functions.[57] While we appreciate GM's arguments for relaxing the out-of-band limits for vehicle radar systems, we do not agree that directional antennas and the use of vehicle radar systems on highways will be sufficient to eliminate interference to airborne passive sensors.

47. We understand that this decision may have an adverse economic impact on the manufacturers of vehicle radars for the 46.7-46.9 GHz band, but believe in this early stage of development of the millimeter wave bands that we should err on the side of caution. We would be willing to reconsider this spurious emission limit if manufacturers of vehicle radar equipment can demonstrate, in collaboration with the manufacturers of equipment operating on harmonically-related frequencies, a low probability of interference, e.g., based on angular distribution and susceptibility of the sensor to off-axis signals.

48. The harmonic emissions from the 59-64 GHz general use band and the 76-77 GHz vehicle radar band fall mainly within other bands being considered for unlicensed

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[55] The reference to atmospheric transmission windows refers to bands within which the attenuation due to dry air is minimized. In dry air, the atmospheric attenuation in these bands is less than 0.04 dB/km. These bands are still affected by moisture levels in the air, especially the band at 140 GHz.

[56] A future application for these bands could be passive imaging systems used as aircraft landing aids in adverse weather conditions.

[57] Current designs of passive imaging systems employing a 4 GHz bandwidth have a noise threshold of about -103 dBW. At this sensitivity, a single transmitter operating at the spurious emission power density limit proposed in the Notice, 2 pW/cm^2 at 3 meters, could cause interference at a distance of about 600 meters. Since passive imaging systems may be employed in aircraft, additional attenuation of the spurious emissions due to intervening objects may not occur.

millimeter wave devices.[58] Given that unlicensed devices generally require less interference protection, we concur with the commenters that the limit on spurious emissions from transmitters operating in the 59-64 GHz and 76-77 GHz bands can be relaxed. We are adopting the limit suggested by HP, 50 dB below the highest permitted power density level.[59] While we understand this suppression requirement is more rigorous than what was proposed by GM and others for vehicle radar use, we believe such suppression is needed to avoid interference to other millimeter wave operations. Examples of frequency bands that could experience interference problems if spurious emissions are not sufficiently suppressed include: 1) the proposed unlicensed and licensed bands at 122-123 GHz, 126-127 GHz, and 152-153 GHz which are harmonically related to the 59-64 GHz and 76-77 GHz transmissions; 2) radio astronomy operations at 182-185 GHz which is at the third harmonic of 59-64 GHz transmissions; 3) radio astronomy operations in nearby millimeter wave bands including 58.2-59 GHz, 64-65 GHz, 86-92 GHz; and, 4) other millimeter wave bands currently being used by the Government. As good engineering practice, we are also requiring that the spurious emissions may not exceed the level of the fundamental emission.

49. We are also adopting our proposal from the Notice to require that emissions from millimeter wave devices that appear below 40 GHz comply with the general limits in 47 CFR Section 15.209. Our proposal to apply these limits to radiated emissions below 47.2 GHz was based on the premise that unlicensed millimeter wave operation would be conducted at frequencies above 47.5 GHz. However, in this proceeding we are establishing Part 15 operation at 46.7-46.9 GHz. We may also, in the future, enable use of additional millimeter wave frequency bands below 46.7 GHz. Accordingly, we are revising our proposal to require that emissions below 40 GHz comply with the limits in 47 CFR Section 15.209.

50. Measurement Requirements. In the Notice, we proposed to extend the frequency range over which emissions must be measured to the 5th harmonic of the fundamental emission or to 100 GHz, whichever is less, for transmitters operating between 10 GHz and 30 GHz. For transmitters operating above 30 GHz, we proposed to require that radiated emissions be measured up to the 5th harmonic or to 200 GHz, whichever is the lower frequency. We also proposed to apply, at least initially, the general Part 15 measurement procedures contained in 47 CFR Sections 15.31, 15.33 and 15.35 of the regulations.

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[58] As indicated in footnote 58, NTIA is concerned about emissions from the third harmonic of vehicle radar systems operating in the 76-77 GHz band. This issue is being addressed in the Second Notice of Proposed Rule Making section of this document.

[59] At this suppression level, the limit on the power density for spurious emissions from transmitters operating in the 59-64 GHz band is 90 pW/cm^2 at 3 meters; the limit on the power density for spurious emissions from forward-looking vehicle radar systems in the 76-77 GHz band is 600 pW/cm^2 at 3 meters; and, the limit on the power density for spurious emissions from side-looking and rear-looking vehicle radar systems in the 76-77 GHz band is 300 pW/cm^2 at 3 meters.

Comments were invited on more specific measurement procedures that could apply to millimeter wave applications. Further, we requested comments on the use of instrumentation using an average detector to measure emissions from millimeter wave devices, as currently specified in the rules for emissions above 1000 MHz, and the use of a 1 MHz resolution bandwidth for the measurement instrument.[60]

51. A number of comments suggest lowering the upper frequency range over which radiated emissions are to be measured. HP suggests that the upper frequency limit for transmitters operating above 30 GHz be limited to 170 GHz since the Commission has not proposed services that would operate above this frequency and this frequency is the edge of a standard waveguide band.[61] HCP states that 153 GHz will be the highest frequency band actually used for some time and, because of the difficultly in measuring emissions above 160 GHz, recommends an upper limit of 160 GHz. Epsilon Lambda states that, for transmitters operating above 30 GHz, measurements to the third harmonic, not to exceed 150 GHz, are adequate. For transmitters operating between 10 GHz and 30 GHz, HP states that we should extend the range over which radiated measurements are made up to 110 GHz which is also at the edge of another standard waveguide band. Epsilon Lambda indicates that for Part 15 transmitters in the 10 to 30 GHz range, measurements to the third harmonic are adequate. Southwest Microwave also suggests only testing the spectrum through the third harmonic for transmitters operating in the 10 to 30 GHz range, stating that if the transmitter meets the limits through the third harmonic there is a high probability that the fourth and fifth harmonics will be within the limits.

52. Epsilon Lambda, GM and VORAD state that the measurement practices for lower frequencies already contained in the regulations should be used for measuring emissions at frequencies above 40 GHz as well. However, HCP states that we should indicate that the power density limits apply to values measured in the far-field, and that such far-field measurements should be interpolated to the specified limit distance using an inverse-distance-squared conversion formula.[62] HCP requests that these far-field results supersede measurements actually taken at 3 meters when this distance is in the near field.[63] HP agrees

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[60] See 47 CFR Section 15.35. This section also contains a limit on peak emission levels that apply in addition to the average limits.

[61] HP, in Appendix C of its comments, supplies a list of the frequency ranges covered by different waveguide bands. HP indicates that most measurement equipment will couple to free space through standard hardware available for these bands. These frequency ranges extend up to 220 GHz.

[62] Southwest Microwave indicates that the near-field can extend over 80 meters.

[63] At these frequencies, the dividing line between the near field and the far field is generally taken to be ($2d^2$/lambda) where "d" is the length or diameter of the antenna and lambda is the wavelength of the signal. Emissions in the far field generally attenuate based

that measuring power density 3 meters from a radiator could lead to ambiguous results, depending on whether 3 meters is in the near-field or far-field region of the radiator. AAMA supports HP's recommendations that measurements be made only in the far-field and that the emission level should be adjusted if the far-field region exceeds three meters. In addition, because of the difficulties encountered in making measurements above 40 GHz, GM indicates that measurements should be limited to the specific frequencies where radiated emissions can be expected, basing these measurements only on the frequencies in the millimeter wave generating circuits.[64] GM adds that a 76 GHz vehicle radar directly generates its signal at 76 GHz, so that only two regions above 40 GHz would need to be measured: the band edges at 76 GHz and 77 GHz and the second harmonic at 152 GHz. GM also requests that we allow the connection of the transmitter and antenna directly to the test equipment in order to decrease testing costs, using separate transmitter measurements and antenna data when practical. Southwest Microwave also suggests that we permit taking measurements at the transmitter output and correcting for the appropriate antenna gain.

53. There were relatively few comments regarding the use of average or peak detectors or our proposal to employ a 1 MHz resolution bandwidth for the measurement instrument.[65] AAMA and GM request that we specify average and peak power density limits differing by 7 dB. HP requests that the limits be based on the use of an average detector, adding that if the power is measured with a frequency selective instrument, then power should be defined as the sum of all frequency components contained within the legal band. Most of the comments discussing potential interference did not differentiate between peak and average limits.

54. In considering the range over which emissions should be measured, we first note that there are several Government radio operations already established above 40 GHz that must be protected from harmful interference. In addition to passive Government operations in the 94 GHz and 140 GHz bands discussed earlier, there are radio astronomy bands at throughout the millimeter wave spectrum that could be susceptible to harmful interference, including bands at 182-185 GHz and 217-231 GHz that could be susceptible to interference

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on an inverse-distance-squared relationship. Thus, when a signal level is known at one distance, the signal level at a different distance can be readily calculated. However, emissions in the near field do not behave in as predictable a fashion. Indeed, in the near field it is possible to make measurements that show a lower signal level than what would be measured at a greater distance.

[64] GM comments at 29 and 31.

[65] The proposal regarding the use of average or peak detectors and the associated power density emission limits may have been confusing in the Notice. While we specifically proposed the limits as peak limits in the text, the appendix containing the rules referenced the same limits as average limits with, based on 47 CFR Section 15.35, a peak-to-average limit of 20 dB. See Notice, at paras. 38 and 47.

from the third harmonics of transmitters operating in the 59-64 GHz and 76-77 GHz bands, respectively. While Southwest Microwave indicates that transmitters complying with the 2nd and 3rd harmonic limits have a high probability of also complying at the 4th and 5th harmonics, our experience with measurement of transmitting devices operating in lower frequency bands indicates that this is not always the case. A number of factors, including antenna gain which can vary by frequency, can affect such emissions. No party has provided information to show that such emissions behave differently at millimeter wave frequencies. We therefore continue to believe that our original proposals are appropriate. Accordingly, we are requiring that emissions from transmitters operating above 10 GHz and below 30 GHz be measured to the fifth harmonic of the highest operating frequency or to 100 GHz, whichever is lower. We are also requiring that emissions from transmitters operating above 30 GHz be measured to the fifth harmonic of the highest operating frequency or to 200 GHz, whichever is lower.[66]

55. Except for amending the correction factor applied to measurements taken at a distance other than what is specified in the rules, we agree with Epsilon Lambda, GM and VORAD that the measurement practices already contained in the regulations for frequencies below 40 GHz should be retained. We agree with the comments regarding the problems that could occur if measurements are taken in the near-field and note that there already is a provision in Section 15.31(f) of our rules dealing with measurements in the near-field.[67] We will, however, amend the rules to clarify that measurements above 40 GHz, when taken at greater distances to avoid making measurements in the near field, may be interpolated to the specified distance using an inverse distance squared correction factor.[68]

56. We do not agree with GM's position that we should require that emissions be measured only at specific frequencies. If a steady-state carrier is employed, it is likely that only the frequency ranges indicated by GM need to be investigated. However, if other types of modulation are used, e.g., swept frequency FM or spread spectrum, it may be necessary to check additional frequency bands. We note that the spurious emissions produced by a transmitter are dependent on the type of modulation employed. If our rules indicate that emissions are to be measured only at specific frequencies, transmission systems could be manufactured that produce emissions exceeding our limits in other frequency bands, resulting in potential interference to other radio systems. Thus, we are not amending the regulations to limit the frequency bands where millimeter wave emissions are to be measured.

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[66] As discussed earlier, we are also proposing in the Second Notice of Proposed Rule Making portion of this document to extend the upper limit of this measurement range to 231 GHz.

[67] See 47 CFR Section 15.31(f).

[68] In the Notice, we indicated that the proposed technical standards and measurement procedures might be altered upon final adoption. See Notice, at paras. 31 and 44 and notes 19 and 43.