Before the
Federal Communications Commission
Washington, D.C. 20554

In the matter of Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems	))))))	ET Docket 98-153

FIRST REPORT AND ORDER

Adopted: February 14, 2002 **Released: April 22, 2002**

By the Commission: Commissioners Copps and Martin issuing separate statements.

I. INTRODUCTION

1. By this action, we are amending Part 15 of our rules to permit the marketing and operation of certain types of new products incorporating ultra-wideband ("UWB") technology. UWB devices operate by employing very narrow or short duration pulses that result in very large or wideband transmission bandwidths. UWB technology holds great promise for a vast array of new applications that we believe will provide significant benefits for public safety, businesses and consumers. With appropriate technical standards, UWB devices can operate using spectrum occupied by existing radio services without causing interference, thereby permitting scarce spectrum resources to be used more efficiently. This First Report and Order ("Order") includes standards designed to ensure that existing and planned radio services, particularly safety services, are adequately protected. We are proceeding cautiously in authorizing UWB technology, based in large measure on standards that the National Telecommunications and Information Administration ("NTIA") found to be are necessary to protect against interference to vital federal government operations. These UWB standards will apply to UWB devices operating in shared or in non-government frequency bands, including UWB devices operated by U.S. Government agencies in such bands. We are concerned, however, that the standards we are adopting may be overprotective and could unnecessarily constrain the development of UWB technology. Accordingly, within the next six to twelve months we intend to review the standards for UWB devices and issue a further rule making to explore more flexible technical standards and to address the operation of additional types of UWB operations and technology.

2. This has been an unusually controversial proceeding involving a variety of UWB advocates and opponents. These parties have been unable to agree on the emission levels necessary to protect Government-operated, safety-of-life and commercial radio systems from harmful interference. It is our belief that the standards contained in this Order are extremely conservative. These standards may change in the future as we continue to collect data regarding UWB operations. The analyses and technical standards contained in this Order are unique to this proceeding and will not be considered as a

basis for determining or revising standards for other radio frequency devices, including other Part 15 devices.

3. The following text first provides an executive summary of the major actions taken in this item. Next, a background section describing Part 15 of the Commission's rules and the history of this proceeding is provided. A comprehensive discussion section consisting of several parts is also included. The first section of the discussion focuses on regulatory treatment and the Commission's definition of ultra wideband technology. The next part of the discussion provides analyses of studies submitted by several parties assessing the interference potential of ultra wideband devices to existing services. This section is followed by a discussion of the emission limits established for ultra wideband deployment. Also included in the discussion section are assessments of the cumulative impact of ultra wideband devices and procedures for measuring the emissions from ultra wideband devices. Finally, the discussion concludes with a section on other matters that impact the authorization of UWB technology.

II. EXECUTIVE SUMMARY

4. Upon consideration of the record, we continue to believe that UWB technology offers significant benefits for Government, public safety, businesses and consumers. However, we recognize that these substantial benefits could be outweighed if UWB devices were to cause interference to licensed services and other important radio operations. Our analysis of the record and the various technical studies submitted indicate that UWB devices can be permitted to operate on an unlicensed basis without causing harmful interference provided appropriate technical standards and operational restrictions are applied to their use.

5. To ensure that UWB devices do not cause harmful interference, this Order establishes different technical standards and operating restrictions for three types of UWB devices based on their potential to cause interference. These three types of UWB devices are: 1) imaging systems including Ground Penetrating Radars (GPRs) and wall, through-wall, surveillance, and medical imaging devices, 2) vehicular radar systems, and 3) communications and measurement systems. Generally, we are adopting unwanted emission limits for UWB devices that are significantly more stringent than those imposed on other Part 15 devices; limiting outdoor use of UWB devices to imaging systems, vehicular radar systems and hand held devices; and, limiting the frequency band within which certain UWB products will be permitted to operate. The frequency band of operation is based on the –10 dB bandwidth of the UWB emission. This combination of technical standards and operational restrictions will ensure that UWB devices coexist with the authorized radio services without the risk of harmful interference while we gain experience with this new technology. In the meantime, we plan to expedite enforcement action for any UWB products found to be in violation of the rules we are adopting and will act promptly to eliminate any reported harmful interference from UWB devices. Specifically, the Order takes the following actions:

- ***Imaging Systems***: Provides for the operation of GPRs and other imaging devices under Part 15 of the Commission's rules subject to certain frequency and power limitations. All imaging systems are subject to coordination with NTIA through the FCC. NTIA has indicated that coordination will be as expeditious as possible, requiring no longer than 15 business days, and may be expedited in emergency situations. The operators of imaging devices must be eligible for licensing under Part 90 of our rules, except that medical imaging devices may be operated by a licensed health care practitioner. Imaging systems include:

  - ***Ground Penetrating Radar Systems***: GPRs must be operated below 960 MHz or in the frequency band 3.1-10.6 GHz. GPRs operate only when in contact with, or within close proximity of, the ground for the purpose of detecting or obtaining the images of buried objects. The energy from the GPR is intentionally directed down into the ground for this purpose. Operation is restricted to law enforcement, fire and rescue organizations, to scientific research institutions, to commercial mining companies, and to construction companies.

- ***Wall Imaging Systems*****:** Wall imaging systems must be operated below 960 MHz or in the frequency band 3.1-10.6 GHz. Wall-imaging systems are designed to detect the location of objects contained within a "wall," such as a concrete structure, the side of a bridge, or the wall of a mine. Operation is restricted to law enforcement, fire and rescue organizations, to scientific research institutions, to commercial mining companies, and to construction companies.

- ***Through-wall Imaging Systems*****:** These systems must be operated below 960 MHz or in the frequency band 1.99-10.6 GHz. Through-wall imaging systems detect the location or movement of persons or objects that are located on the other side of a structure such as a wall. Operation is limited to law enforcement, fire and rescue organizations.

- ***Surveillance Systems*****:** Although technically these devices are not imaging systems, for regulatory purposes they will be treated in the same way as through-wall imaging systems used by police, fire and rescue organizations and will be permitted to operate in the frequency band 1.99-10.6 GHz. Surveillance systems operate as "security fences" by establishing a stationary RF perimeter field and detecting the intrusion of persons or objects in that field. Operation is limited to law enforcement, fire and rescue organizations, to public utilities and to industrial entities.

- ***Medical Systems*****:** These devices must be operated in the frequency band 3.1-10.6 GHz. A medical imaging system may be used for a variety of health applications to "see" inside the body of a person or animal. Operation must be at the direction of, or under the supervision of, a licensed health care practitioner.

- ***Vehicular Radar Systems*****:** Provides for the operation of vehicular radar in the 22-29 GHz band using directional antennas on terrestrial transportation vehicles provided the center frequency of the emission and the frequency at which the highest radiated emission occurs are greater than 24.075 GHz. These devices are able to detect the location and movement of objects near a vehicle, enabling features such as near collision avoidance, improved airbag activation, and suspension systems that better respond to road conditions. Attenuation of the emissions below 24 GHz is required above the horizontal plane in order to protect space borne passive sensors operating in the 23.6-24.0 GHz band.

- ***Communications and Measurement Systems*****:** Provides for use of a wide variety of other UWB devices, such as high-speed home and business networking devices as well as storage tank measurement devices under Part 15 of the Commission's rules subject to certain frequency and power limitations. The devices must operate in the frequency band 3.1-10.6 GHz. The equipment must be designed to ensure that operation can only occur indoors or it must consist of hand held devices that may be employed for such activities as peer-to-peer operation.

III. BACKGROUND

6. Part 15 of our rules permits the operation of authorized low power radio frequency (RF) devices without a license from the Commission or the need for frequency coordination.[1] The technical

[1] Devices are permitted to operate after they have been verified to comply with existing operational restrictions. *See* 47 C.F.R. Chapter 2, Subpart J. & 47 C.F.R. §§ 15.1 *et seq*.

standards contained in Part 15 are designed to ensure that there is a low probability that these unlicensed devices will cause harmful interference to other users of the radio spectrum.[2] Part 15 intentional radiators, *i.e.*, radio transmitters, are permitted to operate under a set of general emission limits[3] or under provisions that allow higher emission levels in certain frequency bands.[4] Part 15 intentional radiators generally are not permitted to operate in certain sensitive[5] or safety-related frequency bands that are designated as restricted bands,[6] or in the frequency bands allocated for television ("TV") broadcasting. Only out-of-band or spurious emissions from Part 15 transmitters are permitted in these restricted bands.

7. UWB radio systems typically employ pulse modulation where extremely narrow (short) bursts of RF energy are modulated and emitted to convey information. Because of the very short duration of these pulses, the emission bandwidths from these systems are large and often exceed one gigahertz.[7] In some cases, "impulse" transmitters are employed where the pulses do not modulate a carrier. Instead, the radio frequency emissions generated by the pulses are applied to an antenna, and the resonant frequency of the antenna determines the center frequency of the radiated emission. The frequency response characteristics of the antenna provide band-pass filtering, further affecting the shape of the radiated signal. UWB devices can be used for precise measurement of distances or locations and for obtaining the images of objects buried under ground or behind surfaces. UWB devices can also be used for wireless communications, particularly for short-range high-speed data transmissions suitable for broadband access to networks.

8. The current Part 15 rules pose two primary obstacles to the implementation of UWB technology. First, the wide bandwidth that is intrinsic to the operation of UWB devices can result in transmission of the intentional emissions into restricted frequency bands or into the TV broadcast frequency bands, which is prohibited under the Part 15 rules. Second, the current emission measurement procedures specified in our Part 15 rules were developed for relatively narrowband systems and may be inappropriate for, and pose unnecessary restrictions to, UWB technology, particularly impulse systems. For example, the Part 15 measurement procedures require the application of a pulse desensitization correction factor.[8] The application of this correction factor is not appropriate for very wideband systems and may can cause UWB systems to exceed the peak emission limits currently specified under the Part 15

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2 In addition to the limiting technical constraints, one of the primary operating conditions under Part 15 are that the operator must accept whatever interference is received and must correct whatever interference is caused. Should harmful interference occur, the operator is required to immediately correct the interference problem, even if correction of the problem requires ceasing operation of the Part 15 system causing the interference. *See* 47 C.F.R. § 15.5.

3 *See* 47 C.F.R. § 15.209.

4 *See* 47 C.F.R. §§ 15.215-15.407. In some cases, operation at the higher emission levels within these designated frequency bands is limited to specific applications.

5 The sensitive bands referenced here are bands employed by radio services that must function, as a nature of their operation, using extremely low received signal levels. These systems may be passive, such as radio astronomy, or active, such as satellite down links and wildlife tracking systems.

6 *See* 47 C.F.R. § 15.205.

7 Typical pulse widths used by UWB devices currently are on the order of 0.1-2 nanoseconds, or less, in width. The emission spectrum appears as a fundamental lobe with adjacent side lobes that can decrease slowly in amplitude. The rise time of the leading edge of the pulse and the passband of the radiating antenna are major factors in determining the bandwidth of the UWB emission.

8 HP Application Note 150-2 specifies the use of a pulse desensitization correction factor.

rules.[9]

9. The Federal Government operates safety-of-life and other critical systems in several of the restricted frequency bands and has raised concerns about the potential for UWB devices to interfere with these operations. The National Telecommunications and Information Administration (NTIA) at the U.S. Department of Commerce is responsible for managing the Federal Government's use of the radio frequency spectrum. In this capacity, NTIA conducted measurements and analysis of potential interference to a range of Federal systems including, for example, the Global Positioning System, Search and Rescue Satellite System, Air Traffic Control System, and Meteorological Radar System. NTIA and the FCC have worked closely throughout this proceeding to ensure that the public interest is best served by the implementation of UWB technology. Specifically, the two agencies have worked together to develop a regulatory paradigm that permits the deployment of promising new UWB technology while adequately safeguarding both Government and non-government operations.

10. On May 10, 2000, the Commission adopted a *Notice of Proposed Rule Making* ("*Notice*") that proposed rules to allow the operation of UWB transmission systems under the Part 15 regulations.[10] In the *Notice*, the Commission requested comments on various aspects of UWB operation, including applications, general characteristics, operation on an unlicensed basis, how UWB should be defined, the frequency ranges of operation, appropriate emission levels, cumulative impact concerns, and measurement procedures. In addition, the Commission requested comments concerning the existing prohibition against Class B, damped wave emissions, the operation of wide bandwidth transmitters under the existing Part 15 rules, and the transition provisions that should be applied. In response to the *Notice*, the Commission received 159 comments and 80 reply comments, as shown in Appendix A.[11]

11. Subsequent to the *Notice*, the Commission, on January 24, 2001, requested comments on two studies presented NTIA regarding the potential for UWB transmission systems to cause harmful interference to U. S. Government radio operations between 400 MHz and 6000 MHz.[12] In response to these studies, the Commission received 16 comments and 7 reply comments, as shown in Appendix C. Subsequent to the NTIA filing, the Commission, on March 26, 2001, requested comments on additional studies addressing potential interference from UWB operation to the Global Positioning System (GPS) and to the Personal Communications Services (PCS) telephones.[13] Time Domain,[14] NTIA,[15] and the

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[9] *See* 47 C.F.R. §§ 15.35(b) and 15.209. UWB systems that operate with a low duty cycle would have peak levels that are quite high compared to the average emission levels.

[10] *See Notice of Proposed Rule Making* in ET Docket No. 98-153, 65 Fed. Reg.37332, June 14, 2000, http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/Notices/2000/fcc00163.doc. *See*, also, *Notice of Inquiry* in ET Docket No. 98-153, 63 Fed. Reg. 50184, September 21, 1998, http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/fedreg/63/50184.pdf.

[11] A large number of late filed comments and *ex parte* comments continued to be filed in this proceeding long after the end of the comment period. While these comments were examined and evaluated, the commenting parties are not shown in Appendix A. A list of all parties filing comments in this proceeding can be found by referencing the Commission's Electronic Comment Filing System located at www.fcc.gov/e-file/ecfs.html.

[12] *See* NTIA Special Publication 01-43, *Assessment of Compatibility between Ultrawideband Devices and Selected Federal Systems*, January 2001, and NTIA Report 01-383, *The Temporal and Spectral Characteristics of Ultrawideband Signals*, January 2001. *See*, also, Public Notice of January 24, 2001, DA 01-171.

[13] *See* Public Notice of March 26, 2001, DA 01-753.

[14] *See* Time Domain's submission of March 9, 2001, *Final Report UWB-GPS Compatibility Analysis Project*, 8 March 2001, prepared by Strategic Systems Department, The Johns Hopkins University/Applied Physics Laboratory. The study consists of testing performed by the University of Texas along with an analysis by the Applied Physics Laboratory of Johns Hopkins University.

Department of Transportation[16] submitted GPS interference studies. Qualcomm submitted the PCS study.[17] In response to these studies, the Commission received 22 comments and 16 reply comments, as shown in Appendix D.[18]

IV. DISCUSSION

A. Authorization and Regulatory Treatment of UWB

12. In the *Notice*, we stated that UWB technology holds significant promise for a vast array of new applications and devices, which may offer significant benefits for public safety, businesses, consumers, and could enhance competition and the economy. In addition, we indicated that UWB technology might enable increased use of scarce spectrum resources by sharing frequencies with other services without causing interference. We noted that most of the near-term applications for UWB technology involve relatively low powers and short operating ranges. Further, most UWB devices are intended to be mass marketed to businesses and consumers making it impractical to individually license each device. We observed that these characteristics are largely consistent with devices that operate on an unlicensed basis under Part 15 of the rules. Accordingly, we tentatively concluded that regulating UWB devices under Part 15 of the Commission's rules would be appropriate.[19]

13. A large number of parties filed comments in response to the *Notice* supporting the authorization of UWB technology and suggesting applications for its use. While many of these endorsements did not provide technical comments on the operating parameters that should be applied to UWB devices, they do provide significant insight into the public interest and demand for the wide array of products that could be developed using UWB techniques. Several UWB applications including ground penetrating radar (GPR) systems, wall-imaging systems, automotive collision avoidance systems, radar level gauges used in storage tanks, and communications systems received significant support. Intel, for example, believed that the greatest potential use is short-range communications in the home or business, allowing equipment mobility and high data rates to facilitate information sharing.[20] Fantasma noted similar applications for supplying simultaneous video, audio, and Internet use throughout homes, schools,

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15 *See* NTIA Special Publication 01-45, *Assessment of Compatibility between Ultrawideband (UWB) Systems and Global Positioning System (GPS) Receivers*, February 2001, and NTIA Report 01-384, *Measurements to Determine Potential Interference to GPS Receivers from Ultrawideband Transmission Systems*, February 2001, submitted to the Commission on March 9, 2001.

16 *See* the study submitted March 21, 2001, by NTIA on behalf of the Department of Transportation regarding tests performed by Stanford University.

17 *See* the March 5, 2001, submission of Qualcomm.

18 As with the *Notice*, a number of late filed comments and *ex parte* comments were filed in this proceeding regarding the potential for UWB transmission systems to cause interference to GPS receivers. While these comments were examined and evaluated, the commenting parties are not shown in Appendix D. A list of all parties filing comments in this proceeding can be found by referencing the Commission's Electronic Comment Filing System located at www.fcc.gov/e-file/ecfs.html.

19 While the Commission recognized that UWB technology may be developed for higher power applications such as wide-area mobile radio services, it found that such applications raised many new and novel questions, such as consistency with the international and domestic table of frequency allocations, and how such services might be licensed to share spectrum across broad frequency ranges used by multiple existing services and licensees. As there was insufficient information in the record to address such issues, no proposals were made to allow high power UWB devices to operate under Part 15 or on a licensed basis.

20 Intel reply comments at pg. 3.

libraries, medical and elder-care facilities, and businesses.[21] AT&T expressed interest in providing high throughput, short-range voice, data and video services on premises and campus environments.[22] National Safe Skies Alliance believed UWB could be used to detect airport runway incursions and provide data distribution within airport terminals, personnel location, and other features.[23] Siemens Automotive ZF suggests using UWB technology for forward looking and lane change collision avoidance systems, backup warning systems, and airbag proximity measurements.[24] TDC noted the potential for using UWB devices in dozens of applications.[25]

14. Most parties supporting UWB also support authorization of UWB technology under Part 15 unlicensed operations. Delphi, Endress Hauser, Lucent and Bosch note that they intend to mass-market UWB devices to businesses and consumers. They argue that licensing UWB devices would be impractical and unwieldy and would increase costs to consumers.[26] Valeo Electronics supports unlicensed operations for UWB but also suggests that higher-powered UWB use should be permitted with individual licensing or under product-specific waivers.[27] Similarly, Zircon, while supporting unlicensed operation for UWB devices complying with the 47 C.F.R. § 15.209 emission limits, indicated that UWB devices that comply with the limits for Class A digital devices should be minimally encumbered by any licensing requirements.[28]

15. In general, the commenting parties associated with authorized radio services are opposed to authorization of UWB technology in their frequency bands of operation or suggest that UWB only be allowed on a licensed basis. For example, Cingular and other PCS operators suggest that UWB devices be limited to spectrum above 6 GHz or below 1 GHz for GPRs only.[29] The U.S. GPS Industry Council asserts that it is inappropriate for communications applications of UWB to be regulated under Part 15, as these are intentional emitters that experience very high peak powers.[30] ARINC and ATA state that licensed UWB operation would provide protection to existing users through frequency coordination, but recognize that another rule making proceeding would be required to address the table of frequency allocations.[31] Alloy states that licensing is essential until UWB is found to be non-interfering.[32] MSSI, while a proponent of UWB operation, states that GPRs are inappropriate for unlicensed operation because

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21 Fantasma comments at pg. 2.

22 AT&T comments at pg. 5-6.

23 National Safe Skies Alliance comments at pg. 1.

24 Siemens Automotive ZF comments at pg. 1. *See*, also, M/A-COM comments at pg. 2.

25 TDC reply comments at pg. 4-19.

26 Delphi comments at pg. 7, Endress Hauser comments at pg. 2, Lucent comments at pg. 2, and Bosch comments at pg. 2 and reply comments at pg. 1.

27 Valeo Electronics comments at pg. 4.

28 Zircon comments at pg. 2. It should be noted that the Commission already declined to permit UWB devices to operate at the Class A digital device limits contained in 47 C. F.R. § 15.109(b). *See Notice*, *op cit.*, at para. 40.

29 See, for example, Cingular *ex parte* comments filed August 20, 2001.

30 USGPSIC comments at pg. 29-30.

31 ARINC and ATA joint comments at pg. 9 and 10. Also, ATA *et al ex parte* comments of 6/6/01, 5/18/01.

32 Alloy reply comments at pg. 6-9. Alloy also believed that the first round of equipment to be authorized under the rules would be restricted to ground penetrating radars and through-wall imaging systems employed mostly by professionals.

of their high power level requirements and limited market.[33]

16. Boeing requests that a new rule part be established under which UWB devices would be licensed.[34] Boeing expresses concern that the potential aggregate impact of UWB devices is too significant to permit unless there is sufficient means to control the number of UWB devices in use. Under Boeing's proposal, the UWB manufacturers would obtain from the Commission authority to manufacture and market a fixed number of UWB devices under specific technical and operating conditions, such as limiting distribution to only public safety officials. Similarly, Lockheed states that the Commission needs to establish a regulatory regime that allows it to limit the number of devices that can operate at one time in the same area.[35] Professor Peha suggests a scheme where the Commission would issue permits for UWB devices and allow only a fixed number of devices to be introduced per year. Professor Peha argues that this approach would allow the Commission to track usage and the number of devices deployed.[36] SIA and Sirius also request that we implement some form of blanket licensing to limit the number of devices that can be operated in one area.[37] Sirius believes that licensing enables potentially affected services to receive advance notice of the proposed UWB use and to comment on those proposals. Kohler opposes licensing and the use of permits stating that the Commission does not have the authority to implement this method of licensing. Kohler argues that such an approach would create mutual exclusivity by designating the number of UWB devices that could be authorized per year and would not comport with 47 U.S.C. 309(j).[38]

17. Based on our review of the record, we continue to believe that UWB technology offers significant benefits for public safety, businesses and consumers. We anticipate that the authorization of UWB technology will create new business opportunities for manufacturers, distributors and vendors that will enhance competition and the economy. We also find that the use of this technology would promote spectrum efficiency by sharing frequencies with other services without causing interference. We also note that authorization of UWB is consistent with Section 7 of the Communications Act of 1934, as amended, which requires the Commission "… to encourage the provision of new technologies and services to the public."[39]

18. We are cognizant; however, that the substantial benefits of UWB technology could be outweighed if UWB devices were to cause interference to licensed services and other important radio operations. Our analysis of the record and the various technical studies submitted indicates that UWB devices can be permitted to operate without causing harmful interference if appropriate technical standards and operational restrictions are applied to their use. In this regard, we are establishing different technical standards and operating restrictions for different types of UWB equipment based on their potential to cause interference. As discussed below, we are, *inter alia,* adopting emission limits for UWB that are generally more stringent than those imposed on other Part 15 devices and limiting the frequency range below which certain UWB products will be permitted to operate. We believe that this combination of technical standards and operational restrictions will enable UWB devices to coexist with the authorized

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33 MSSI comments at pg. 12. MSSI subsequently cosigned the ATA *et al ex parte* comments of 6/6/01, 5/18/01.

34 Boeing comments at pg. 13-14.

35 Lockheed reply comments at pg. 5. Lockheed suggested that unlicensed operation could be considered only on frequencies where there is no reasonable interference concerns for safety services.

36 Prof. Peha comments at pg. 6.

37 SIA reply comments at pg. 5. Sirius reply comments at pg. 3, 11 and 18.

38 Kohler reply comments at pg. 5-6.

39 *See* 47 U.S.C. § 157(a) (1998).

radio services without the risk of harmful interference.

19. We also continue to believe that unlicensed operation under Part 15 of our rules is the most appropriate manner in which to authorize UWB devices at this time. These products, in general, will operate with very low power making licensing unnecessary. In this regard, we are not permitting UWB devices to be employed in higher power applications, such as wide-area mobile radio services. Instead, we are adopting emission limits that are designed to ensure that harmful interference to the authorized radio services is minimized, including interference from the cumulative effect of multiple UWB devices. We also are placing several restrictions on how and where UWB devices may be operated to ensure that harmful interference is not caused by these operations. We do not believe that requiring licensing is appropriate. However, we are implementing a coordination requirement for imaging devices, as requested by NTIA.[40] We also do not believe that it is practical to limit the number of devices being produced by a manufacturer. We anticipate that many of these devices will be small or portable and therefore any such limits would not necessarily limit the number of transmitters concentrated in any specific location. We believe that regulating UWB through power restrictions and other technical requirements is sufficient and has worked successfully for other Part 15 devices. Accordingly, we see no benefits, commensurate with the added costs to the public and manufacturers, from requiring individual operators to obtain a license or from attempting to limit the yearly production of individual UWB manufacturers. Thus, we are promulgating the regulations for UWB operation under Part 15 of our rules.

20. For regulatory purposes, we have categorized UWB devices into three types: 1) imaging systems (including GPRs), 2) vehicular radar systems, and 3) communications and measurement systems. We believe that these categories provide a logical way to address the various technical characteristics of the different applications. Most imaging systems emit energy that is largely absorbed by the material against which they are placed. A GPR operates only when in contact with or within close proximity to the ground for the purpose of detecting or obtaining the images of buried objects. Imaging systems can be used to detect objects within or on the other side of walls. A wall imaging system is designed to detect the location of objects contained within a "wall," such as a concrete structure, the side of a bridge, or the wall of a mine. A through-wall imaging system detects the location or movement of persons or objects that are located on the other side of a structure such as a wall or a ceiling. A surveillance system is a stationary radar system used for security purposes by establishing an RF perimeter and detecting the movement of persons or objects within that perimeter. Vehicular radar systems are able to detect the location and movement of objects near a vehicle, enabling features such as near collision avoidance, improved airbag activation, and suspension systems that better respond to road conditions. Communications and measurement systems consist of indoor and hand held devices that can encompass a wide variety of applications including high-speed home and business networking devices.[41] The term "hand held devices," as used in this Order, refers to portable devices, such as a lap top computer or a PDA, that are primarily hand held while being operated and that do not employ a fixed infrastructure when operating outdoors.

21. We have established different standards for these devices based on their individual operating characteristics and potential for causing interference to the authorized radio services. We recognize that our initial restrictions on applications, operating frequencies and emission levels may limit some UWB applications. However, we believe that we should be cautious until we have gained further experience with this technology. Once additional experience has been gained with UWB operation, we may consider whether more flexible standards are appropriate. Within their permitted bands of operation,

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40 *See* letter of February 13, 2002, from William T. Hatch, Associate Administrator, Office of Spectrum Management, U.S. Department of Commerce to Edmond J. Thomas, Chief, Office of Engineering and Technology, FCC. A copy of the letter is on file in this proceeding.

41 Indoor systems, because of the additional shielding provided by building walls, are able to operate with slightly higher levels of unwanted emissions.

UWB devices may operate at the emission limits specified in 47 C.F.R. § 15.209. The other basic operating parameters for these devices are summarized below:

- ***Imaging Systems***: Imaging systems include GPRs, wall imaging systems, through-wall imaging systems, surveillance systems and medical systems. All imaging systems are subject to coordination with NTIA through the FCC. NTIA has indicated that coordination will be as expeditious as possible, requiring no longer than 15 business days, and may be expedited in emergency situations. Except for medical imaging systems, the operators of imaging devices must be eligible for licensing under Part 90 of our rules. The standards for the different imaging systems are as follows:

    - ***Ground Penetrating Radar Systems*:** GPRs must be operated with their –10 dB bandwidth below 960 MHz or in the frequency band 3.1-10.6 GHz. GPRs operate only when in contact with, or within close proximity of, the ground for the purpose of detecting or obtaining the images of buried objects. The energy from the GPR is intentionally directed down into the ground for this purpose. Operation is restricted to law enforcement, fire and emergency rescue organizations,[42] to scientific research institutions, to commercial mining companies, and to construction companies.

    - ***Wall Imaging Systems*:** Wall imaging systems must be operated with their –10 dB bandwidth below 960 MHz or in the frequency band 3.1-10.6 GHz. Wall-imaging systems are designed to detect the location of objects contained within a "wall," such as a concrete structure, the side of a bridge, or the wall of a mine. Operation is restricted to law enforcement, fire and emergency rescue organizations, to scientific research institutions, to commercial mining companies, and to construction companies.

    - ***Through-wall Imaging Systems*:** These systems must be operated with their –10 dB bandwidth below 960 MHz or in the frequency band 1.99-10.6 GHz. Through-wall imaging systems detect the location or movement of persons or objects that are located on the other side of a structure such as a wall. Operation is limited to law enforcement, fire and emergency rescue organizations.

    - ***Surveillance Systems*:** Although technically these devices are not imaging systems, for regulatory purposes they will be treated in the same way as through-wall imaging systems used by police, fire and rescue organizations and will be permitted to operate with their –10 dB bandwidth in the frequency band 1.99-10.6 GHz. Surveillance systems operate as "security fences" by establishing a stationary RF perimeter field and detecting the intrusion of persons or objects in that field. Operation is limited to law enforcement, fire and emergency rescue organizations, to public utilities and to industrial entities.[43]

    - ***Medical Systems*:** These devices must be operated with their –10 dB bandwidth in the frequency band 3.1-10.6 GHz. A medical imaging system is used to detect the location or movement of objects within the body of a person or animal. Operation must be at the direction of, or under the supervision of, a licensed health care practitioner.

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[42] As used in this Order, law enforcement, fire and emergency rescue organizations refers to parties eligible to obtain a license from the FCC under the eligibility requirements specified in Section 90.20(a)(1) of this chapter.

[43] As used in this Order, the reference to public utilities and industrial entities refers to the manufacturers licensees, petroleum licensees or power licensees defined in 47 C.F.R. § 90.7.

- ***Vehicular Radar Systems*****:** Provides for the operation of vehicular radar systems using directional antennas on terrestrial transportation vehicles provided the center frequency of the emission and the frequency at which the highest radiated emission occurs are greater than 24.075 GHz. The -10 dB bandwidth must be between 22 and 29 GHz. These devices are able to detect the location and movement of objects near a vehicle, enabling features such as near collision avoidance, improved airbag activation, and suspension systems that better respond to road conditions. Attenuation of the emissions below 24 GHz is required above the horizontal plane in order to protect space borne passive sensors operating in the 23.6-24.0 GHz band.

- ***Communications and Measurement Systems*****:** Provides for use of a wide variety of other UWB devices, such as high-speed home and business networking devices as well as storage tank measurement devices under Part 15 of the Commission's rules subject to certain frequency and power limitations. The devices must operate with their –10 dB bandwidth in the frequency band 3.1-10.6 GHz. The equipment must be designed to ensure that operation can only occur indoors or it must consist of hand held devices that may be employed for such activities as peer-to-peer operation. The limits on unwanted emissions are more stringent for hand held devices than they are for indoor-only systems.

B. UWB Definition

22. Proposal. In the *Notice*, the Commission proposed to adopt a modified version of the UWB definition established by the OSD/DARPA UWB radar review panel.[44] Specifically, the Commission proposed to define a UWB device as any device where the fractional bandwidth is greater than 0.25 or occupies 1.5 GHz or more of spectrum.[45] The formula proposed by the Commission for calculating fractional bandwidth is $2(f_H-f_L)/(f_H+f_L)$ where f_H is the upper frequency of the –10 dB emission point and f_L is the lower frequency of the –10 dB emission point. The center frequency of the transmission was defined as the average of the upper and lower –10 dB points, i.e., $(f_H+f_L)/2$.[46] The Commission proposed to base its modified definition of an UWB device on –10 dB bandwidth, rather than the –20 dB bandwidth used by OSD/DARPA, because under the Part 15 limits, UWB devices operate so close to the noise floor that in many cases it may not be possible to measure the –20 dB bandwidth. The Commission also proposed that the bandwidth be determined using the antenna that is designed to be used with the UWB device. Comments were requested on: 1) the proposed definition; 2) whether the fractional bandwidth should be changed to account for the narrower bandwidth that would be measured using the –10 dB emission points instead of the –20 dB points; 3) whether we should use some other method to determine the emission bandwidth, such as a calculated bandwidth based on pulse width; 4) whether we should define UWB devices as limited to devices that solely use pulsed emissions where the bandwidth is directly related to the pulse width;[47] and 5) whether extremely high speed data systems that comply with the UWB bandwidth requirements only because of the high data rate employed, as opposed to meeting the definition solely from the narrow pulse width, should be permitted. In the *Notice*, the Commission indicated it would pursue a conservative initial approach until more experience was gained with UWB

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44 *Assessment of Ultra-Wideband (UWB) Technology*, OSD/DARPA, Ultra-Wideband Radar Review Panel, R-6280, Office of the Secretary of Defense, Defense Advanced Research Projects Agency, July 13, 1990.

45 Under the proposed definition of an UWB device, the 1.5 GHz maximum bandwidth limit would only apply where the center frequency is greater than 6 GHz.

46 In some UWB systems, there is no clear center frequency as with other modulation techniques, such as AM and FM. Furthermore, the shape of the transmitted spectrum may be significantly modified by the frequency response of the antenna such that even the carrier frequency, where employed, may not represent the center frequency.

47 Other types of modulation, such as linear sweep FM, could be employed to produce UWB equipment.

operations.

23. Comments. The commenting parties generally supported basing the definition of UWB either on a fractional bandwidth or some minimum emission bandwidth.[48] They disagreed, however, on the specific values that should be applied for a device to be defined as UWB. There was also disagreement among the parties with regard to limiting the modulation to pulsed modulation, and requiring that the bandwidth be directly related to the narrow pulse width instead of the data rate. There were no objections to determining the bandwidth of the UWB emission using the antenna designed to be employed with the UWB transmitter.[49]

24. A number of commenting parties supported the proposal in the *Notice* to use the –10 dB emission points to determine the fractional bandwidth. Bosch, for example, stated that the definition of UWB should be based solely on bandwidth using the –10 dB emission points.[50] It stated that the –20 dB emission points were too near the noise floor to be measured reliably. Bosch also noted that the –20 dB emission points would be ambiguous as such points appear on both the fundamental lobe and the side lobes. Similar concerns about use of the –20 dB emission points were echoed by Valeo,[51] Kohler,[52] and others.

25. Objections to the use of the –10 dB emission points to determine the fractional bandwidth were filed by NBAA. It stated that the –10 dB fractional bandwidth was arbitrary and asserts that it would ignore emission components that "could account for peak powers of hundreds of watts."[53] NBAA suggests that the bandwidth of the device be more than 5 percent of its center frequency. AOPA requests that the bandwidth be based on the –20 dB points stating that emission levels vary too much to use the –10 dB points.[54] ARRL requests that the bandwidth be determined using the –23 dB points believing that this would be consistent with other Commission regulations on spurious and out-of-band emissions.[55]

26. Several parties requested that the fractional bandwidth of 0.25 and minimum bandwidth of 1.5 GHz limit be reduced from that proposed in the *Notice* due to the use of –10 dB rather than the –20 dB emission points.[56] SME and Valeo, for example, requested a fractional bandwidth of around 0.17 and

48 *See*, *e.g.*, the comments of Aether Wire and Location at pg. 7, ANRO at pg. 1, CSSIP at pg. 1, Delphi at pg. 10, Endress Hauser at pg. 3, Lucent at pg. 5, M/A-Com at pg. 1, Bosch at pg. 2, TDC at pg. 21, and Zircon at pg. 2. We have used the term "minimum bandwidth" in this proceeding to reference the bandwidth above which a product qualifies as a UWB device regardless of its fractional bandwidth.

49 As noted by Aether Wire and Location, the antenna is an integral part of the system that affects the radiated bandwidth and the phase response. Aether Wire and Location comments at pg. 7.

50 Bosch comments at pg. 2-3 and reply comments at pg. 1-2.

51 Valeo comments at pg. 4.

52 Kohler comments at pg. 4.

53 The limits being adopted in this proceeding do not permit peak emissions approaching this amplitude.

54 AOPA comments at pg. 4.

55 ARRL comments at pg. 18. It should be noted that these emission points are representative of the attenuation requirements for the authorized radio services where the radiated emission levels are powerful enough to be easily measured.

56 ARRL requested that a minimum frequency bandwidth be applied to the UWB definition since a 0.25 fractional bandwidth would not result in a very wide emission for a system operating at, say, 3.5 MHz. *See* ARRL comments at pg. 13. However, ARRL did not suggest a lower limit. We did not address this issue in this proceeding since UWB systems, other than GPRs and certain imaging systems are required to operate in considerably higher frequency ranges. GPRs and imaging systems need to operate at frequencies higher than 3.5 MHz in order to obtain the needed object resolution.

an upper bandwidth limit of one gigahertz.[57] Siemens requests that the fractional bandwidth be reduced to 0.15 with a 1 GHz upper bandwidth limit.[58] Bosch requests a fractional bandwidth of 0.15-0.20 and a minimum bandwidth of one to 1.5 gigahertz.[59] ANRO and Kohler request a fractional bandwidth of 0.20.[60] Daimler Chrysler requested an upper bandwidth limit of one gigahertz.[61]

27. Delphi requested that a minimum bandwidth of 500 MHz be used to define UWB, regardless of center frequency, and that all forms of modulation be permitted.[62] It added that absent such changes manufacturers producing radar devices under the current regulations would be disadvantaged because they would not be permitted to operate their equipment within the restricted bands. M/A-Com objected to Delphi's request stating that the Commission is not promoting the operation of narrowband systems in restricted bands.[63] On the other hand, MSSI stated that UWB systems should be permitted with bandwidths as low as 200 MHz, indicating that UWB devices could be constructed with bandwidths as narrow as 20-30 MHz.[64]

28. With regard to the use of modulation types other than pulsed or impulse emissions, AOPA expressed concern that such proposals to expand the definition of UWB would open the door for additional types of devices.[65] These additional devices could have different interference characteristics. Similarly, TDC did not believe that all devices above a certain minimum fractional bandwidth or upper bandwidth limit should be characterized as UWB, stating that most of the benefits of UWB come from having very few cycles within the pulse envelopes, not the duration of the pulse envelope itself.[66] TDC also raised concerns that minimal information exists regarding the interference potential and applicable measurement procedures for stepped and swept frequency systems.[67] Endress Hauser and USGPSIC also expressed concerns about permitting the operations of linear sweep systems and chirped systems respectively.[68] On the other hand, ARRL agreed with Delphi that all modulation types should be permitted provided proper peak, average and power spectral density limits are met.[69] CSSIP[70], Krohne[71], Siemens[72] and Valeo[73] specifically requested that stepped frequency or swept frequency systems be

57 SME comments at pg. 2 and 4. Valeo comments at pg. 4.

58 Siemens comments are pg. 2.

59 Bosch comments at pg. 2-3 and reply comments at pg. 1-2.

60 ANRO comments at pg. 1. Kohler comments at pg. 4.

61 *Ex parte* filing of Daimler Chrysler on July 31, 2001.

62 Delphi comments at pg. 9-17. Delphi later amended its proposal to include only pseudo-noise direct sequence binary phase shift key type of modulation. Delphi *ex parte* filing of July 13, 2001.

63 M/A-Com reply comments at pg. 2.

64 MSSI comments at pg. 15.

65 AOPA reply comments at pg. 10-11.

66 TDC comments at pg. 21.

67 TDC comments at pg. 25.

68 Endress Hauser comments at pg. 3-4 and USGPSIC comments at pg. 2 of Attachment A.

69 ARRL reply comments at pg. 9.

70 CSSIP comments at pg. 1.

71 Krohne comments at pg. 4.

72 Siemens comments at pg. 2.

73 Valeo comments at pg. 5.

permitted under the UWB definition. Krohne argued that there is sufficient information on measurement procedures and emission limits for these devices.

29. Bosch stated that basing the definition on the use of a narrow pulse width to achieve a wide emission bandwidth could impede the development of novel pulse or modulation schemes, including high-speed data systems.[74] XSI stated that we should include extremely high-speed data systems that comply only because of the high-speed data rate and not because of narrow pulse width.[75] XSI stated that the threat of harmful interference depends primarily on the average and peak emissions and the location of significant spectral lines and is affected little, if at all, by the nature of the modulating signal. AOPA objected indicating that other modulation techniques, such as chirping, are likely to have different interference potential characteristics.[76]

30. Discussion. We are adopting our proposal to use the –10 dB emission points to determine the bandwidth and the center frequency of the UWB emission. As pointed out by Bosch and others, the –20 dB emission points could be so near the noise floor that making accurate measurements would be difficult or impractical. Similarly, it would be impractical to specify the –23 dB points recommended by ARRL. In addition, we agree that the minimum required fractional bandwidth should be reduced given that the use of the –10 dB bandwidth measurement points will result in a smaller measured bandwidth.[77] Accordingly, we are reducing the –10 dB fractional bandwidth from 0.25 to 0.20. For this same reason, we also are reducing the minimum bandwidth limit from the 1.5 gigahertz proposed in the *Notice* to a limit of 500 megahertz for UWB devices.[78] A minimum bandwidth limit of 500 megahertz should accommodate most of the proponents in this proceeding. While some parties have suggested that we could eliminate all restrictions on fractional bandwidth and minimum bandwidth, we disagree. In the absence of a minimal bandwidth requirement, many devices could be designed to operate in restricted bands even though they have no need to do so. For example, devices such as radio control toys typically employ bandwidths of 25 kHz or less and there are ample provisions to operate such devices outside of the restricted bands.

31. We also do not believe that there is any justification for reducing the minimum bandwidth to 200 MHz, as sought by MSSI. One of the major regulations being addressed in this proceeding is the operation of Part 15 devices in the restricted bands described in 47 C.F.R. § 15.205. We are amending the rules in this Report and Order to permit UWB devices to emit in certain restricted bands because the bandwidths employed by those systems are so wide that they have difficulty finding spectrum to operate without transmitting in one or more of the restricted bands. We do not find a similar difficulty finding 200 MHz of contiguous spectrum outside of the restricted bands. For example, unlicensed Part 15 operation at, or higher than, the emission levels being permitted for UWB devices currently is permitted in the frequency bands 1722.2-2200 MHz, 2900-3260 MHz, 3359-3600 MHz, 5150-5350 MHz, 5460-7250 MHz, etc. Further, Part 15 devices operating in these bands could be employed for any purpose without having to comply with the additional standards that are being adopted for UWB devices. At this time, we do not wish to open the restricted bands for operation by any Part 15 device that can operate

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74 Bosch comments at pg. 3.

75 XSI comments at pg. 8.

76 AOPA comments at pg. 5.

77 The fractional bandwidth value of 0.25, or 25 percent, was established by the OSD/DARPA UWB radar review panel based on the use of a –20 dB emission bandwidth.

78 As noted, UWB devices would be required to have a –10 dB fractional bandwidth of at least 0.20 or a –10 dB bandwidth of at least 500 MHz. The effect of this change is that UWB systems with a center frequency greater than 2.5 GHz need to have a –10 dB bandwidth of at least 500 megahertz while UWB systems operating with a center frequency below 2.5 GHz need to have a fractional bandwidth of at least 0.20.

satisfactorily between the restricted bands. Accordingly, we are limiting the minimum bandwidth limit to 500 MHz. Once additional experience has been gained with UWB operation, we may revisit these values.

32. We agree with Bosch and XSI that transmission systems should not be precluded from the UWB definition simply because the bandwidth of the emission is due to a high speed data rate instead of the width of the pulse or impulse. We also agree with ARRL and Delphi that various modulation types should be permitted as long as the products comply with all of the technical standards that are being adopted in this proceeding. Thus, as long as the transmission system complies with the fractional bandwidth or minimum bandwidth requirements at all times during its transmission, we agree that it should be permitted to operate under the UWB regulations. We recognize that this may preclude certain types of modulations, such as swept frequency (*e.g.*, FMCW), stepped frequency or frequency hopping systems. The current measurement procedures require that measurements of swept frequency devices be made with the frequency sweep stopped.[79] The sweep is stopped because no measurement procedures have been proposed or established for swept frequency devices nor has the interference aspects of swept frequency devices been evaluated based on the different measurement results that would be obtained from measurements taken with the sweep active. Similarly, measurements on a stepped frequency or frequency hopping modulated system are performed with the stepping sequence or frequency hop stopped. With the sweep, step function or hopping stopped, it is unlikely that swept frequency (linear FM or FMCW) or stepped frequency modulated emissions would comply with the fractional bandwidth or minimum bandwidth requirements. It also is unlikely that frequency hopping systems would comply unless an extremely wide bandwidth hopping channel is employed.[80]

C. Frequency Bands and Operational Requirements for UWB Devices

33. Proposal. In the *Notice*, the Commission indicated that it considered a number of factors in addressing which frequency bands should be made available for UWB devices. First is the need to protect from interference the vitally important and critical safety systems operating in the restricted frequency bands, including GPS operations. Second, there are a broad variety of potential applications for UWB technology, each of which has unique spectrum attributes and requirements. Third, various regions of the spectrum have different propagation characteristics. To realize the full benefits of this technology, the Commission indicated that it should establish as few restrictions as possible on UWB operating frequencies, except as necessary to protect existing services against interference.

34. The Commission noted that it had a number of concerns about generally permitting the operation of UWB devices in the region of the spectrum below approximately 2 GHz. This is perhaps the most heavily occupied region of the spectrum and is used for public safety, aeronautical and maritime navigation and communications, AM, FM and TV broadcasting, private and commercial mobile communications, medical telemetry, amateur communications, and GPS operations. Further, 41 of the 64 restricted frequency bands are at or below 2 GHz, not counting the TV broadcast bands. Of particular concern is the impact of any potential interference to the GPS band at 1559-1610 MHz. The Commission also expressed concern about interference to any additional frequencies allocated to GPS, *e.g.*, the planned L5 frequency in the 960-1215 MHz band. GPS will be increasingly relied upon for air navigation and safety, and is a cornerstone for improving the efficiency of the air traffic system. GPS also may be used by commercial mobile radio E-911 services to enable police and fire departments to quickly locate individuals in times of emergency. Moreover, businesses and consumers are now employing GPS for various applications, such as for navigation by automobiles, boats and other vehicles, surveying, hiking,

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79 *See* 47 C.F.R. §15.31(c).

80 We note that NTIA recently agreed that a waiver could be issued to Krohne to permit the Part 15 operation of its level measuring radar system in steel tanks. This should alleviate Krohne's concerns in the UWB proceeding. *See* letter of September 5, 2001, from William Hatch of NTIA to Bruce Franca, Acting Chief, OET, FCC. *See*, also, letter of October 26, 2001, from Bruce A. Franca to Fish & Richardson granting Krohne its waiver request.

and geologic measurements. Therefore, any harmful interference to GPS could have a serious detrimental impact on public safety, businesses and consumers. In addition, propagation losses are not as great below 2 GHz, and services in this region of the spectrum tend to employ omnidirectional antennas that do not discriminate against undesired signals. These factors tend to increase the risks of interference below 2 GHz.

35. In light of these factors, the Commission expressed concern about the operation of UWB devices, except for GPRs and possibly through-wall imaging devices, in the region of the spectrum below approximately 2 GHz. Comments were invited on whether UWB devices should be restricted from operating on frequencies below 2 GHz, and the impact such a restriction would have on the potential applications for UWB technology. Comments also were requested as to the precise frequency below which the operation of UWB devices may need to be restricted.[81] For example, should operation be restricted below the GPS band at 1610 MHz, or below the restricted band at 1718.8 - 1722.2 MHz, or below the Personal Communication Service band at 1850 - 1990 MHz, or below some other frequency?

36. Notwithstanding the above concerns, the Commission noted that GPRs must operate at frequencies in the region below 2 GHz in order to obtain the penetration depth and resolution necessary to detect and obtain the images of buried objects. It noted, however, that the risk of interference from GPRs is low because the majority of their energy is directed into the ground. In addition, GPRs are expected to have a low proliferation and usually operate at infrequent intervals. Accordingly, the Commission proposed to allow GPRs to operate in any part of the spectrum. It proposed to define a GPR as an UWB device that is designed to operate only when in contact with, or in close proximity to (*i.e.*, within 1 meter), the ground for the purpose of detecting or obtaining the images of buried objects. It also proposed to require GPRs to include a switch or other mechanism to ensure that operation occurs only when the device is activated by an operator and is aimed directly down at the ground.

37. In the *Notice*, the Commission also indicated it is unclear whether the same considerations apply to other imaging devices used to detect or obtain the images of objects inside or behind walls or other surfaces.[82] For example, in contrast to GPRs where signals are aimed at the ground, wall imaging and through-wall imaging devices could aim their energy in any direction. While the wall structure could attenuate these signals, the amount of attenuation can vary widely depending on the composition of the wall. The Commission noted, however, that it expected that such systems would have a low proliferation and would be operated infrequently. Thus, the Commission indicated that one option would be to treat all imaging devices the same way as GPRs. Alternatively, it indicated that it could restrict the operation of such devices to bands below a certain frequency or apply other restrictions to such devices. Comments were invited on: 1) these and other approaches for GPRs and imaging systems; 2) the provisions needed to ensure that these systems operate only when they are in contact with a wall; 3) whether the operation of through-wall imaging systems should be limited to parties eligible for licensing under the Public Safety Pool of frequencies in Part 90 of our rules, as required under the earlier waiver to Time Domain;[83] and, 4) whether through-wall imaging systems should be required to incorporate automatic power control features that would reduce power levels to the minimum necessary to

[81] Our concerns apply to all emissions within the –10 dB bandwidth of the UWB signal, not just at the center frequency.

[82] Time Domain's through-wall imaging system, authorized under a waiver issued on June 29, 1999, by the Chief, Office of Engineering and Technology, operates over a frequency band ranging from a few hundred Hertz to greater than 4 GHz. Through-wall imaging systems are limited to products that detect objects located on the other side of a wall. Under the waiver, operation was limited to parties eligible for licensing under the Public Safety Pool of frequencies in Part 90 of this chapter.

[83] Waivers were issued on June 29, 1999, to Time Domain Corporation, Zircon, and U.S. Radar and on August 6, 2001, to Kohler Co. to permit the limited marketing of UWB devices.

function based on the composition of the surface and its absorption of RF energy.

38. The Commission observed that it appears that most other applications of UWB technology could satisfactorily operate in a variety of regions of the spectrum. It further observed that UWB devices generally can operate compatibly with other radio services in the region of the spectrum above approximately 2 GHz without causing harmful interference to other radio services for two main reasons: 1) the UWB signals will quickly fall off to levels below the background noise because of the high propagation losses at 2 GHz and above; and 2) most radio services operating above 2 GHz use directional antennas that generally discriminate against reception of undesired signals. Accordingly, the Commission proposed to allow the operation of all types of UWB devices on frequencies above approximately 2 GHz, subject to the general limits on technical operation set forth elsewhere herein.

39. The Commission also requested comment on alternative approaches to restricting or prohibiting operations in the frequency bands below 2 GHz. It noted that certain UWB applications might be feasible using extremely low signal levels. Comments were invited as to whether and at what levels, if any, operation should be permitted in the restricted bands below 2 GHz for devices that can operate using extremely low signal levels. While UWB technology generally cannot completely notch out certain frequency bands, comments were requested as to the viability of establishing a general emission limit for UWB devices below 2 GHz, and whether a more stringent limit, or notch, should be applied to the GPS band.

40. Discussion. As discussed above, we are establishing different technical standards and operating restrictions for three categories of UWB devices based on their potential to cause interference. These three categories of UWB devices are 1) imaging systems including ground penetrating radar (GPR), wall, through-wall, surveillance, and medical imaging devices, 2) vehicular radar systems, and 3) communications and measurement systems. The discussion below sets forth the frequency and operational limitations that will apply to each of these device categories.

1. Imaging Systems

41. Most of the commenting parties support allowing GPRs to operate in all frequency bands provided that certain conditions are met, such as requiring a switch to avoid unattended operation and ensuring that they are operated in close proximity to the ground. The commenting parties expressed differing views, however, with regard to other types of imaging systems. Some parties state that imaging systems need to operate across a broad range of frequencies in order to accommodate the wide range of applications and to allow imaging sensors to effectively penetrate a wide variety of materials. Other commenting parties are concerned that imaging systems may be more likely to cause interference to licensed services. These parties suggest limiting imaging systems to certain frequency bands and applying other restrictions on their use.

42. The ARRL, for example, states that it does not object to permitting GPRs to operate anywhere in the spectrum, subject to appropriate emission limits.[84] It states that these devices are expected to be deployed in limited numbers and will direct their signals towards the ground. ARINC, ARRL, and ATA state that limiting UWB operations in restricted bands to GPRs that direct most of their energy into the ground may serve to minimize the impact of any harmful interference to GPS and other safety-of-life operations.[85] Nortel states that GPRs are unlikely to cause significant interference to communications systems as the energy is directed into the ground and extraneous radiation is low.[86]

84 ARRL comments at pg. 16.

85 ARINC & ATA comments at pg. 13.

86 Nortel comments at pg. 7.

Nortel also agreed that a switch or other mechanism should be required to ensure operation only when activated by the operator and aimed at the ground. The USGPSIC also requested that GPRs be equipped with a switch to shut off the transmitter if it was not in contact with the ground.[87] Sirius requested that GPRs operate exclusively below 2 GHz so as to avoid the DARS frequency band.[88] Aether Wire indicated that the use of frequencies below 1 GHz is optimal for transmitting through walls, pavement, debris, earth, water, snow, etc.[89] The Colorado School of Mines stated that, depending on soil conditions, GPR operation may be in the 100 MHz to 2 GHz region.[90] On the other hand, USGPSIC stated that there is no valid reason why GPRs can not operate above 3 GHz.[91]

43. AOPA questioned permitting GPRs to operate one meter from the ground. It argued that one meter represents a half-wavelength of about 150 MHz and indicates that GPRs can emit significant energy above this frequency and states that there is the possibility of substantial "coupling leakage" and reflection from the ground's surface.[92] Alloy requested that GPRs be limited to a maximum one-foot separation from the ground, requiring the GPR to be as close to the ground as possible, since metal objects could reflect the RF signal.[93] Peter Annan objected to requiring an automatic switch permitting operation only when the GPR is pointed at the ground, indicating that GPRs may be operated on steep slopes, into the sides of cliffs, or retaining walls, in underground pipes, and at other locations.[94] Mr. Annan requested that GPRs be permitted to have an override switch, *e.g.*, a press to operate switch. He also requested that certification of GPRs not be required since the interference potential from GPRs is low.

44. With regard to imaging systems, Bosch argued that the emission limits for UWB should ensure that there is no interference to other services and that the use of wall contact switches as well as automatic power control are unnecessary.[95] It pointed out that automatic power control is impracticable because it is not possible to predict the exact attenuation of every wall. TDC indicated that the best center frequency for through-wall sensors is 2 GHz due to the ability at this frequency to penetrate construction materials.[96] TDC also expressed concern regarding the requirement for a wall contact switch, noting that there may not always be flat surfaces, *e.g.*, walls in a collapsed building.[97] TDC also noted that police would prefer the ability to operate these devices remotely for the safety of their personnel. Zircon stated that its UWB radar operates between 200 MHz and 4 GHz, adding that the use of frequencies below 2 GHz is necessary to obtain through-wall imaging definition of narrow objects.[98] While Zircon stated that it does not oppose a contact switch in principle it needs an override mechanism to permit a few seconds of

87 USGPSIC comments at pg. 23-24.

88 Sirius comments at pg. 15.

89 Aether Wire comments at pg. 6.

90 Colorado School of Mines reply comments at pg. 3-4.

91 USGPSIC reply comments at pg. 10.

92 AOPA comments at pg. 7. NBAA comments at pg. 8. Sirius comments at pg. 19-20.

93 Alloy reply comments at pg. 14.

94 A. Peter Annan comments at pg. 3. The Colorado School of Mines on page 4 of its reply comments also noted that GPRs are sometimes used to investigate cliff faces and overhangs.

95 Bosch comments at pg. 3 and reply comments at pg. 2.

96 TDC comments at pg. 11.

97 TDC comments at pg. 26.

98 Zircon comments at pg. 1 and 5.

calibration or to pass closely over uneven surfaces that might not always permit direct contact.[99] XM stated that it is unlikely that imaging systems would pose a significant threat of interference to DARS.[100]

45. Nortel noted that caution is needed with systems that are designed to penetrate walls or floors as emissions from these systems could interfere with in-building communications systems.[101] Alloy expressed concern that through-wall-imaging systems could be aimed at CMRS antennas and wants these devices activated only if they are in direct contact with a wall surface and equipped with automatic power control.[102] USGPSIC requested that the use of through-wall imaging systems be restricted to public safety applications or to the protection of life or property in order to avoid proliferation of the equipment.[103] It also stated that these devices must be required to meet all of the conditions established by NTIA for UWB devices operating under a waiver from the Commission.[104] These conditions mandate the keeping of records of all parties to whom the equipment is marketed, coordination by the equipment users of detailed areas of operation with the Frequency Assignment Subcommittee of the Interdepartmental Radio Advisory Committee under NTIA, and other requirements. TDC stated that the operation of through-wall systems should not be limited to law enforcement and public safety even though the more sophisticated versions were likely to be used by these groups.[105] TDC noted that similar technology could provide high security sensors for commercial and residential applications. Zircon also requested that the Commission not restrict the operation of imaging systems to safety-of-life or property as its customers would be contractors and remodelers who would not be permitted to use the equipment under these conditions.[106]

46. Discussion. Based on the record and recommendations from NTIA,[107] we find that imaging systems can be permitted to operate in most regions of the frequency spectrum without causing harmful interference provided appropriate technical standards and operational restrictions are applied to their use. With regard to GPRs, we find that these devices must operate over a range of frequencies, including in the region below 2 GHz, in order to obtain the penetration depth and resolution necessary to detect and obtain the images of buried objects. We also agree with the majority of the commenting parties that the risk of interference from GPRs is low since the energy from these devices is directed into the ground, where most of the energy is absorbed, and emissions in other directions can be shielded without affecting the operating characteristics of the GPR. Further, we expect that GPRs will have a low proliferation and usually operate at infrequent intervals. In addition, the low heights at which GPRs are operated and the low duty cycles employed by GPRs[108] ensure that there is a minimal risk of interference from these devices.

47. GPRs must operate only when directed at the ground and in contact with, or in close proximity (*e.g.*, 1 meter) to, the ground for the purpose of detecting or obtaining the images of buried

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[99] Zircon reply comments at pg. 3.

[100] XM reply comments at pg. 6, footnote 8.

[101] Nortel comments at pg. 7.

[102] Alloy reply comments at pg. 14-16.

[103] USGPSIC comments at pg. 23-34.

[104] *See* letter of June 15, 1999, from William T. Hatch of NTIA to Dr. Dale Hatfield, Chief, OET, FCC.

[105] TDC comments at pg. 26.

[106] Zircon reply comments at pg. 3.

[107] *See* letter of February 13, 2002, from William Hatch, *supra.*

[108] GPRs generally operate at low PRFs as they must pause between pulses to give the signal transmitted into the ground sufficient time to be reflected and to return to the receiver.

objects, and we will require that they be tested at their operational height. This will ensure that any emissions due to leakage or to reflections can be detected. We do not agree with Alloy that reflections that may occur from infrequent metal objects that may appear under the GPR would increase the potential for interference. Such objects would likely be quite small and would reflect the signal low to the ground where it would quickly be attenuated with distance and by intervening objects. To ensure that operation occurs only when the GPR is directed towards the ground, we are requiring that the device be equipped with a switch accessible by the operator. The switch shall be manually operated and shall cause the transmitter to cease operation within 10 seconds of being released by the operator. It is permissible for the switch to be operated by remote control provided the GPR system ceases transmission within 10 seconds of the remote switch being released by the operator.

48. We reject the request to exempt GPRs from the Commission's equipment certification procedure. This procedure was established as a method to ensure that RF products comply with the appropriate standards before they are imported, marketed or used. We do not have sufficient experience with this equipment at this time to ensure that such devices do, or will continue to, meet our technical standards.

49. We recognize that wall, through-wall, and medical imaging systems generally do not direct their energy into the ground and therefore present a somewhat greater risk of interference. However, it is desirable for these imaging systems to operate across a broad range of frequencies in order to accommodate different applications and to effectively penetrate a wide variety of materials. We believe that sufficient protection from harmful interference can be achieved by a combination of technical requirements and operational restrictions on imaging systems. We are therefore designating three classes of imaging systems, each subject to different technical standards and operational restrictions.

50. *Low-frequency imaging systems.* The first class of imaging systems includes all imaging systems operating with a –10 dB bandwidth that is wholly contained below 960 MHz. These systems will be permitted to operate at the emission limits contained in §15.209. They are also required to meet the following out-of-band emission limits:

Frequency in MHz	EIRP in dBm
960-1610	-65.3
1610-1990	-53.3
Above 1990	-51.3

51. We are restricting the use of this class of equipment to parties eligible for licensing under the provisions of Part 90 of the FCC's rules. We also are requiring that the operators of imaging systems in this class complete a coordination procedure with the Government. These devices radiate energy in arbitrary directions and operate in the vicinity of materials that may provide, in some instances, very little energy absorption. While the record showed that the GPS and other authorized services are generally robust against interference from devices, such as GPRs, with low PRFs, the record did not directly support extending this conclusion to all systems operating in this low frequency range. Other technical and operational requirements for low-frequency imaging systems are contained in new Section 15.509 in Appendix D. The specifics of the coordination process are detailed in the Section 15.525 contained in Appendix D of this Order.

52. *High-frequency Imaging Systems*. The second class of imaging systems are those that operate with a -10 dB bandwidth between 3.10 GHz and 10.6 GHz.[109] Emission levels from this category

[109] It should be noted that GPRs are a specialized application of imaging systems and can operate under this second category of imaging systems using any PRF provided, however, that they comply with all of the other technical and operational restrictions associated with this equipment category.

of device must meet an emissions mask for the appropriate frequency bands. The emission limits are as follows:

Frequency in MHz	EIRP in dBm
Below 960	15.209 limits
960-1610	-65.3
1610-1990	-53.3
1990-3100	-51.3
3100-10600	-41.3
Above 10600	-51.3

53. The high-frequency imaging system class includes GPRs, wall, and medical imaging devices. As with the low-frequency imaging systems, Government coordination is required for the operation of these devices, following the procedures described in Section 15.525 in Appendix D. Specific technical and operational requirements for high-frequency UWB devices are contained in Section 15.513 in Appendix D.

54. *Mid-frequency Imaging Systems.* This class of imaging systems consists solely of through-wall and surveillance systems. These devices operate with a – 10 dB bandwidth between 1990 MHz and 10,600 MHz. Higher unwanted emission limits than those applied to the other classes of imaging devices are permitted. The emission limits are as follows:

Frequency in MHz	EIRP in dBm
Below 960	15.209 limits
960-1610	-53.3
1610-1990	-51.3
1990-10600	-41.3
Above 10600	-51.3

55. Parties seeking to operate this mid-frequency class of devices must be eligible for licensing under the provisions of Part 90 of the FCC's rules. The systems in this class are considered to pose a greater risk for harmful interference because of the lower frequency of the fundamental emission and the higher power levels reflected in the less conservative emissions mask; however, consideration of the substantial benefits to the public safety and the limited user base tend to mitigate the interference concerns. This class of UWB imaging systems requires Government coordination. This coordination will provide for operation in a pre-approved geographic area, with perhaps, certain restrictions on specific locations identified by the Government. This should provide maximum flexibility to safety services while still assuring that the risk for harmful interference is appropriately minimized. Surveillance systems will operate only at fixed locations such that harmful interference can be avoided through coordination. In addition, if harmful interference were to occur the source can be readily identified and corrected. See Section 15.511 for the specific technical provisions for mid-frequency UWB devices.

56. The limits specified above for imaging systems reflect an abundance of caution to protect the GPS and PCS services, and the passive bands employed in radio astronomy and by satellite sensors. We believe that by restricting the parties and requiring coordination before the device is used that the proliferation of these systems will be limited and the use controlled to a narrow range of applications that should not present interference concerns. We believe that the requirement for coordination will have a minimal impact on UWB equipment users as NTIA must complete its coordination efforts within 15 business days of its receipt of the request for routine UWB operations. Special temporary operations may be handled with a much faster turn-around time when circumstances warrant. Further, the operation of UWB systems in emergency situations can be commenced immediately pursuant to the notification procedures specified in 47 C.F.R. Section 2.405(a)-(e). We believe that these technical requirements and

operational restrictions will ensure that imaging systems do not cause harmful interference.

57. We agree with Bosch, TDC and Zircon that there is no need for a wall contact switch or automatic power control for imaging devices. However, as with GPRs, we are requiring that wall imaging systems be equipped with a manually operated switch, the release of which causes the transmitter to cease operation within no more than 10 seconds. Recognizing that police and other public safety officials may employ these systems in hostile situations, we will permit this switch to operate by remote control. We do not agree with the request from USGPSIC to require detailed record keeping such as that which was required by NTIA for the UWB manufacturers that obtained waivers from the Commission.

2. Other UWB Devices

58. Comments. The comments from parties associated with an authorized radio service generally objected to the operation of UWB devices in "their" spectrum regardless of the emission level. For example, objections to the operation of UWB were filed by ARRL regarding the amateur bands, Cisco regarding MMDS operations, Motorola and Sprint PCS regarding operation in the PCS band, Sprint on several services including MDS, ITFS, PCS and LMDS, XM and Sirius regarding operation in the SDARS band, Nortel regarding PCS, UNII[110] and fixed wireless access systems, AT&T on UNII operation, MCHI regarding MSS, and several others.[111] Based on these objections, several different frequencies were suggested in the comments below which UWB devices should not be permitted to operate. For example, Nortel requested that UWB systems not be permitted to operate below 5.9 GHz.[112] Sirius requested that UWB systems not be permitted to operate below 2.9 GHz, with a possible exception for GPRs and wall imaging systems.[113] Lockheed Martin requested that UWB systems be excluded from operating below 2.9 GHz due to the sensitive nature of many operations conducted in restricted bands used for military and public safety applications and other sensitive uses.[114] MCHI requested that UWB devices, other than certain ground radars, not be permitted below 3 GHz.[115] Rockwell requested that UWB devices be prohibited from operating below 5.15 GHz, except for GPRs and wall imaging systems, in order to accommodate radio altimeters at 4.2-4.4 GHz and MLS receivers at 5.03-5.09 GHz.[116] ARRL requested that non-GPRs be located above 2.5 GHz.[117] XM requested that UWB devices be prohibited from operating below 3 GHz in order to provide protection to DARS.[118] Alloy wants all UWB devices, except GPRs, to operate above 2.7 GHz.[119] ARINC & ATA want UWB operation permitted only above 5.5 GHz and then only outside of the existing restricted bands.[120] ATA and several other industry

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110 UNII devices operate under Part 15 of our rules and are not provided any protection from harmful interference. *See* 47 C.F.R. § 15.5.

111 ARRL comments at pg. 2-3. Cisco comments at pg. 3. Motorola comments at pg. 11-30. Sprint PCS reply comments at pg. 2. Sprint comments at pg.3. XM comments at pg. 10. Sirius comments at pg. 7-10. Nortel comments at pg. 6. AT&T comments at pg. 5. MCHI comments at pg. 1-2. We note that UNII is a Part 15 operation and is provided no protection from harmful interference. *See* 47 C.F.R. § 15.5.

112 Nortel comments at pg. 6.

113 Sirius comments at pg. ii and 7-10.

114 Lockheed Martin comments at pg. 8.

115 MCHI comments at pg. 4.

116 Rockwell comments at pg. 5.

117 ARRL comments at pg. 17.

118 XM comments at pg. 1 and 10.

119 Alloy reply comments at pg. 16.

120 ARINC & ATA reply comments at pg. 7.

representatives stated later that UWB operation must be above 6 GHz.[121] American Trans Air stated that UWB devices should not be permitted to operate in any of the safety-of-life bands.[122] M/A-Com noted that the bands within which Motorola, Sprint, Nortel, Cisco and others requested that UWB systems be prohibited from operating are not restricted bands and may already be used by Part 15 devices.[123]

59. TDC stated that the best center frequencies are as follows: 2 GHz for wireless local area networks with precision tracking, precision tracking systems, buried victim rescue radar, and security fences; 4 GHz for RF identification tags, medical telemetry tags, short range high resolution radar, and short range data links; and 8 GHz for automotive pre-crash sensors, airbag deployment sensors, construction inspection equipment, and high resolution radars.[124] Fantasma indicated that it could operate above 2 GHz.[125] MSSI stated that UWB should initially be allowed above 3.1 GHz.[126] XSI indicated that its UWB equipment could operate with a center frequency above 3.1 GHz. Valeo Electronics stated that it expects automotive radars to be designed at frequencies above 4 GHz as antenna aperture is proportional to wavelength and space is limited.[127] Daimler Chrysler wants to operate its vehicular radar systems with a center frequency at 24.125 GHz.[128]

60. XM noted that radio receivers for several services operating above 2 GHz do not rely on directional antennas, but added that most radio receivers operating above 3 GHz do rely on directional antennas.[129] MSSI noted that fifty percent of the U.S. Government radio operations and forty percent of non-government radio operations occur below 3.1 GHz and requested that UWB operation be permitted above this frequency.[130] NTIA, in its analysis of potential interference from UWB systems to non-GPS systems, concluded that the operation of UWB devices is feasible in portions of the spectrum between about 3.1 and 5.65 GHz at heights of about 2 meters with some operating constraints but that operation below 3.1 GHz would be quite challenging.[131] This statement by NTIA was echoed in several of the comments filed in response to the NTIA analysis.

61. Aether Wire stated that rather than confining operation to above 2 GHz we should set reasonable limits in the GPS bands consistent with noise sources that already exist and let manufacturers choose how to meet these limits.[132] It added that an outright ban to UWB operation below 2 GHz would be dictating a political solution to an engineering problem and would favor some UWB systems over others. The USGPSIC requested that we require UWB transmitters to be equipped with filters to protect the GPS band, stating that it is impossible to prevent significant changes in the frequency and bandwidth

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121 ATA *et al ex parte* comments of 6/6/01, 5/18/01.

122 American Trans Air reply comments at pg. 2.

123 M/A-Com reply comments at pg. 2.

124 TDC comments at pg. 11.

125 Fantasma comments at pg. 3.

126 MSSI comments at pg. 2.

127 Valeo Electronics comments at pg. 7.

128 Daimler Chrysler *ex parte* filing of 7/31/01.

129 XM comments at pg. 10.

130 MSSI comments at pg. 10 and reply comments at pg. 2.

131 NTIA Special Publication 01-43, *supra*, at pg. x. We note that NTIA, in performing its analysis leading up to this statement, did not consider the 12 dB reduction below the Part 15 general emission limits that was proposed in the *Notice*.

132 Aether Wire comments at pg. 7.

of a UWB emitter due to accidental or intentional changes to the UWB antenna.[133] It attached a new element to a UWB antenna and removed a radiating element from another UWB device to demonstrate that the UWB transmitter could be made to change frequency.

62. Discussion. We recognize that the UWB proponents wish to build various types of UWB devices oriented towards the general consumer marketplace. However, we also are concerned about harmful interference absent sufficient constraints. As noted earlier, we believe that a cautious approach is needed during the initial stages of UWB development. For that reason, we are adopting very conservative emission limits for consumer UWB applications for three categories of devices: vehicular radar systems; indoor; and hand-held, short range, peer-to-peer systems.

63. *Vehicular Radar Systems.* We are limiting vehicular radar systems to operation with a center frequency greater than 24.075 GHz.[134] Further, we are requiring that the frequency at which the highest radiated emission level occurs also must be greater than 24.075 GHz and that the -10 dB bandwidth be contained between 22-29 GHz. This is high enough in frequency to ensure antenna directionality along with a high level of signal attenuation with increasing distance and intervening objects. It also is high enough in frequency to permit the use of an antenna small enough to be mounted on an automobile. Further, by requiring the center frequency to be this high the emissions appearing within the frequency bands below 10.6 GHz that were investigated by NTIA and others should be similar to spurious emissions from conventional Part 15 transmitters or to emissions from digital devices and of no greater interference threat. Consistent with our cautious approach, we are requiring that emissions below 960 MHz be at or below the § 15.209 limits and that emissions appearing above 960 MHz conform to the following emissions mask:

Frequency in MHz	EIRP in dBm
960-1610	-75.3
1610-22,000	-61.3
22,000-29,000	-41.3
29,000-31,000	-51.3
Above 31,000	-61.3

64. While we believe that the emission mask that we are adopting will prevent harmful interference to radio systems operating in these bands, out of an abundance of caution we also are requiring that vehicular radar systems employ directional antennas or other methods that will attenuate the emissions 38 degrees or higher above the horizontal plane in the 23.6-24.0 GHz band by at least 25 dB below the Part 15 general emission limits.[135] As requested by NTIA, and as discussed in paragraphs 195-197 of this Order, this level of attenuation will be increased in steps such that emissions 30 degrees or higher above the horizontal plane in the 23.6-24.0 GHz band must be attenuated 35 dB below the Part 15 general emission limits by January 1, 2014. Since we expect vehicular radar to become as essential to passenger safety as air bags for motor vehicles, the greater number of vehicles using these systems could pose an increased risk to terrestrial passive sensing by satellites. Therefore, we are adopting the additional emission requirements. See Section 15.515 in Appendix D for the specific provisions for

133 USGPSIC comments of 7/25/01. XSI in its comments of 7/25/01 at pg. 4 and 9 noted that its antenna can not be manipulated in such a manner. The Commission also previously recognized that UWB devices might not be able to notch out frequency bands that are a subset of their operating frequencies. *See Notice*, *supra*, at para. 23 and 30.

134 Most comments supporting UWB operation for vehicles wished to operate above 24 GHz.

135 The angle above the horizontal plane is based on measurements from a properly installed vehicle radar system with the vehicle resting horizontally.

vehicular radars.

65. *Indoor UWB Systems*. Devices operating under this category must demonstrate that the system units will fail to operate if they are removed from the indoor environment. One acceptable procedure may be to show that the transmitting unit requires AC power to function. Based on the concerns expressed by NTIA and others regarding operation below 3.1 GHz, we are requiring that –10 dB bandwidth of indoor UWB systems must lie between 3.1 GHz and 10.6 GHz. We are adopting a very conservative out of band emission mask to address the concerns of companies which make or market indoor electronic equipment. In the frequency band below 960 MHz these devices are permitted to emit at or below the § 15.209 limits, and emissions appearing above 960 MHz will conform to the following emissions mask:

Frequency in MHz	EIRP in dBm
960-1610	-75.3
1610-1990	-53.3
1990-3100	-51.3
3100-10600	-41.3
Above 10600	-51.3

66. An additional requirement for indoor UWB devices is that they may transmit only when operating with a receiver. A device connected to AC power is not constrained to reduce or conserve power by ceasing transmission, so this restriction will eliminate unnecessary emissions. In addition, if a device is designed to operate pointed downwards in an enclosed structure such as a metal or underground storage tank, it may operate at the levels allowed in this section. See Section 15.517 in Appendix D. We are convinced that the conservative emission limits and restrictions we are adopting for UWB indoor devices will prevent harmful interference. Not only will indoor operation provide additional attenuation due to surrounding structure, the signals from the UWB transmitters would no longer be directly in the beam of high gain antennas, such as MMDS antennas mounted on rooftops or aeronautical antennas at airports. Indeed, the majority of interference problems reported by NTIA in its analyses of interference to non-GPS systems concerned outdoor systems and especially outdoor systems operating at an elevation of 30 meters.[136] These provisions will ensure that even nearby RF devices, including devices that also may operate indoors, will not receive interference.

67. *Hand Held UWB Systems.* Section 15.519 of Appendix D contains the provisions for miscellaneous UWB devices that are primarily hand held and intended to operate in a peer-to-peer mode without restriction on location. Operation among peer-to-peer devices is expected to be a strong driver for the development of UWB technology. We recognize that the greatest concerns of interference in the record were centered about the potential for uncontrolled proliferation of these devices. Therefore, out of an abundance of caution the limits that we are adopting here are the most stringent for UWB operation. We are requiring that these devices operate with a –10 dB bandwidth between 3.1 GHz and 10.6 GHz. We are adopting an extremely conservative out of band emission mask to address the concerns of the great majority of commenters. In the frequency band below 960 MHz these devices are permitted to emit at or below the § 15.209 limits, and emissions appearing above 960 MHz must conform to the following emissions mask:

Frequency in MHz	EIRP in dBm
960-1610	-75.3
1610-1900	-63.3
1900-3100	-61.3

136 NTIA Special Publication 01-43, *supra*.

3100-10600	-41.3
Above 10600	-61.3

68. Further, we also require that these devices transmit only when in communication with an associated receiver. The transmitter will cease transmission within 10 seconds unless it receives an appropriate acknowledgment from the associated receiver, and the acknowledgment will continue during the transmission at 10-second intervals. Devices operating under these emission levels should result in battery operated, hand held units with a viable range of about 10 to 15 meters. The out of band emissions are reduced by 10 dB below the requirement for indoor devices except in the GPS bands where the limit is already approaching the practical bound on our ability to verify compliance by measurement. We are adopting these requirements out of an abundance of caution and we believe that these emission levels and restrictions address the majority of the concerns and analyses in the record. See Section 15.519 in Appendix D for the specific technical requirements for these devices.

69. We find no validity to the statement from USGPSIC that an operator would modify the UWB antenna to change operating frequency or bandwidth or that equipment that has been damaged in such a fashion would continue to be operated. We are aware that the emitted frequency of an impulse system is a function not only of the pulse width and shape but also of the resonant frequency of the antenna. Any major modification to the antenna could result in the UWB transmitter operating at a different frequency. However, such a significant change would also render the equipment unusable as the associated receiver would now be on the wrong frequency. Significant phase errors likely would be introduced as well. Because of this, we expect that UWB manufacturers would design equipment with some serious thought to protecting the antenna from damage. Accordingly, we find no basis to require UWB transmitters to be equipped with filters.

D. Analyses of Interference Studies

70. Proposal. In the *Notice*, the Commission noted that NTIA and others were planning experimental programs to study the interference potential of UWB devices. The Commission encouraged these testing programs, believing that the information they yielded would be important for developing emission limits for UWB devices. The establishment of emissions limits requires a firm understanding of the characteristics of UWB signals, their impact on victim receivers, and the minimum separation distance between UWB devices and victim receivers. Thus, the Commission requested parties performing interference tests to consider and provide information on receiver susceptibility to UWB signals along with the spatial geometries assumed for evaluating potential interference.

71. Submissions. Several parties submitted analyses of potential interference to various radio services from UWB devices. NTIA[137], NTIA on behalf on DOT[138], and TDC[139] provided reports addressing potential interference to GPS receivers.[140] NTIA presented two studies regarding the potential for UWB transmission systems to cause harmful interference to U. S. Government radio operations between 400 MHz and 6000 MHz. [141] In addition, DOD provided a mathematical analyses of possible interference from

137 *See* NTIA Special Publication 01-45, *supra*, and NTIA Report 01-384, *supra*.

138 NTIA, on behalf of DOT, also submitted a preliminary version of this report on October 30, 2000.

139 The study consists of testing performed by the University of Texas along with an analysis by the Applied Physics Laboratory of Johns Hopkins University.

140 *See* Public Notice of March 26, 2001, DA 01-753.

141 *See* NTIA Special Publication 01-43, *supra*, and NTIA Report 01-383, *supra*. *See*, also, Public Notice of January 24, 2001, DA 01-171, requesting additional comments on this study.

UWB operation to its Space-Ground Link Subsystem (SGLS) at 2.2-2.3 GHz.[142] The following additional reports were filed: ARRL calculated increases to receiver noise floors for receivers located at 420 MHz and 2500 MHz;[143] Motorola,[144] Sprint PCS, Telcordia Technologies and Time Domain Corporation,[145] and Qualcomm[146] performed analyses and testing of potential interference to PCS systems; Cisco presented an analysis of interference to MMDS systems;[147] and XM calculated the impact on Satellite DARS systems.[148] Comments were specifically requested on the NTIA, DOT, TDC, and Qualcomm reports.[149] In the following section, we summarize each of these analyses and present our findings.

1. NTIA, DOT and TDC Analyses of Potential Interference to GPS

72. NTIA, DOT, TDC, and Qualcomm performed measurements and analyses to determine the UWB emission levels necessary to prevent interference to GPS operation. Qualcomm conducted UWB interference test on a GPS receiver that is intended to provide location information for E-911 services. The information below summarizes various measurement reports on UWB interactions with GPS receivers.

73. *Measurements*: Initially, NTIA tested two GPS receivers, a coarse/acquisition (C/A) code tracking receiver architecture that is representative of most GPS applications, and a semi-codeless receiver architecture used for applications that are less dynamic and require more precision such as surveying. In a follow-on measurement effort, NTIA also performed measurements on a GPS receiver employing a narrowly spaced correlator architecture and an aviation GPS receiver compliant with FAA Technical Standard Order-C129a (TSO-C129a) also employing the C/A code receiver architecture.[150] The performance criteria used to define and assess interference to receiver operations were: (a) break-lock (BL), a condition that causes a loss of signal lock between the GPS receiver and the satellite, and (b) increase in reacquisition time (RQT), the amount of time it takes a receiver tracking a GPS signal to reacquire the signal after it has been momentarily removed. NTIA also developed a representative set of impulse waveform parameters to characterize the UWB emission environment. The parameters included four PRFs of 0.1, 1, 5, and 20 MHz; four modulation types consisting of constant PRF, On-Off keying, 2% relative reference dither, and 50% absolute dither; and two types of signal gating - 100% and 20%; resulting in 32 permutations. These permutations identified the single source UWB signal structure. An additional set of 5 aggregate signal structures was developed to investigate how several UWB devices acting together would affect the GPS receiver performance.

74. NTIA performed testing to determine the interference thresholds of the GPS receiver. A GPS simulator was used to establish the GPS receiver operational state. In the test constellation, GPS signals from a four satellite constellation (five satellites were used for the TSO-C129a compliant receiver in order to meet receiver autonomous integrity monitoring requirements) based on ephemeris data taken

142 Filing of U.S. Department of Defense submitted 10/1/00, Attachment 2.

143 ARRL comments at Appendix A.

144 *See* Motorola comments at pg. 11-38.

145 Sprint PCS and TDC joint comments at Attachments 1 and 2.

146 *See* Public Notice of March 26, 2001, DA 01-753.

147 Cisco comments, Attachments 2 and 3.

148 XM comments, Technical Appendix.

149 Other parties indicated that test reports would be filed with the Commission, but these have not been forthcoming.

150 See NTIA Report 01-389 Addendum to NTIA Report 01-384: Measurements to Determine Potential Interference to GPS Receivers from Ultrawideband Transmission Systems, September 2001.

from an actual GPS constellation present on December 16, 1999. For the measurements performed on the C/A code, narrowly-spaced correlator, and TSO-C129a receivers the simulator power of the satellite being monitored was set to the minimum specification level of –130 dBm at the GPS receiver input.[151] The simulator power of the satellite being monitored for the semi-codeless receiver was set to –133 dBm at the GPS receiver input. One commenter states that using the minimum guaranteed signal power represents an overly worst-case scenario.[152] The commenter also provides a detailed discussion of the difficult propagation conditions that GPS receivers must operate in.[153] Tracking and acquiring/reacquiring satellites in an open field with no obstructions is relatively straightforward. The challenge comes when there is a partial blockage that reduces the amount of signal energy that reaches the receiver. As pointed out by the commenter, the key factors that characterize the GPS signal propagation include multipath and blockage from buildings and foliage. These factors reduce the received GPS signal level in urban and suburban areas where GPS receivers are used in land-based applications. The received GPS signal levels from unobstructed satellites can be as much as 7 dB higher, than the guaranteed minimum signal level; however, it is the difficult propagation environment for land-based GPS receiver applications that justifies the use of the minimum signal level in the establishment of regulatory limits.

75. Conducted measurements were used to evaluate the interference levels on the GPS receivers, and radiated measurements, using an anechoic chamber to determine whether the GPS antennas altered the UWB radiated signals before they reached the GOS receiver. The results of the radiated measurements confirmed that the GPS antenna does not cause any effects to the portion of the UWB signal within the GPS operating band beyond that of amplifying the signal by the antenna gain in the direction of the UWB device. One commenter criticized the NTIA and DOT measurements programs for not including outdoor radiated measurements in assessing the impact of UWB devices on GPS receivers.[154] We believe that conducted measurements that are repeatable in a controlled environment are more appropriate at this stage where we are trying to set conservative limits for a new technology. Since the ambient noise environment and the contributions from multi-path will change for each geographic location, outdoor, radiated measurements performed in a specific location are more difficult to interpret for establishing regulatory limits and that we have an inadequate record at this time for basing standards on such measurements.

76. The measurements performed by NTIA also included collecting amplitude probability distribution (APD) statistics, which, together with results from the interference measurements of the GPS receivers, were used to classify the UWB signal interference effects in the GPS receiver into 3 categories; pulse-like, CW-like, and noise-like. The pulse-like category was defined by received UWB pulses that were independent,[155] and low duty cycle (low PRF), and could not cause a GPS break-lock condition within the available power of the UWB test generator. The CW-like category was defined by a received UWB environment composed of dominant spectral lines, which produced severe disruption in GPS receiver performance when one spectral line aligned with a C/A code line in the received GPS signal. The noise-like category was defined as UWB spectra without dominant lines and with repeatable measured values for GPS receiver reacquisition thresholds. The UWB signals and GPS noise measured signals were expressed in terms of a 20-MHz bandwidth (centered at 1575.42 MHz), and power

151 Global Positioning System Standard Positioning Service Signal Specification, Second Edition, GPS NAVSTAR (June 2, 1995) at pg. 18.

152 TDC Comments in response to Public Notice at pg. 40.

153 *Id* at pg. 49.

154 *Id* at pg. 36.

155 Pulses are independent when the filter bandwidth is greater than the pulse repetition rate. To remain independent the minimum pulse repetition period of a dithered signal must be greater than the duration of the filter impulse response.

measurements were expressed as RMS power levels. The measurements produced values of the RMS power level for interference using BL and RQT thresholds for all of the 32 UWB signal variations and 5 aggregate UWB signal cases.

77. NTIA's classification of the UWB signals, as they existed in the GPS receivers tested, is similar to classifications for general interference to GPS made by the RTCA (pulsed, CW, and broadband noise) and the ITU-R (CW and broadband noise).[156]. The ITU-R and the RTCA have both derived permissible interfering signal limits for each of these classes of GPS interference. For the case of in-band pulsed interference, the RTCA derived limit is a peak power of +20 dBm for pulse widths less than 1 ms and pulse duty cycles less than 10%. For the in-band CW interference case, both the RTCA and the ITU-R interference limits are defined as –120.5 dBm for GPS receivers operating in the tracking mode.[157] For in-band broadband noise interference, both the RTCA and the ITU-R limits are -110.5 dBm/MHz for GPS receivers operating in the tracking mode.[158] The NTIA measurement and analysis results are consistent with these values. These RTCA and ITU-R limits are based on a minimum available GPS C/A code signal level of –130 dBm with the GPS receiver antenna gain assumed to be -4.5 dBi.[159] The RTCA and ITU-R interference limits are based on a Minimum Operational Performance Standard for GPS receivers used for Category I/II/III precision approaches.

78. NTIA demonstrated that independent UWB pulses of sufficient amplitude would saturate one or more elements in the GPS receiver during the pulse period. If the pulses are relatively short, and produce an impulse response at the output of the filter, and are of a relatively low duty cycle, they will not seriously degrade GPS performance. Further, the interference effect is independent of the pulse amplitude as long as the amplitude is below the receiver peak pulse power limit (approximately +20 dBm). NTIA concluded that GPS performance is relatively robust to pulse-like UWB emissions. The NTIA measurements for the C/A code receiver architecture show that a UWB signal with a PRF of 100 kHz[160] causes a low-duty cycle pulse-like interference effect that does not degrade GPS receiver performance. The measurements performed by NTIA for the narrowly spaced correlator and TSO-C-129a receivers, which use the C/A code architecture, also show this low duty cycle, pulse-like interference effect.

79. NTIA also performed measurements of UWB interference to a semi-codeless GPS receiver. The measured susceptibility values, based on the RQT performance criterion, are for a variety of UWB characteristics. The GPS receiver performance criterion for RQT is a "sharp" increase in the average time to reacquire a GPS signal that has been interrupted for ten seconds. This average time was determined by measuring the reacquisition time for each of ten trials (for the same set of test conditions) and then computing the average time of the successful reacquisitions. That is, if the receiver was not able to reacquire within the time allowed for a trial, this trial was not considered in the determination of average reacquisition time. The RQT threshold value was determined by engineering judgment by observing a plot of average reacquisition time and deciding at what UWB input signal level there was a

156 NTIA Special Publication 01-45, *supra*, at pg. 2-8.

157 ITU-R Recommendation M. 1477, *Technical and Performance Characteristics of Current and Planned Radionavigation-Satellite Service (Space-to-Earth) and Aeronautical Radionavigation Service Receivers to Be Considered in Interference Studies in the Band 1559-1610 MHz* (2000), at Tables 1 and 2. As noted in footnote 2 to these tables, the interference threshold already takes into account the effects of GPS intra-system interference based on random code analysis. This threshold value must account for all other aggregate interference.

158 *Id*.

159 Document Number RTCA/DO-229B, Minimum Operational Performance Standard for GPS/Wide Area Augmentation System Airborne Equipment (January, 1996). Recommendation ITU-R M.1477, *supra*, at ANNEX 1, Section 3-2.

160 These low PRFs are found in most of the proposed GPR systems.

sharp increase in reacquisition time. In general, this sharp increase was more evident for the UWB signals involving higher PRFs (*i.e.*, 5 and 20 MHz) and was more a judgment for the lower PRF conditions.[161]

80. The DOT sponsored measurements considered a UWB signal with a PRF of 100 kHz and came to the same conclusion as NTIA. Thus as long as the PRF of the UWB emission is no greater than, 100 kHz, and the output level of the UWB emission is low enough so as not to overload the front end of the GPS receiver, interference to GPS from UWB operation is unlikely. Based on the test data, UWB devices could operate at the Part 15 general emission limits, provided the PRF does not exceed 100 kHz, without causing interference to GPS reception. Thus from the GPS protection viewpoint, GPRs with PRFs less than 100 kHz are not an interference concern.

81. For the measurements of the C/A code receiver architecture, NTIA classified 19 of the 32 UWB signal permutations in the pulse-like category. The majority of the PRF values were 100 kHz (8 cases) and 1 MHz (7 cases), however two of the 5 MHz PRF (2% relative and 50% absolute dither with 20% gate), and one 20 MHz PRF (2% relative dither, 20% gate) produced pulse-like interference effects. The NTIA measurements confirmed, as theory would predict, that there is a relationship between the interference effect and the receiver bandwidth. For example, some of the UWB signals (particularly among the 1 MHz PRF signals) that produced pulse-like interference effects in the wider band GPS receivers (the 10 MHz C/A code and 16 MHz narrowly-spaced correlator receivers) produced a response characteristic of the more disruptive noise-like or CW-like interference effects in the narrower bandwidth receiver (2 MHz TSO-C129a). As the PRF of the UWB emission increases above 1 MHz, the interference to the GPS receiver can be classified as either noise-like or CW-like. The noise like signal permutations included the 5 and 20 MHz PRF, 100% gated waveform with 2% relative or 50% absolute dithering. Among these four noise-like cases, the worst-case measured interference threshold for the C/A code receiver was –95 dBm/20 MHz (-108 dBm/MHz) corresponding to the 20 MHz PRF, with 50% absolute dithering signal. Nine of the 32 UWB signal permutations were categorized as CW-like. There were four 5 MHz and four 20 MHz PRF cases and one 1 MHz PRF signal set that resulted in CW-like GPS interference effects. Among these 9 CW-like cases, the worst-case interference threshold measured for the C/A code receiver was –99.5 dBm/20 MHz. The adjustments to convert this value to the power level for a single spectral line in a one MHz bandwidth include a 3 dB reduction for the division of power between discrete spectral lines and the continuous spectrum for on-off keying (OOK), a 7 dB reduction to account for the 20% gate-on time relative to total time of 20 milliseconds, and a 7 dB reduction to adjust

161 Of particular concern for the interference protection of the semi-codeless GPS receiver is the reacquisition data point listed for the UWB signal with a 100 kHz, 2% relative dither and 20% gating. The listed value is -88 dBm/20 MHz. This single value would indicate the semi-codeless receiver is susceptible to low PRF UWB interference. This single value is at least 17 dB lower than the other listed values for a 100 kHz PRF UWB signal. This 17 dB difference includes a 7 dB adjustment to determine the average interference power for the 20% gated signal. Because this 17 dB difference is significant in determining interference protection requirements, a further review of this data point was carried out. The measured data plots for all the 100 kHz PRF, 20% gated UWB signal cases for the semi-codeless receiver tests were reviewed. This resulted in reviewing four data plots for reacquisition tests from the measured data report. As previously stated the reacquisition threshold was determined through a judgment as to the power level where a sharp increase in reacquisition time occurred. For three of the data plots, the previous judgment was that no sharp increase was observed over the range of measured interference power levels. Only in the case of concern (100 kHz with 2% relative dither and 20% gating) was a reacquisition threshold selected. In retrospect, because the curves are all similar, a comparative review of the data across the four cases would indicate that a reacquisition threshold should not have been selected over the range of UWB signal powers measured for the 100 kHz PRF, 2% relative dither and 20% gating case. Thus, the entry in Table 2-2 of NTIA Special publication 01-45 should be [-66] rather than -88. The [-66] shows that this was the limit of the power available in the test setup and the effect of interest (the reacquisition threshold) was not observed. This GPS receiver performance, in the presence with low PRF UWB interfering signals, is in agreement with the C/A code receiver architecture results.

for a single spectral line that is modulated by a sinc function by the gating period, producing –116.5 dBm.[162] The measured level at which interference occurred to the GPS C/A code receiver was 8 dB less for a CW-like UWB signal than for the noise-like UWB signal.[163] This measured difference is in agreement with the RTCA and ITU-R standards noted above which identify a 10 dB difference for the two interference effects.

82. *Analysis*: In order to calculate the maximum allowable EIRP for a UWB device, a source-path-receiver analysis must be performed. The basic parameters that must be defined for this type of analysis are the receiver interference threshold, the source output power and antenna gain, the propagation path between the transmitter and receiver, and the antenna gain of the receiver in the direction of the source transmitter. The data obtained from the measurements performed by NTIA define the interference threshold level at the input of the GPS receiver as a function of UWB signal structure (*e.g.*, power, PRF, modulation scheme) for each of the GPS receiver architectures examined. The EIRP of an UWB device can be estimated by the Part 15 emission limit to which it is subject. However, this EIRP thus derived is in most practical cases an overestimate, particularly when the receiver of interest has a bandwidth which is narrow compared to the difference between the upper and lower frequency of a emission limit.

83. In the case of the emission limits in Appendix D, the bracket containing the GPS band is 960-1610 MHz with a total bandwidth of 650 MHz. Part 15 devices are measured for approval purposes using the methodology contain in ANSI Standard C63.4.[164] This methodology checks the limit, expressed in field strength units, over the whole bandwidth of the bracket and over a surface 3 meters away from the device under test with measurement height ranging from 1 to 4 meters. Furthermore, the device is measured over a conducting surface that causes reflections of emissions to reach the antenna in addition to direct rays from device under test. This multipath contribution to the measured field strength means that the measured field strength corresponds to an EIRP 4-5 dB higher than a mathematical conversion from field strength to EIRP would indicate. Furthermore the fact that the highest field strength measurement over a cylinder 3 meters in radius and 3 meters high and over the whole bandwidth of a bracket is used for compliance comparison, leads to an additional overestimate compared with the signal that might be emitted from a UWB device in a specific direction and at a specific frequency measurement with a 1 MHz bandwidth. For the following analysis to determine UWB emission limits we will use the worst case, but probably unrealistic, assumption that the EIRP in the direction of the GPS receiver or any other victim receiver is the same as implied by compliance measurement. This is necessary at this time because we do not have reliable information in the record concerning the evenness of the spectral emissions over frequency and the variability of UWB antenna patterns with frequency and direction.

84. In order to make reasonable assumptions regarding the remaining values needed for the analysis, information regarding how the transmitter and receiver can interact within their operating environment is necessary. Collectively, this information defines an operational scenario, which establishes how close the two systems may come to one another under actual operating conditions, and the likely orientation of the antennas. This information is then used to compute the propagation loss and the receive antenna gain in the direction of the transmitter. The operational scenario can also be used to determine the applicability of factors such as building attenuation, multiple transmitters, and safety margins.

[162] NTIA Special Publication 01-45, *supra*, at pg. 2-12.

[163] Our discussion in this section primarily is directed to noise-like UWB emissions. Additional protection will be provided to GPS reception of CW-like emissions to accommodate the 8 dB difference measured by NTIA and the 10 dB specified in the RTCA and ITU-R standards.

[164] *See 47 C.F.R. § 15.31(a)(6).*

85. NTIA, RTCA, and the USGPSIC performed analysis to compute the maximum allowable EIRP for the UWB devices with the GPS receiver and UWB device for different operational scenarios. NTIA hosted a series of open public meetings to develop operational scenarios to be considered. The meetings were announced in the *Federal Register* and participation was encouraged within the UWB and GPS communities and among the interested Federal agencies. Specific proposals for operational scenarios to be considered included GPS receivers used in the following applications: land-based (*e.g.*, public safety, emergency response vehicle navigation, geographic information systems, precision machine control); maritime navigation (in constricted waterways, harbors, docking, and lock operations); railway operations (positive train control); surveying; and aviation (en-route navigation and non-precision approach). The input received at the public meetings was used by NTIA to develop the operational scenarios considered in their analysis. RTCA Working Group 6 developed operational scenarios for GPS receivers used in Category I, II, and III precision approach landings. The USGPSIC developed an operational scenario for an E-911 GPS receiver. Since the *Notice* did not specify any operating restrictions for UWB devices, the operational scenarios considered both indoor and outdoor operation of UWB devices. These operational scenarios are the developers' best estimates of acceptable geometries between GPS receivers and UWB devices. However, the scenarios do not have the legal status of law or regulation and our willingness to use them for this analysis is based mostly on the absence of other standards that reflect a broad consensus and a balancing of all public interests. Spectrum management is a complex subject and interference protection goals in general must consider both the benefits of authorizing new emitters as well as the interference risk to other systems.

86. There are two operational scenarios proposed on the record that serve as the limiting scenarios for establishing the emission limits for UWB devices operating indoors: 1) the land-based multiple UWB device operational scenario developed by NTIA and 2) the E-911 operational scenario developed by the USGPSIC. The following paragraphs provide a detailed discussion of these operational scenarios.

87. The first limiting operational scenario for the indoor use of UWB devices is where there are several UWB devices operating inside of a building and the GPS receiver is operating outdoors. The following table provides an overview of the technical factors for noise-like interfering UWB signals considered in the analysis for this operational scenario. In order to err on the conservative side, worst case assumptions have been used for most parameters, as advocated and explained by NTIA.

Table 1 Technical Factors Considered for Indoor UWB Interference to GPS

Parameter	Value	Value
GPS Receiver Interference Susceptibility (dBm/MHz) (Performance Metric)	-102.5 (BL)	-108 (RQT)
Propagation Loss (dB) (Minimum Distance Separation (m))	55 (8.6)	55 (8.6)
GPS Receive Antenna Gain (dBi)	-3	-3
UWB Device Interference Allotment (dB) (Percentage UWB)	-3 (50)	-3 (50)
Allotment for Multiple UWB Devices (dB) (Number of Devices)	-6 (4)	-6 (4)
Manufacturer Variation (dB)	-3	-3
Average Building Attenuation (dB)	9	9
Allowance for Acquisition (dB)	-6	0
Maximum Allowable EIRP (dBm/MHz)	-59.5	-59
47 C.F.R.§15.209 Emission Limit (dBm/MHz)	-41.3	-41.3
Additional Attenuation Required (dB)	18.2	17.7

88. The UWB emission limit recommended in the above table is calculated by adding the values in the columns. As shown in the table, for noise-like UWB signals an additional 18 dB of attenuation below the 47 C.F.R.§15.209 emission limit is necessary to protect the GPS receiver under the conservative assumptions in this operational scenario. The following paragraphs will provide a detailed discussion of each of the technical factors considered in this operational scenario.

89. The GPS interference susceptibility levels used in this analysis correspond to the break-lock and reacquisition performance metrics of the GPS receiver. As discussed earlier, the GPS receiver interference susceptibility referenced to the input of the receiver was obtained from the single source measurements performed by NTIA. The values used in this analysis are based on the UWB signal structure that causes the most susceptible noise-like interference threshold that was measured by NTIA.

90. The propagation loss is computed using the minimum distance separation between the GPS receiver and the UWB device as defined by the operational scenario considered. For this operational scenario the minimum distance separation is computed from the slant range with the GPS receiver located 5 meters from the building and the UWB device 7 meters above the GPS receiver. The computed minimum distance separation is 8.6 meters. For this distance separation the free space propagation model is applicable. One commenter suggests that a factor for loss due to vegetation be included in the analysis.[165] Although such a factor may be applicable in other operational scenarios, NTIA does not believe that it is appropriate in this case and that it should not be included in the analysis. The commenter also suggests that a factor be included for scattering loss that would result from the fact that most of the world is cluttered with objects that will reflect the UWB signals and create frequency selective nulls.[166] Signal scattering similar to the effects of multi-path is difficult to predict and are highly dependent on the surrounding obstacles. Since there is no way to accurately predict the types of obstacles that exist in a given area, the inclusion of such a factor in this analysis may not be appropriate given the lack of operational experience with UWB.

91. The UWB devices, which are indoors, in this operational scenario, are located above the GPS receiver, which is outside. The antenna model used by NTIA for the GPS receiver indicates that the receive antenna gain is 3 dBi. The antenna for the UWB device is assumed to be omnidirectional. One commenter suggested that the antenna gain of the UWB device in the direction of the GPS receiver be reduced by 2 dB to account for off-axis antenna alignment.[167] Another commenter stated that in the analysis of aggregate interference to airborne GPS receivers it is appropriate to reduce the gain of the UWB device based on the elevation angle.[168] The commenter states that most UWB applications will employ omnidirectional antennas that will provide essentially uniform coverage in the horizontal direction and in the vertical direction for low elevation angles.[169] The commenter recommends that the antenna gain of the UWB device be reduced by approximately 40 dB to 4 dB respectively for elevation angles from the vertical down to 45 degrees.[170] At the lower elevation angles, the commenter does not recommend a reduction in the UWB device antenna gain. We agree that it would be appropriate to include such a factor if the UWB devices were employing directional antennas and the locations of the devices

165 TDC Comments in Response to Public Notice at pg. 64.

166 *Id.*

167 *Id.*

168 Comments of XtremeSpectrum, Inc., *On Issues of Interference Into Global Positioning System Receivers* (April 25, 2001) at pg. 21.

169 *Id.*

170 *Id.*

were known. However, it may not be appropriate to include an off-axis antenna alignment factor in the analysis of this operational scenario, where omnidirectional antennas might to be employed. Off-axis discrimination is typically employed when analyzing stations in the fixed radio service, for example, where the locations of the transmitters and antenna pointing angles are known. Since the locations, the types of antennas being employed, and the antenna pointing angles of the UWB devices are all unknowns; it may be inappropriate to include a factor for off-axis antenna alignment in this analysis. An off-axis antenna alignment factor could be applied in an operational scenario examining aggregate interference to an airborne receiver from a large number of land-based UWB devices, such as in an en-route navigation operational scenario. However, it may not be appropriate to include such a factor in the analysis of this operational scenario based on the record.

92. One commenter states that antenna polarization mismatch loss should be included in the analysis to minimize the interference effects of UWB devices to GPS receivers.[171] Polarization mismatch loss, also referred to as polarization discrimination or polarization isolation, is the ratio at a receiving point between received power in the expected polarization and received power in a polarization orthogonal to it from a wave transmitted with a different polarization. Polarization mismatch is a common technique used in sharing the same frequency for fixed point-to-point microwave systems and fixed satellite earth stations. The key factor being that the transmitter and receiver antennas are fixed and their polarization are known. Moreover, the polarization of an antenna remains relatively constant throughout the main lobe of the antenna pattern, but varies considerably in the minor lobes.[172] In practice, polarization of the radiated energy varies with the direction from the center of the antenna, such that different parts of the antenna pattern and different sidelobes have different polarizations.[173] This is also true for GPS antennas where in the mainbeam the polarization is circular, but outside the mainbeam in the lower elevation angles the polarization is nearly linear. Since the locations of the UWB devices, and polarizations are unknown at this time we do not believe that a factor for polarization mismatch loss should be included in the analysis.

93. In addition to the potential interference from UWB devices, several other potential sources of interference to GPS receivers have been identified. These potential sources of interference include but are not limited to: 1) adjacent band interference from mobile-satellite service Mobile Earth Terminals (METs); 2) harmonics from television transmitters; 3) spurious emissions from 700 MHz public safety base, mobile, and portable transmitters; and 4) spurious emissions including harmonics from 700 MHz commercial base, mobile, and portable transmitters. Multiple sources of interference, which might individually be tolerated by a GPS receiver, may combine to create an aggregate interference level that could prevent the reliable reception of the GPS signal. The emission limit of the MSS METs, 700 MHz public safety and commercial transmitters is –40 dBm/MHz for noise-like interference. The zone of interference of each of these transmitters could be as much as a circle of 30-meter (100-foot) radius, if it emits out-of-band radiation at the limit. The emission from digital television (DTV) transmitters is –110 dBc and will result in a zone of interference that is as much as a circle of 270 meters (884-foot) radius at the same height as the antenna. As a consequence these transmitters do not have to be located next to a GPS receiver to disrupt signal reception in land-based applications. In this conservative operational scenario one half of the total allowable interference budget is allotted to UWB devices and the other half is allotted to all other interfering sources combined. The factor for UWB device interference allotment is computed from 10 Log (UWB interference allotment ratio). For a UWB device interference allotment of 50% (a ratio of 0.5), a 3 dB factor is included in this analysis. One commenter argued against including a factor for interference allotment in the analysis.[174] However, their argument is at odds with their other

171 TDC Comments in Response to Public Notice at pg. 64.

172 Antenna Engineering Handbook, R.C. Johnson, H. Jasik (Second Edition) at pg. 1-7.

173 Antenna Analysis, E.A. Wolff (1966) at pg. 17

174 TDC Comments in Response to Public Notice at pg. 56.

comments, wherein they acknowledge that there may be sources of interference such as incidental and unintentional radiators, as well as licensed transmitters with spurious emissions in the GPS bands.[175] The use of allotments for multiple sources of interference is not a new concept in studies examining interference from one radio service to another. For example, ITU-R Recommendation F.1094-1 specifies an interference allotment of 89% for transmitters of the same radio service, an interference allotment of 10% for radio transmitters in other radio services, and a 1% interference allotment for all other sources (*e.g.*, unlicensed transmitters).[176] This is also consistent with ITU-R Recommendation M.1477, which states that when there is a potential for more than one source of interference at the same time, it will be necessary to apportion the interference threshold among the potential interference sources.[177] Since the GPS/UWB measurements that are part of the public record in this proceeding did not include other potential sources of interference, it may be appropriate to include a factor in the analysis to take them into account. Out of an abundance of caution, we shall do so here but may request comments in future proceedings on appropriate interference modeling.

94. The factor for multiple UWB devices was obtained from the multiple source (aggregate) measurements performed by NTIA. The measurements performed by NTIA verified that if the individual signals cause an interference effect that is noise-like, the interference effect of the multiple noise-like signals is noise-like. Based on the measurements, for UWB signal permutations that have been characterized as causing noise-like interference, a factor of 10 Log (number of UWB devices) is included in the analysis. Based on the record, it is unclear whether this modeling of cumulative effects of multiple spatially separated UWB devices will be representative of typical UWB environments. However, erring again on the side of conservatism in order to protect GPS in the near future we are accepting NTIA's analysis of multiple UWB device effects at this time.

95. One commenter recommends that an activity factor of 3 dB be included in the analysis to account for the fact that UWB devices will not be transmitting continuously.[178] The factor of 3 dB would indicate that each UWB device is transmitting 50% of the time. The inclusion of an activity factor may be appropriate when there are a large number of UWB devices considered in the operational scenario. The activity factor is also dependent upon the UWB application. Since there are only four UWB devices in this operational scenario and it is not possible to accurately estimate representative values of activity factors at this time, we will not use an activity factor in this analysis (*i.e.,* the UWB devices will be continuously transmitting).

96. A 2001 GPS Receiver Survey lists 64 different manufacturers of GPS receivers.[179] The survey lists approximately 500 different models of GPS receivers representing the C/A code, semi-codeless, and narrowly spaced correlator receiver architectures. The NTIA measurements included one receiver from each of the three GPS architectures. Based on the NTIA measurements, the results of the other measurement efforts, and the analyses of the data that is part of the public record in this proceeding, initial engineering modeling of the interference effects of UWB signals on the different GPS receiver architectures has emerged. However, the number of different models of GPS receivers and manufacturers considered in the current measurement efforts may not completely represent the performance of all the

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175 *Id.* at pg. 44.

176 ITU-R Recommendation F.1094-1, *Maximum Allowable Error Performance and Availability Degradations to Digital Radio-Relay Systems Arising from Interference from Emissions and Radiations from Other Sources*.

177 ITU-R M.1477 at Annex 5.

178 TDC Comments in Response to the Public Notice at pg. 64.

179 *GPS World Receiver Survey,* GPS World Magazine, January 2001, at pg. 32.

GPS receivers currently being manufactured. There may be differences in hardware, firmware,[180] or software (*e.g*., tracking and acquisition algorithms) employed in the receivers that were not considered in the current measurement efforts. There may be differences in the models produced by the same manufacturer as well as between receivers produced by different manufacturers. Therefore, the inclusion of a factor in the analysis to account for these possible differences is reasonable at this time. Based on an analysis performed by NTIA of the data that is on the public record in this proceeding, the range of data indicates that the more susceptible interference thresholds are within 3 dB of the median.[181] One commenter objected to the inclusion of the 3 dB factor for manufacturer variation.[182] The commenter stated that the industry would not accept a 3 dB variance from the stringent specifications required by the aviation and surveying receivers.[183] With the exception of the aviation community, NTIA indicates that it is unaware of any specifications for GPS receivers. The NTIA analysis included this factor to take into account the small number of GPS receivers considered in all of the measurement efforts. The analysis performed by JHU/APL also acknowledged that there are differences in GPS receivers. Specifically JHU/APL concluded that variations in the measurements of performance due to different GPS receivers are greater than those due to the operating modes of the UWB tested devices. JHU/APL further concluded that the impact of UWB devices on all GPS receivers could not be assessed using a single GPS receiver.[184] Based on the analysis performed by NTIA, the absence of detailed information on receiver variability in the record, and the conclusions reached in the JHU/APL analysis, we are applying a value of 3 dB in this analysis for manufacturer variation.

97. As part of a separate measurement effort, NTIA has conducted building attenuation loss measurements at 912, 1920, and 5990 MHz.[185] The measurements were performed for different buildings representing typical residential and high-rise office construction. Based on the results of these measurements, an average building attenuation of 9 dB in the range 960-1610 MHz in which GPS operates is used in this analysis. The standard deviation for the measurements, however, is on the same order of magnitude as the value of building attenuation loss.[186]

98. The NTIA measurements did not consider the acquisition of a new satellite in the presence of a UWB signal. The acquisition threshold is known to be more sensitive than the tracking threshold, which can, in part, be attributed to the time and frequency search performed by the GPS receiver as part of the satellite acquisition scheme. As part of the satellite acquisition process, the loop filter bandwidths are increased, which causes the noise (N) to increase reducing the effective carrier-to-noise ratio (C/N). The acquisition mode of the GPS receiver is extremely difficult to measure, because it is highly dependent on manufacturer-specific acquisition algorithms. A 6 dB factor is typically used in GPS interference analyses to account for the greater sensitivity of satellite acquisition.[187] This 6 dB reduction in the interfering signal power level only provides protection of 2.5 dB in C/N+I, which is a

[180] Firmware is software installed in a device that is typically stored in read only memory (ROM) or programmable read only memory (PROM).

[181] *See* NTIA Special Publication 01-47, *Assessment of Compatibility Between Ultrawideband (UWB) Systems and Global Positioning System (GPS) Receivers* (Report Addendum), November 2001.at pg. 2-13.

[182] TDC Comments in Response to Public Notice at pg. 56.

[183] *Id.*

[184] JHU/APL Report at ES-2.

[185] NTIA Report 95-325, *Building Attenuation Measurements From Low-height Base Stations at 912, 1920, and 5990 MHz*, September 1995, at pg. 43.

[186] *Id.* at pg. 36.

[187] *Understanding GPS Principles and Applications*, E. D. Kaplan (Editor), Artech House, 1996, pg. 211; ITU-R M.1477 at Annex 1

critical factor in GPS receiver performance. Since the performance metric of break-lock is related to the tracking performance of the GPS receiver, including the acquisition factor in the analysis when the interference susceptibility is based on the break-lock performance is appropriate.

99. The second limiting operational scenario to be considered for UWB devices is the indoor use of E-911 GPS receivers. Because buildings and other structures attenuate the received GPS satellite signals, indoor reception has been not been possible previously. However, Global Locate and Snap Track (Qualcomm) have developed technologies that permit indoor, enhanced GPS reception for E-911 applications. These technologies rely on enhancing the signal processing of the E-911 received GPS signal with information provided from a separate GPS receiver located at the base station. This supplemental information provides Doppler and code shift data to allow acquisition and tracking of low level GPS signals. In addition, information involving phase shifts caused by the GPS navigation signal is provided to allow coherent integration of the E-911 GPS signal for a period longer than 20 milliseconds. The enhanced GPS receiver integrates the satellite signal over a longer time period, allowing the receiver to obtain a 20 to 30 dB higher processing gain than a conventional GPS receiver. [188] This higher processing gain permits the reception of a GPS signal that is significantly below the receiver noise floor in a 1 MHz bandwidth.[189]

100. This processing, to determine location of the E-911 receiver, can be carried out at the E-911 receiver using supplemental data from the base station that is provided via the phone connection. An alternative is to do the final processing at the base station. For example, a snapshot (in time) of the signals (in the GPS band) received at the E-911 receiver is forwarded to the base station via the phone connection where the signal and supplemental information is processed to determine location of the E-911 receiver. These processing technologies require that the E-911 receiver not be on a platform that is moving rapidly. Significant motion could, for example, invalidate the supplemental Doppler information and/or invalidate the final position solution, which involves some time latency due to the signal processing procedure. At this time, it is expected that the E-911 position determination would not be invoked until the emergency (911) call is placed.

101. Regardless of the processing gain or the bandwidth of the tracking loop, the minimum level of the GPS signal that can be used for an E-911 position determination will be determined by the receiver system noise density. An interfering signal that adds to the system noise density will necessitate a higher GPS signal level thus decreasing the indoor coverage of the E-911 position determination capability. Thus, we believe that an analysis of an indoor UWB transmitter and an E-911 GPS receiver provides the more stringent interference example. The USGPSIC provided an operational scenario for an E-911 GPS receiver.[190] The following table provides an overview of the technical factors considered in the USGPSIC analysis for this operational scenario.

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[188] Note that these are only estimates of what values of processing gain can be achieved and may vary depending on the implementation of the technology.

[189] No E-911 receivers were available for testing purposes. The information herein is based on our meeting with Qualcomm on 9/26/01.

[190] Stephen D. Baruch, Counsel for the U.S. GPS Industry Council, Written Ex Parte Presentation in ET Docket No. 98-153, June 21, 2001, at pg. 11.

Table 2 USGPSIC Analysis of UWB Indoor Interference to E-911 Indoor System

Parameter	Value
Receiver Susceptibility Mask (dBm/MHz) (Broadband Noise)	-111.5
Public Safety Margin (dB)	-6
Multiple System Allotment (Excluding MSS) (dB)	-3
Single Emitter Allotment	-6
GPS Antenna Gain in Direction of RFI Source (dBi)	0
Propagation Loss (dB) (Minimum Distance Separation (meters))	46 (3)
Noise-Like RFI Emission Limit (dBm/MHz)	-80.5
47 C.F.R.§15.209 Emission Limit (dBm/MHz)	-41.3
Additional Attenuation Required (dB)	39.2

102. The UWB emission limit recommended in the above table is calculated by adding the values in the columns. As shown in the table, the USGPSIC states that for noise-like interference, UWB signals must be 39 dB below the 47 C.F.R.§15.209 emission limit to protect the GPS receiver under the conditions in this operational scenario. The following paragraphs will examine and assess the viability of each of the technical factors considered in this operational scenario.

103. The interference susceptibility level specified by the USGPSIC is –111.5 dBm/MHz, which is equal to an interference density of –171.5 dBm/Hz. The typical receiver system noise density of a GPS receiver is –171.5 dBm/Hz for a 3 dB receiver noise figure.[191] Therefore the specified interference susceptibility represents an I/N of 0 dB or a 3 dB increase in the system noise density. This means that interference at this level can cause a 100% increase in the GPS receiver system noise density. As stated earlier, the receiver system noise density determines the minimum level of the GPS signal that can be used for an E-911 position determination. Therefore, an interfering signal that adds to the system noise density will limit the GPS signal level that can be tracked by the receiver. Conventional GPS receivers require a relatively high C/N_0 because of the wide loop bandwidths that are employed. In contrast GPS receivers used in E-911 applications can take full advantage of communication network support to obtain and remove the GPS navigation data and to stabilize the receiver clock. In addition, it is assumed that the dynamics are very low (e.g., the user is walking). As a result, the tracking bandwidth can be narrowed very substantially, thus maintaining a positive signal-to-noise ratio in the tracking loop at much lower C/N_0 values. Receivers are being designed today which can track with a 20 dB C/N_0, and the industry is striving to track with a C/N_0 of 10 dB. Based on the system noise density of –171 dBm/Hz, a 20 dB C/N_0 represents a received signal level of –151 dBm, and a 10 dB C/N_0 represents a received signal level of –161 dBm. There are existing GPS receivers that are capable of tracking signals that are 21 dB weaker than the signal levels considered in the measurement efforts that are part of the public record in this proceeding. If improvements permit tracking at a C/N_0 of 10 dB, the tracked signal level would be 31 dB weaker than the signal levels considered in the measurement efforts. Based on the lower received signal levels that can be tracked by GPS receivers, a 100% increase in the system noise may not be acceptable. We are therefore limiting at this time the increase in system noise caused by noise-like UWB signals to 50%, which equates to an I/N of –3 dB. Based on the I/N of –3 dB the interference susceptibility level used in the analysis will be –114.5 dBm/MHz.

104. ITU-R M.1477 specifies a 6 dB safety margin to account for uncertainties on the aviation side of the link budget that are real but not quantifiable, which include but are not limited to: multipath of the GPS signal; receiver implementation losses; antenna gain variations; and approach path deviation.

191 The noise figure of a GPS receiver typically is in the range of 2 to 4 dB.

Since the GPS signal level cannot be increased, the aviation safety margin is implemented by lowering the allowable interference. In Annex 5 of ITU-R M.1477 the need for an aviation safety margin is justified by citing examples of other aviation systems such as the Instrument Landing System, and the Microwave Landing System that both use a safety margin. ITU-R M.1477 specifies a 6 dB margin for aviation safety of life applications employing GPS receivers. Therefore, it is not appropriate to apply this margin to non-aviation safety of life applications using GPS receivers, and the public safety margin of 6 dB specified by the USGPSIC should not be used in the E-911 operational scenario analysis.

105. The USGPSIC defined E-911 GPS receiver operational scenario includes a 3 dB factor for multiple interfering systems allotment, excluding MSS. This factor is used for the composite of all UWB and future radio frequency interference sources. The 3 dB factor is equivalent to a 50% interference allotment to UWB devices. The remaining 50% is to account for all other potential sources of interference. Since the GPS receiver is operating indoors this will minimize the potential for interference from other sources such as 700 MHz commercial and pubic safety mobile and base stations transmitters and harmonics from DTV stations. Furthermore, as shown in the table above, the minimum distance separation is 3 meters. For operational scenarios where the minimum distance separation between the GPS receiver and UWB devices is on the order of several meters, the UWB device is expected to be the dominant source of interference. Therefore, for the E-911 GPS receiver operational scenario it is not appropriate to include a factor for other sources of interference.

106. The USGPSIC defined E-911 GPS receiver operational scenario includes a factor for multiple UWB devices. As shown in the table there is a factor that accounts for 4 UWB devices causing noise like interference each operating at the minimum separation distance of 3 meters. Although this minimum distance separation may be acceptable when assessing interference from a single UWB device, we believe that it is not appropriate when assessing interference from multiple UWB devices. Therefore, for this operational scenario, it is not appropriate to consider multiple UWB devices operating at such a close distance. When considering interference to GPS E-911 receivers from a single indoor system, NTIA employed a minimum separation distance of 2 meters in this analysis. We have employed the antenna model specified in the NTIA analysis, using an antenna gain of 0 dBi in the direction of the UWB device. We also have employed NTIA's use of the free space propagation model to compute the propagation loss.

107. The table below shows the amount of additional attenuation below the current 47 C.F.R.§15.209 emission limits that is needed to protect an E-911 GPS receiver under the revised conditions.

Table 3 Analysis of Indoor E-911 Using Revised Conditions

Parameter	Value
Receiver Susceptibility Mask (dBm/MHz) (Broadband Noise)	-114.5
GPS Antenna Gain in Direction of RFI Source (dBi)	0
Propagation Loss (dB) (Minimum Distance Separation (meters))	42.4 (2)
Noise-Like RFI Emission Limit (dBm/MHz)	-72.1
47 C.F.R.§15.209 Emission Limit (dBm/MHz)	-41.3
Additional Attenuation Required (dB)	30.8

108. As shown in the table above, for noise-like interference, UWB signals should be 31 dB below the 47 C.F.R.§15.209 emission limit to protect the GPS receiver in this operational scenario. This conclusion is based on limited quantitative information that was inserted recently into the record by NTIA. Out of an abundance of caution to protect the newly emerging GPS-based indoor E-911 systems

and their safety implications from UWB devices with which we also have minimal operational experience, we are basing our UWB rules on this analysis.

109. Qualcomm submitted an *ex parte* presentation for the public record reporting on a series of test to assess the impact of UWB emissions on the performance of a GPS enabled PCS phone.[192] This type of GPS receiver is designed to provide location information for E-911 callers in compliance with our E-911 mandate. The Qualcomm measurements used a GPS signal level at the input to the receiver that resulted in a C/N_0 of 34 dB-Hz.[193] The noise figure of the GPS receiver was 4 dB.[194] This results in a receiver noise density level of –170 dBm/Hz (-110 dBm/MHz) and a GPS signal level of -136 dBm for a 34 dB-Hz condition. Qualcomm selected the 34 dB-Hz level as it represented a value exceeded in 5% of the test cases for within building applications.[195] The UWB signal was then input to the GPS receiver and the location accuracy determined as a function of UWB signal level. For dithered (noise-like) UWB signals the 50th percentile position accuracy increased to 50 m at -97.5 dBm/2 MHz or -100.5dBm/MHz. This interference level is 9.5dB above receiver noise (I/N = 9.5dB). However, our requirement for E-911 performance includes a specification for 95% of the calls. Using the Qualcomm cumulative distribution plots for C/N_0, a value that would be exceeded in 95% of the cases can be determined.[196] This value is 22.5 dB-Hz and is 11.5 dB below the value for 5% of the cases. That is the carrier (GPS signal) is 11.5 dB weaker. GPS performance is related to the carrier-to-interference ratio so that an 11.5 dB decrease in carrier level should result in a requirement to lower the UWB interference level by approximately 11.5 dB to maintain the required position accuracy. Relating this to the measured I/N of 9.5dB would indicate an I/N of -2dB would be required for 95th percentile C/N_0 level.

110. Similarly, the Qualcomm test effort evaluated UWB signals with a constant PRF resulting in a UWB spectrum with CW lines. As previously discussed in paragraph 82, *supra*, GPS can be more susceptible to CW-like interference than to noise-like interference. The Qualcomm test results showing 50th percentile position errors for noise-like and CW-like interference cases show very similar position error versus UWB power level performance characteristics. This could be interpreted that there was no difference in susceptibility for noise-like and CW-like interference. This could be explained by considering the accuracy performance is a 50th percentile value and one would not expect the alignment of GPS and interference spectral lines to occur in a significant number of cases considering the narrow loop bandwidths used in the E-911 GPS receivers and the fairly short length of time to determine position. A few instances of CW line alignment would not seriously impact the 50th percentile position error. As shown in the test report an 800-meter position error was used as a default value when there is not sufficient information to obtain a position measurement[197]. Examination of the UWB impact versus time information shows 5 cases of 800-meter errors in approximately 50 calls.[198] Some of these 800-meter errors could have been caused by CW-like interference, which is expected to be a low probability event for E-911 service. In addition some E-911 GPS receivers are reportedly using processing techniques that in effect converts CW energy into broadband interference. It is not known whether the Qualcomm receiver includes such processing. We believe, therefore, that the Qualcomm test data is inconclusive in the area of increased susceptibility of the GPS receiver tested to CW-like interference as compared to

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[192] Written *Ex Parte* Presentation, ET Docket 98-153, Revisions of Part 15 of The Commission's Rules Regarding Ultra-Wideband Transmission Systems (January 11, 2002)

[193] *Id* at pg.12.

[194] *Id* at Fig 4-19

[195] *Id* at Fig 3-6

[196] *Id*

[197] *Id* at pg. 14

[198] *Id* at Fig 4-1

noise-like interference.

111. Based on the above analysis, of the two limiting operational scenarios for the indoor use of UWB devices, a UWB signal level 31 dB below the Part 15 general emission limits would be required for noise-like UWB emissions in the 960-1610 MHz range. Based on the various uncertainties at this time and the lack of operational experience with UWB systems, we believe that an additional attenuation of 3 dB is reasonable giving a total attenuation of 34 dB below the §15.209 emission limit. This attenuation will be required for all indoor and outdoor non-imaging UWB systems, including vehicular radars and hand held systems.

112. We are permitting imaging systems, vehicular radar systems and hand held devices to operate outdoors, at any PRF provided the emissions in the GPS bands are below the Part 15 general emission limit. The limiting operational scenario considered for the outdoor use of GPS and imaging systems is given in the table below.

Table 4 Outdoor Analysis for Imaging System Interference to GPS

Parameter	Value
GPS Receiver Interference Susceptibility (dBm/MHz) (Broadband Noise)	-114.5
Propagation Loss (dB) (Minimum Distance Separation (m))	49.5 (4.5 m)
GPS Receive Antenna Gain (dBi)	0
Maximum Allowable EIRP (dBm/MHz)	-65
47 C.F.R. §15.209 Emission Limit (dBm/MHz)	-41.3
Additional Attenuation Required (dB)	23.7

113. As shown in the table above, a signal level 24 dB below the Part 15 general emission limit is required for noise-like emissions in the 960-1610 MHz frequency range from imaging systems under the conservative assumptions we are using based on the record. We also believe that imaging systems typically will emit RF energy only for short periods of time, so any possible interference from operation at closer distance separations should be transient.

114. In limited cases involving public safety uses of UWB imaging where there are positive public safety benefits from the UWB use and where coordination can be used to limit the risk of interference to safety-related uses of GPS, we believe that 12 dB less attenuation, resulting in an emission level 12 dB below the §15.209 emission limit, represents the appropriate balancing of public interests.

115. The limiting operational scenario considered for the outdoor use of GPS and vehicular radar systems is given in the table below.

Table 5 Analysis for Vehicular Radar System Interference to GPS Receivers

Parameter	Value
Receiver Susceptibility Mask (dBm/MHz) (Broadband Noise)	-114.5
GPS Antenna Gain in the Direction of UWB Device (dBi)	4.5
Propagation Loss (dB)	45.9

(Minimum Distance Separation (meters))	(3)
Allotment for Multiple UWB devices (dB)	-7.8
Noise-Like Emission Limit (dBm/MHz)	-71.9
47 C.F.R. § 15.209 Emission Limit (dBm/MHz)	-41.3
Additional Attenuation Required (dB)	30.6

116. The typical implementation of the vehicular radar systems will consist of multiple radar systems (as many as 12 per vehicle) that are mounted on the bumpers and fenders of the vehicle. Vehicular radar systems will also employ directional antennas and will be installed at a height of approximately 0.5 meters.[199] Based on anticipated operational use of vehicular radar systems the antenna discrimination of a GPS antenna in the direction of the vehicular radar systems and interference from multiple vehicular radar systems must be considered in the analysis.

117. Since the vehicular radar systems are mounted at a height of approximately 0.5 meters they will typically be below the GPS antenna. Based on the antenna model provided by NTIA, the GPS receive antenna gain in the direction of the vehicular radar systems would be –4.5 dBi. In order to determine the location of vehicles and objects that surround the vehicle multiple vehicular radar systems employing directional antennas will be employed. In this analysis it will be assumed that there are six vehicular radar systems transmitting in the direction of the GPS receiver and a factor of 10 Log (6) or 7.8 dB will be included in the analysis.

118. The calculations shown in Table 5 lead to a conclusion that a signal level 31 dB below the Part 15 general emission limit is required for noise-like emissions from vehicular radar systems in the 960-1610 MHz frequency range based on the conservative assumptions and limited record on operational experience that we are using at this time. Because of the present uncertainties in predicting interference from UWB devices for which we have no operational experience and our concern about certain safety-related applications of GPS, we agree to employ the additional safety margin applied by NTIA to the receiver susceptibility mask, resulting in an emission level 34 dB below the Part 15 limits.

119. The previous discussion has focused on interference from noise-like UWB emissions to GPS. UWB emissions can also have discrete spectral lines or CW-like emissions in addition to noise-like emissions depending on the statistical details of time spacing between adjacent pulses.[200] Now will we consider limits on these CW-like emissions.

120. The measured level at which interference occurred to the GPS C/A code receiver was 8 dB less for a CW-like UWB signal than for the noise-like UWB signal. As also indicated, this measured difference is in agreement with the RTCA and ITU-R standards, which specify a 10 dB difference for the two interference effects. Accordingly, we agree that UWB emissions appearing within the 960-1610 MHz frequency range due to narrowband CW-like interference signals should be 10 dB below the emission power level measured in a 1 MHz bandwidth permitted for noise-like emissions. As discussed in the section addressing emission limits, we are implementing this by requiring that the UWB transmitters be demonstrated to comply with this limit when measured with a spectrum analyzer

[199] BOSCH presentation to European Ultra Wideband Workshop, *Short Range Automotive Radar (SRR) … another generic (ultra) wide band device at 24 GHz* (March 20, 2001) at. pg. 4.

[200] In theory these spectral lines could be eliminated, the requirement in practical systems to have a lower bound on the time between pulses leads to structure in the signal's autocorrelation function and therefore spectral lines of some magnitude.

employing a resolution bandwidth no less than 1 kHz.[201] The above requirements for UWB emission levels appearing in the 960-1610 MHz frequency range also will be satisfactory for GPS receivers that work with satellite-based augmentation systems (SBAS) and ground based augmentation systems (GBAS). ITU-R Recommendation M.1477 provides receiver specifications for an SBAS air navigation receiver to be used in Category I precision approach operations and a GBAS air navigation receiver to be used with Category II/III precision approach operations. In both instances, the minimum required power level at the input is specified at –131 dBm, only one dB lower than the specification for the C/A code GPS receiver. In both cases, the specified receiver aggregate wideband interference threshold in track and acquisition mode is identical to the RTCA and ITU-R thresholds for the C/A code GPS receiver. Hence, the conclusions above will apply to SBAS or GBAS and GPS receivers.

121. The semi-codeless GPS receivers have more stringent requirements on GPS received signal levels (3 dB lower) than the C/A code GPS receivers, and the wideband interference requirements for tracking mode is 6 dB lower than the C/A code GPS receiver.[202] The wideband interference requirement for acquisition is the same for both classes of receiver. Because the semi-codeless receiver works with the GPS P-signal, which has essentially no spectral line content, this receiver is not sensitive to the spectral lines in the CW-type UWB emissions, as demonstrated by NTIA's measurements for the C/A code receiver architecture. NTIA's measurements also demonstrated the same robust operations for low PRF signals as the C/A code receiver. The NTIA measurements supported an increased sensitivity to noise-like UWB emissions than for the C/A code receiver architecture. Nevertheless, the operational scenarios examined by NTIA involving surveying applications that employ the semi-codeless architecture receiver produced interference levels that were higher than the terrestrial operational scenarios. In any case, since the semi-codeless receiver relies on the C/A code for initial acquisition and it typically defaults to C/A code operation if the P-signal becomes unavailable the C/A code receiver performance drives the UWB threshold limits for all receiver types discussed earlier.

2. NTIA Analyses of Interference to Various U.S. Government Systems:

122. NTIA analyzed the interactions between UWB transmitters and a number of U.S. Government radio communication systems to determine, *inter alia,* the maximum UWB emission levels that could be allowed without causing interference. These analyses were based on an extensive laboratory measurement program at the Institute for Telecommunication Sciences, in Boulder, CO. The measurement program identified various methods being currently used to generate UWB signals and characterized the essential parameters of UWB systems provided by various UWB manufacturers. The ITS verified how filters of varying bandwidths respond to numerous types of UWB signals and determined measurement techniques that correctly measure the emission spectra of UWB devices. The ITS also performed a measurement program to determine the nature of the aggregation of UWB signals.[203] NTIA also initiated a measurement program consisting of field measurements of radiated UWB signals at the FAA Aeronautical Center in Oklahoma City, OK to determine the effects of one UWB device operating at the current Part 15 limits on Air Route Surveillance Radars (ARSR), and Airport Surveillance Radars (ASR) in order to validate the prediction models used in the analysis. In its reports, NTIA provided quantitative values for UWB emission limits involving federal systems for the following: RMS power limits for a UWB device located at 2 m and at 30 m above the ground for 15 systems (and peak power limits for two of the systems); and developed a computer model for assessing the impact of aggregate UWB interference. The NTIA interference analyses of the effects of RMS and peak power were based on a link budget equation involving the system threshold for interference, as

201 This is similar to an approach we have used to protect GPS from Mobile Satellite System (MSS) out-of-band emissions. *See* 47 C.F.R. 25. ____

202 ITU-R M1477 at Annex 1 Table 3.

203 *See* NTIA Special Publication 01-43, *supra*, and NTIA Report 01-384, *supra*.

determined using standard established interference protection criteria, actual antenna elevation gain patterns for the victim receivers, the smooth earth option of the Irregular Terrain Model for propagation loss, estimated system losses, and the empirically determined correction factors for bandwidth to determine the UWB limits in power per megahertz (dBm/MHz).

123. The NTIA analysis was performed for 7 UWB PRFs ranging from 1 kHz to 500 MHz for both dithered and undithered signals. The NTIA study used the current Part 15 limit, an RMS EIRP of -41.3 dBm/MHz at frequencies above 1 GHz, as the baseline for the study. The study determined the allowable UWB emission levels and did not specifically address the 12 dB reduction from the current Part 15 level in the bands below 2 GHz as proposed in the *Notice*. The analysis also assumed that the UWB devices were located out of doors. The following is a summary of NTIA's report. A more detailed analysis has been placed in the docket file for this proceeding.

Table 6 Maximum UWB EIRP for Outdoor Use of UWB at 2m & 30 m

System	Frequency (MHz)	Maximum UWB EIRP (dBm/MHz) UWB Outdoors 2 m height	Maximum UWB EIRP (dBm/MHz) UWB Outdoors 30 m height
DME, Interrogator	960-1215	-47	Not Applicable
DME, Transponder	1025-1150	-64	-57
ATCRBS, Transponder	1030	-44	Not Applicable
ATCRBS, Interrogator	1090	-31	-45
ARSR-4	1240-1370	-61	-82
SARSAT	1544-1545	-69	-66
ASR-9	2700-2900	-46	-66
NEXRAD	2700-2900	-42	-76
Marine Radar	2900-3100	-56	-57
FSS, 20 degrees	3700-4200	-36	-42
FSS, 5 degrees	3700-4200	-51	-77
CW Altimeters	4200-4400	25	Not Applicable
Pulsed Altimeter	4200-4400	14	Not Applicable
MLS	5030-5091	-54	Not Applicable
TDWR	5600-5650	-35	-63

124. NTIA investigated the potential interactions of proposed UWB systems on 15 U.S. Government systems operating between the frequencies of 960 and 5650 MHz. The systems investigated included Distance Measuring Equipment (DME) interrogator airborne receiver, DME ground transponder receiver, Air Traffic Control Radio Beacon System (ATCRBS) air transponder receiver, ATCRBS ground interrogator receiver, ARSR), Search and Rescue Satellite (SARSAT) ground station land user terminal, ASR, Next Generation Weather Radar (NEXRAD), Maritime Radar, Fixed Satellite Service (FSS) earth stations, CW and Pulsed Radar Altimeters, Microwave Landing Systems (MLS), and Terminal Doppler Weather Radar (TDWR). Table 6 denotes these systems and their frequency band of operation and summarizes NTIA's conclusions of emission limits necessary to preclude interference from a UWB transmitter operating at a height of 2 or 30 meters. The maximum UWB EIRP is the maximum signal level that NTIA calculated at which a UWB transmitter could operate without causing interference to the

system when the UWB is allowed unrestricted outdoor operation independent of the UWB's pulsewidth, PRF, or other modulation schemes or the nature of it's intended operation (e.g. radio determination or communication). Where there was a difference due to the PRF of the UWB emission, we have included the results from the PRF that required the UWB emissions to be reduced to the lowest level. In the column for 30 meters, "Not Applicable" indicates that the particular scenario would involve a UWB transmitter on a fixed antenna tower at the same altitude as the airborne victim, which would not be likely.

125. The NTIA protection criteria for most of the systems were determined from International Civil Aeronautical Organization (ICAO), RTCA and ITU-R standards developed from system spectrum sharing criteria. The protection levels for the DME interrogator, the ATCRBS systems, and the MLS were based, however, on specific system performance specifications and on additional protection margins recommended by the FAA's Spectrum Management and Policy Program Division. NTIA chose to use international and national sharing and coordination criteria partly because harmful interference is a subjective criterion. Moreover, these are well-established critical operations, many involving safety of life situations. Therefore, NTIA believes that it is appropriate to provide them protection from interference rather than ensuring that harmful interference is unlikely. We recognize that there is usually more than one valid approach to interference analysis. In several of the analyses discussed below, we present a short discussion of the rationale for less conservative values also identified in the record. However, out of an abundance of caution, we have deferred to NTIA's experience with these systems and used NTIA's conservative analyses to develop the requirements for UWB operations. The following discussion examines these protection criteria for each of the examined systems.

126. *DME, Interrogator*. This system is used to provide civil and military aircraft pilots with the distance from a specific ground beacon, the transponder, for navigational purposes. In Appendix A of its report, NTIA referenced the RTCA specification[204] for a 70 percent reply efficiency at a –83 dBm receiver sensitivity, and calculated that the interference threshold should be set at –115 dBm, which is an I/N of -7 dB as shown by Table A-9. [205] NTIA concluded that for all conditions studied and proposed, a UWB EIRP of –47 dBm is adequate to protect the operations of the DME interrogator receiver.

127. Our evaluation of the NTIA approach used the –99 dBm RTCA protection criterion but found no basis for including the additional 16 dB of safety margin suggested by NTIA. NTIA indicates they applied a partitioning of total interference allowing 10 percent for UWB (a -10 dB factor) and 6 dB for an aeronautical safety margin directly to the -99 dBm RTCA protection criterion calculating that the interference threshold should be -115 dBm. Employing a -99 dBm protection criterion appears to be consistent with NTIA's analysis of the ATCRBS systems where a very similar set of operational conditions applies, and where we agree with the NTIA methodology. We concluded that this system would not experience interference from a UWB device operating at the Part 15 general emission level.

128. *DME, Transponder*. This device responds to interrogations from the DME airborne component. NTIA applied a 10 dB UWB partitioning and 6 dB aeronautical safety margin directly to the –106 dBm receiver thermal noise level calculating that the interference threshold should be–122 dBm. The NTIA initial study of the DME transponder showed that an EIRP of –64 dBm was necessary to protect its operations from UWB emissions with the additional caveat that no UWB could come as close as 15 meters. NTIA's analysis also showed that an EIRP of –41.3 dBm would be adequate to protect the transponder; however, it would be necessary to ensure that UWB devices not operate any closer than 260 meters, which cannot be guaranteed. The operational limits required for the protection of the GPS will

[204] *Minimum Operational Performance Standards for Airborne Distance Measuring Equipment (DME) Operating within the Radio Frequency Range of 960-1215 MHz*, RTCA DO-189, at 2.2.11 (September 1985).

[205] NTIA Special Publication 01-43, *supra*, at page A-19, Table A-9.

also be adequate to protect DME operations.

129. We question the applicability of the 10 dB value NTIA applied for "UWB partitioning." However, applying NTIA's 16 dB protection criterion directly against the –94 dBm receiver sensitivity, similar to the analysis applied to the DME interrogator, resulted in an interference criterion of –110 dBm, which is 4 dB below the receiver thermal noise floor. We concluded that a UWB EIRP of –52 dBm provides an adequate protection threshold for the DME interrogator receiver and that the 260-m separation distance determined by NTIA was a conservative value. We note that the protection criterion employed by NTIA for this system was based on a CW-type interfering signal level. Thus, we believe that NTIA's analysis results in a conservative protection value since UWB emissions are designed to be predominantly noise-like. We agree with NTIA that the operational limits for GPS protection will protect DME operations.

130. *ATCRBS Transponder and Interrogator*. These systems are used in conjunction with the ASR and ARSR and other air traffic control radars to provide controllers with the location, altitude, and identity of civil and military aircraft through an interrogate and reply operation. The protection criteria employed by NTIA were based on the minimum triggering levels, that is the minimum input power levels supplied to the sensor RF port that results in a 90 percent reply ratio for the transponder, -77 dBm, and a 90 percent reply ratio for the interrogator, -79 dBm. Both the interrogator and the transponder must be able to demodulate and decode 90 percent of the interrogations (replies) with a S/I of 12 dB.[206] NTIA used the power level for 90 percent reply detection as the system threshold and applied the RTCA and FAA 12 dB S/I criterion to these values to determine the interference thresholds. NTIA's final system interference thresholds are 11 dB above the receiver thermal noise floor for the interrogator system and 9 dB above the receiver noise floor for the transponder system. We agree with the NTIA analysis and note that ATCRBS transponder and interrogator operations will be protected from harmful interference at the emission limits being established to protect to other nearby systems (*e.g*., ARSR-4, and GPS).

131. *ARSR-4*. This system is used by the FAA and DOD to monitor aircraft during enroute flight to distances of beyond 465 km (250 nautical miles). NTIA used a protection criterion of an interference-to-thermal noise ratio of -10 dB, *i.e.*, I/N = -10 dB, while the current protection criteria in ITU-R Recommendation M.1463 is for an I/N of –6 dB for both radionavigation and radiolocation applications of radar.[207] NTIA calculated that low PRF operations of UWB devices, even near ground level, must be limited to -60 dBm EIRP to protect the ARSR-4. We note that the emission limits being required for emissions in the GPS bands are adequate to protect ARSR-4 operations.

132. We noted in our analysis that the ITU-R rationale for I/N = -6 dB relates to the desensitization of the radar receiver for noise-type interference due to the increases in the apparent noise floor that the receiver perceives. This desensitization effect results in a decrease of the maximum working range of the radar (about 6 %) for the smallest cross section target that the radar can detect. The effect occurs only at the distance where the signal to noise (S/N) of the radar is marginal for normal performance, which is at the boundaries of an azimuthal angular section of about half the azimuthal beam width in the direction of the UWB source. We also noted that radar range decreases by much larger amounts due to atmospheric effects such as rain. We believe that the specific events that could cause this effect, such as UWB device location and antenna orientation with respect to the radar, and the relatively

206 *Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/MODE S) Airborne Equipment*, Radio Technical Commission for Aeronautics, RTCA DO-181A, at 2.2.8.1 (January 1992) and Federal Aviation Administration, US Department of Transportation, *Specification for Mode Select Beacon System (Modes) Sensor*, Amendment 2, FAA-E-2716 (March 1993).

207 An I/N of –6 dB translates to an increase in the noise floor of 1 dB and a reduction in the maximum radar range of just under 6 percent. A value of –10 dB translates to an increase in the noise floor of about 0.5 dB and a reduction in the maximum radar range of just under 3 percent

mild nature of this effect greatly reduce the risk of interference. We further note that the NTIA analysis did not include an effect due to the scanning beam of the operating radar. TDC stated that because the antenna's main lobe is actually tapered, the response signals being integrated could not have the UWB transmitter fixed at the maximum of the lobe; instead, it appears smeared over the beamwidth of the antenna.[208] TDC also stated that beam shape losses raise the level of the noise in a typical radar receiver by at least 1.6 dB above the thermal noise floor and possibly as high as 3 dB.[209] We concluded that the potential for UWB interference to the ARSR-4 was more limited than the NTIA analysis suggests. However, a more detailed analysis would involve statistical estimates and require information specific to individual radar sites. Therefore, we deferred to the NTIA analysis values for this system. These remarks also apply to the ASR-9 and the Marine radar.

133. *SARSAT-LUT*. This system provides distress alert and location information to appropriate public safety rescue authorities for maritime, aviation, and land users in distress. NTIA used a protection criterion of I/N = -9 dB. The NTIA SARSAT-LUT analysis was based on the SARSAT receive antenna operating at an elevation angle of 0 degrees, *i.e.*, the receive antenna is pointed directly at the horizon. At this elevation angle, the large gain of the antenna amplifies emissions from a UWB device at 2 m height. TDC and XSI correctly noted that the performance specification for SARSAT dictates acquiring the satellite when it reaches an elevation angle of 5º above the horizon where there is 10 dB less gain provided by the SARSAT-LUT antenna than at 0º.[210] However, the acquisition process begins at, or near 0º elevation. The SARSAT-LUT antenna is scanned to a lower elevation angle to permit faster acquisition of the COSPAS/SARSAT satellites as they appear above the horizon. Thus NTIA concluded that use of the maximum antenna gain is appropriate. Of the UWB operations proposed, outdoors use will have the greatest potential to interfere with SARSAT operations.

134. Our analysis of the SARSAT noted that the NTIA protection criterion was not referenced from a specific standard or recognized criteria. SARSAT is a digital communications system, and we do not consider it necessary to protect communications systems from signals that are below the noise floor. These systems operate at some margin above the noise floor to account for aging components, adverse propagation conditions, and other system degradations. Hence, we used the noise floor as the protection level, *i.e.*, an I/N of 0 dB. We also used the angle of 5º above the horizon based on the SARSAT specification. We concluded that a UWB EIRP of –50 dBm was an adequate protection threshold for the SARSAT system for UWB emissions at a height of 2m. Further, we noted that the NTIA analysis values are critically dependent on the height of the SARSAT antenna used in the analysis (NTIA used an average height). Since there are only 7 SARSAT systems mostly located on Government installations, we believed that each system could have been addressed individually and that this approach would have shown that UWB operations would not cause interference to SARSAT operations.

135. *ASR-9*. This radar monitors the location of civil and military aircraft in and around airports to a range of 110 km (60 nautical miles). NTIA stated that the protection criterion for this radar was an I/N of –10 dB. The U.S. Submission to ITU-R Working Party 8B proposed this level in a revision to ITU-R M.1464, which is under consideration by ITU-R Study Group 8 and is an official US position. There is also a proposal by Working Party 8B to decrease the I/N to –12 dB involving an evaluation of

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[208] TDC comments of February 23, 2001, at pg. 26-27. Also, Skolnik, M. I., *Introduction to Radar Systems*, (1980) at pg. 58-59.

[209] We believe that TDC means that the intensity of the received signal is reduced by 1.6 to 3 dB due to beam smearing.

[210] TDC comments of 3/12/01 at pg. 10, footnote 18. XSI comments of 3/12/01 at pg. 7. *See COSPAS-SARSAT LEOLUT Performance Specifications and Design Guidelines*, Document C/S T.002, Issue 3, Rev. 1 (Oct. 1999) in Section 3.5 at 3-1. This states that the LUT shall be able to track the LEO SARSATs when they reach 5 degrees above the horizon.

expected interference to radars from systems using Orthogonal Frequency Division Multiplex (OFDM) modulation methods. The proposal to change the I/N to –12 dB also includes noise like interference sources, and is not solely based on an OFDM type emission.[211] However, the –10 dB level is the agreed upon U.S. position with the ITU and is appropriate for this analysis. In calculating the required emission limits for UWB devices to protect the ASR-9, NTIA used average antenna heights and antenna tilt angles. Only indoor UWB operation in a 30 m building exceeds the predicted protection limit for the ASR-9. The ASR-9 requires a limitation of the EIRPs of UWB devices operating inside buildings to –57 dBm, while the proposed limit for indoor UWB devices in this band is –51.3 dBm. Further calculations show that if the protection level is –51.3 dBm, the required separation distance for a UWB operating at this EIRP level is 270 meters. This 3.7 dB difference effectively would reduce the I/N from –10 to –6 for this system and would increase the noise floor by 1 dB instead of ½ dB. While NTIA indicates that this would diminish the capabilities of this radar in the same azimuth of the building, NTIA concluded that it is not as severe a problem as the reduction of the coverage in this azimuth due to the physical line-of-sight blockage caused by a 10-story building within 270 meters of an ASR-9.

136. *NEXRAD*. This radar provides quantitative and automated real-time information on storms, precipitation, hurricanes, tornadoes, and a host of other important weather information. We note that NTIA refers to ITU-R M.1464, the same specification called out for the ASR-9 but uses a level of –6 dB below the noise floor as the applicable protection level since the NEXRAD radar is used for meteorological purposes. Only indoor UWB operation in a 30 m building less than 760 meters away exceeds the predicted protection limit for the NEXRAD. The NEXRAD requires a limitation of the EIRPs of UWB devices operating inside buildings to -57.3 dBm, while the proposed limit for indoor UWB devices in this band is –51.3 dBm. Given the 0.5-degree minimum elevation angle of the antenna mainbeam, the beam would only be 6.6 meters above the ground at 270 meters. The building itself would at least partially obstruct the 3 dB beam width of the mainbeam and be the limiting factor along the given azimuth and not the UWB's EIRP. An elevation angle of greater than 2 degrees is required to clear a 30-meter obstacle at a distance of 270 meters.

137. Our analysis of this weather radar examined the possible locations of the UWB devices that were required to produce an interference level –6 dB below the radar noise floor. At these locations, we computed the field strength emitted by the radar. We concluded that UWB devices would not be found at these locations because the radar fields were large enough to disrupt the operation of standard electronic devices. We also were informed of NOAA's siting criteria[212] that requires a large exclusion area around the radar to assure operational capability. We were unable to confirm that such exclusion areas actually exist as required due to the absence of site specific data showing the distance and location of large buildings around the radar sites. Therefore, we deferred to the NTIA analysis values for this system. These remarks also apply to the TDWR weather radar.

138. *Marine Radionavigation Radar*. These S-band radars provide information on surface craft locations, obstructions, buoy markers, and navigation marks, *e.g.*, shore-based beacons and radar beacons to assist in navigation and collision avoidance. NTIA employed an I/N protection criterion of –10 dB, indicating that this level is contained in a proposed revision to ITU-R M.1313-1 under consideration by ITU-R Study Group 8 and entitled, *Technical Characteristics of Maritime Radionavigation Radars.* Only the level proposed for UWB indoor operation at 30 meters height exceeds the calculations for maritime radar. Indoor UWB operations in this band will be limited to –51.3 dBm. The level computed for protection of marine radar was –56 dBm. The distance at which a UWB with an EIRP of –51.3 dBm

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[211] *Study on 2700-2900 MHz Frequency Band Sharing Between Existing Aeronautical Radar Equipment and Planned Digital ENG/OB and digital Aeronautical Telemetry Services*, EUROCONTROL, Edition Date 29/05/2001.

[212] *See* XSI *ex parte* comments of February 4, 2002, at pg. 21-22. XSI also indicates that there are similar FAA siting requirements for its radar systems.

satisfies the protection criteria equation is 370 meters. At such a close separation distance, it does not appear that marine radionavigation radar systems would receive harmful interference from UWB operations. As shipboard UWB operation is prohibited at the request of NTIA, marine radar systems must be less than 370 meters from land in order to receive interference from UWB systems. At this distance, the return signal from the target being detected by the marine radar would be considerably higher than the signal received from the UWB device. Accordingly, no harmful interference would occur.

139. *FSS*. These 4-GHz earth stations are used to receive downlink transmissions from geosynchronous satellites for a variety of applications including voice, data, and video services for Government agencies. NTIA examined interactions with FSS systems employing antenna elevation angles of 20 degrees and 5 degrees. NTIA used an I/N protection criterion of –10 dB based on a general discussion of factors affecting the sensitivity of digital communication systems. Only the level proposed for UWB indoor operation at 30-meter heights exceeds the calculations for protection of receivers in the fixed satellite service with an elevation angle of 8º. Emissions from indoor UWB operations in this band will be limited to –51.3 dBm. The level computed for protection of FSS receivers with an elevation angle of 8 degrees was –67 dBm. For the proposed level of –51.3 dBm, the required separation distance to satisfy the protection criterion, a separation distance of 240 meters must be maintained. For the given scenario of an FSS earth station with an 8º elevation angle, if the separation distance is less than 240 meters, a 30 meter building would at least partially obstruct the 3 dB beamwidth of the mainbeam of the earth station antenna based purely on the geometry of the scenario. Hence the level –41.3 dBm appears adequate.

140. Our analysis of the FSS noted that the NTIA protection criterion was not referenced from a specific standard or recognized criterion. FSS is a digital communications system, and as discussed in the SARSAT analysis, we believe the noise floor should be applied as the protection level, *i.e.*, an I/N of 0 dB. We applied the analysis procedure found in the Radio Regulations of the ITU[213] and concluded that for an I/N of 0 dB, UWB interference would not be allowed to occur for more than 2.5% of the time without requiring coordination. We considered that UWB devices in tall buildings would not be an interference risk for the FSS terminals. The FSS antenna would not point at a building since the building would block signals from the satellite. We were unable to confirm this conjecture because of the absence of site specific data showing the distance and location of large buildings around the FSS sites. Therefore, we defer to the NTIA analysis values for this system.

141. *CW and Pulsed Radar Altimeters*. These systems provide pilots of civil and military aircraft and, through them, air traffic controllers with information on the height of an aircraft above ground level. NTIA's investigation demonstrated that UWB devices operating at the Part 15 general emission limits would not result in interference to these operations. For that reason, we have not investigated these systems in any greater detail.

142. *Microwave Landing Systems*. These systems are used for precision approach and landing of civilian and military aircraft. The MLS ground station supports navigation and guidance out to a range of 43 km at an altitude of 20,000 feet. NTIA stated that RF interference could lead to errors in the estimation of time intervals associated with beam passage of the MLS transmitting station's antenna beam.[214] It added that, depending on the frequency components of the error process and the aircraft flight control system guidance loop bandwidth, this could lead to the physical displacement of the aircraft relative to the desired approach path. NTIA added that the ICAO specified the maximum permissible

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213 Radio Regulations of the ITU, Appendix 7, *Method for the Determination of the Coordination Area Around an Earth Station in Frequency Bands Between 1 GHz and 40 GHz Shared Between Space and Terrestrial Radiocommunications Services*. Section 2.3, "Derivation and Tabulation of Interference Parameters," and Section 2.3.1, "Permissible Level of the Interfering Emission," was applied.

214 NTIA Special Publication 01-43, *supra*, at pg. A-17.

interference power into a MLS receiver as –130 dBm to prevent this from occurring.[215] NTIA subtracted 4 dB from the ICAO threshold "to partition the UWB interference into the link budget," resulting in NTIA's maximum permissible UWB interference level of –134 dBm, a level that is 22 dB below the thermal noise floor of the MLS receiver and 31 dB below the sensitivity of the MLS receiver. NTIA employed a 5-dBi gain antenna, the maximum available to the aircraft at an angle of about 30 degrees below the horizontal.

143. Our analysis of the MLS focused on two approaches. First, the receiver noise floor is –112 dBm, and the ICAO maximum interference level is –130 dBm. This interference level is 18 dB below the noise floor and 27 dB below the sensitivity level of the receiver. An interfering signal at 18 dB below the noise floor would result in an increase to the MLS receiver noise floor of only 0.07 dB. Such a small increase in the noise floor is not detectable by the receiver or by measurement instrumentation. We believe that employing the ICAO value as a protection criterion is overly conservative for this system. Further, we do not agree with the comments from Rockwell stating that the 4 dB additional safety margin added by NTIA is inadequate for MLS operation in a Category III approach. Rockwell did not provide any justification for an additional safety margin. Indeed, we believe that the ICAO threshold, even without the 4 dB additional safety margin applied by NTIA, is too conservative. Second, we note that NTIA calculated that harmful interference would be caused to MLS from a UWB transmitter operating at the Part 15 general emission limits at a maximum separation distance of 160 meters. We also note that the expected operating range of the MLS system is 43 km at an altitude of 20,000 feet. There is little likelihood that at this range from the MLS transmitter the aircraft will be within 160 meters of a UWB transmitter. As the aircraft approaches the ground, it will come much closer to the MLS transmitter, increasing the level of the received signal to the point that the MLS signal would be considerably greater than the signal level from a UWB transmitter operating at the Part 15 general limits.[216] NTIA also stated that its calculations were based on the aircraft being at a height of 30 meters. At this height, the aircraft would be near the MLS transmitter, whose signal level would override any potential interference.

144. *TDWR*. These radars operate in the 5600-5650 MHz band and provide measurements of gust fronts, microbursts, and other weather hazards at for improving safety operations at major airports in the United States. They are located within 24 kilometers (15 miles) of airports and need to have a clear line-of-sight (LOS) at the runway to observe weather phenomena for aircraft approaches and landings. Indoor UWB operation is the only UWB operation not directly protected by the proposed limits. The proposed UWB EIRP level for this band is –41.3 dBm which is 8 dB above the calculated EIRP. To achieve the required protection for the TDWR, a UWB located in a 30-meter building would have to be located 1370 meters away. Given the 0.2º minimum elevation angle of the antenna mainbeam, the beam would only be 5 meters above the horizon. The building itself would at least partially obstruct the 3 dB beamwidth of the mainbeam and be the limiting factor along the given azimuth and not the UWB's EIRP. An elevation angle of greater than 1.25 degrees is required to clear a 30-meter obstacle at a distance of 1370 meters. Therefore, the geometry of the TDWR is the limiting factor for this scenario, not the EIRP of the UWB.

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[215] International Standards and Recommended Practices Annex 10 to the Convention of International Civil Aviation, Volume 1 (Radio Navigation Aids) Fifth Edition, July 1996.

[216] In order for the aircraft to be within 160 meters, horizontal, from the UWB transmitter at a receive angle of 30 degrees, as employed by NTIA in its calculations, the aircraft would be less than 93 meters above the ground.

Table 7. Maximum UWB EIRP for UWB Use Indoors

System	Frequency (MHz)	Maximum UWB EIRP (dBm/MHz) UWB Indoors 2 m height	Maximum UWB EIRP (dBm/MHz) UWB Indoors 30 m height	Average Building Attenuation Losses [217] (dB)
DME, Interrogator	960-1215	-38	Not Applicable[218]	9
DME, Transponder	1025-1150	-55	-48	9
ATCRBS, Transponder	1030	-35	Not Applicable	9
ATCRBS, Interrogator	1090	-22	-35	9
ARSR-4	1240-1370	-52	-73	9
SARSAT	1544-1545	-60	-57	9
ASR-9	2700-2900	-37	-57	9
NEXRAD	2700-2900	-33	-67	9
Marine Radar	2900-3100	-34	-45	12
FSS, 20 degrees	3700-4200	-24	-30	12
FSS, 5 degrees	3700-4200	-39	-65	12
CW Altimeters	4200-4400	37	Not Applicable	12
Pulsed Altimeters	4200-4400	26	Not Applicable	12
MLS	5030-5091	-42	Not Applicable	12
TDWR	5600-5650	-23	-51	12

145. The above table reflects NTIA's calculation of the maximum signal levels that could be permitted for UWB devices operated indoors. The possibility of restricting most applications of UWB technology to indoor use but imaging and vehicular radar applications was not considered in the NTIA analysis because it was not specifically proposed in the *Notice*. Thus, the constraints NTIA's analysis originally concluded were necessary to protect government receivers from outdoor use of UWB devices must be reformulated to account for the indoor use of UWB devices and the inherent additional expected propagation attenuation. This is done by simply adding a term for the value of expected building attenuation as a function of frequency to the link budget analysis model described earlier. The column on the far right contains the average building attenuation factor. NTIA analyzed UWB devices operating in-doors at heights of 2 meters (roughly equivalent to ground level) and 30 meters (roughly equivalent to the tenth floor in a typical suburban, office building) and calculated the maximum allowable UWB EIRP. The building attenuation level was subtracted from the values NTIA obtained in Table 6 to obtain the indoor limits at a 2 meter height. The results of the NTIA analyses are summarized in Table 7.

146. *UWB Interference due to Peak Emission Levels*. NTIA also performed a limited analysis of potential interference to SARSAT and FSS stations due to the peak level of the UWB transmitter. However, NTIA did not consider the proposed limits on peak power levels in the *Notice,* since their measurements did not show a need for such limits for analog systems and only very limited

[217] NTIA Report 95-325, Building Attenuation, at pg. 43.

[218] "Not Applicable" indicates that the particular scenario would involve an airborne receiver at the same altitude as a UWB transmitter, which should not occur.

measurements were made on digital systems. No conclusion can be made from the peak power analysis due to the non-linear nature of the digital systems, unique error correcting schemes, and unknown characteristics of individual UWB systems operating in these bands. The actual impact to a digital wideband system from the peak power received from a UWB device will depend on many receiver parameters not generally available such as modulation scheme, and bit error rates. As a result, the peak values NTIA used for its analysis are far in excess of the levels the Commission proposed in the *Notice*.[219] Consequently, we do not envision interference problems from peak emissions from UWB devices if the peak power limits proposed in the *Notice* are embraced.

3. U.S. Department of Defense Analysis of Interference to the SGLS

147. DOD provided a mathematical analysis of possible interference from UWB operation to its Space-Ground Link Subsystem (SGLS) at 2.2-2.3 GHz.[220] DOD applied free space attenuation without intervening objects, assumed a noise-like UWB emission, and applied SGLS receive antenna gains ranging from 6 to 26 dB corresponding to antenna elevation angles ranging from 20 to 3 degrees. Interference was defined with I/N ranging from +17.5 dB to –5.4 dB. It calculated minimum separation distances ranging from 19 meters to 1.522 km.

148. Few details were included with the DOD analysis. We do not agree that it is appropriate to use free space analysis or to assume the lack of intervening objects in determining propagation attenuation. We also do not believe that these DOD satellite receive stations will be located in areas were UWB devices would be sufficiently close to cause interference problems, especially with the operational constraints we are adopting in this proceeding. Similarly, as with the SARSAT and FSS stations, these antennas will not be directed at buildings or other structures that would block reception of the satellite transmissions.

4. ARRL Analysis of Noise Floor Increase in Amateur Radio Bands

149. The ARRL presented analyses of potential increases in the noise floor in the Amateur Radio Service frequency bands at 420-450 MHz (420 MHz) and 2400-2450 MHz (2450 MHz). ARRL performed calculations to show that an amateur radio receiver operating in the 420 MHz band, using a 20 dBi receive antenna gain and a receiver bandwidth of 1 kHz would experience a 56.5 dB increase in the noise floor at a distance of 30 meters from an UWB transmitter operating with an average EIRP of –80 dBm/Hz (0 dBm/100 MHz). Similar calculations were performed showing that an amateur radio receiver operating in the 2450 MHz band using a 0 dBi or a 20 dBi receive antenna gain and a receiver bandwidth of 1 kHz would experience a 11.4 and 31 dB increase, respectively, in the noise floor at a distance of 30 meters from a UWB transmitter operating with an average EIRP of –90 dBm/Hz (0 dBm/GHz).[221] Additional calculations showed that the increase in the receiver noise floor did not change if the receiver bandwidth was increased from 1 kHz to 10 kHz or from 1 kHz to 50 MHz.[222]

150. We find that ARRL's calculations overestimate the potential increase in the noise floor to amateur radio receivers from UWB devices. As an initial matter, the use of the thermal noise floor of a receiver is not a reasonable approach for evaluating whether or not harmful interference may occur. The thermal noise floor represents the minimum signal level that can be received under ideal conditions. In

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[219] The primary effect of the Commission's peak power limits as proposed in the *Notice* is that the peak power limit provides the restriction at lower PRFs while the average power limit provides the restriction at higher PRFs. .

[220] Attachments to U.S. Department of Defense filing of 10/1/00.

[221] ARRL employed a receiver noise level of –141 dBm and a noise figure of 3 dB, resulting in a thermal noise floor of –139 dBm, for both 1 kHz bandwidth receivers used in its analyses.

[222] This would be expected with a constant envelope signal level.

practice, the actual received signal levels are typically well above the thermal noise floor of the receiver. ARRL assumed that the UWB transmitter would be operating at an average EIRP of –80 dBm/Hz at 420 MHz or at –90 dBm/Hz at 2500 MHz. The specific limits proposed in the *Notice* were 200 uV/m, as measured at 3 meters with a quasi-peak detector, for 420 MHz and 500 uV/m, as measured at 3 meters with an average detector and a 1 MHz resolution bandwidth, for 2450 MHz. These limits are equivalent to an EIRP of 12 nW/120 kHz[223] or –49.2 dBm/120 kHz or –100 dBm/Hz at 420 MHz and to an EIRP of 75 nW/MHz or –41.25 dBm/MHz or –101.25 dBm/Hz at 2450 MHz. Therefore, the levels ARRL applied to the UWB emissions are 11 to 20 dB higher than those proposed in the *Notice*. We also believe that it is extremely unlikely that the UWB emission would be in the main beam of a 20 dBi gain antenna, particularly given the operating restrictions we are applying to UWB devices.[224] Adjusting ARRL's analyses to take these factors into account substantially reduces ARRL's estimate of the increase in the noise floor of the receivers.

151. In addition, we note that Part 15 devices already operate in the 2400-2450 MHz band used by the amateur radio service at considerably higher power levels that those proposed in the *Notice*. For example, frequency hopping spread spectrum transmitters are permitted to operate at a signal level of 36 dBm/MHz and at even higher signal levels for fixed point-to-point links. Similarly, microwave ovens and other Part 18 devices are permitted to operate on a primary basis within this frequency band without a limit on the level of their emissions. Nevertheless, amateurs have coexisted successfully with these devices. This leads us to conclude that it is unlikely that UWB devices will have any significant impact on Amateur operations in this spectrum. We find nothing in the ARRL analysis that leads us to conclude that the existing Part 15 emissions limits are inadequate to control interference from UWB devices to the Amateur Radio Service.

5. Analyses of Potential Interference to PCS

152. Several parties performed tests and analysis of potential interference to PCS systems operating in the 1850 – 1910 MHz and 1930 -1990 MHz bands.[225] These studies are discussed in the following paragraphs.

153. *Motorola Analysis.* Motorola performed mathematical analyses of potential interference from UWB devices to PCS systems. Motorola bases its definition of harmful interference on a PCS receiver as any signal that causes a 1 dB rise in the receiver thermal noise floor, *i.e.*, resulting from an UWB device that produces signal in the PCS receiver that is 6 dB below the thermal noise floor. Motorola assumed that the receiver would have a 10 dB noise figure and an antenna with –8 dBi of gain. Using free space attenuation, it calculated that the UWB and the PCS receiver must be separated by at least 13 meters. It then demonstrated how this separation distance increased with increasing antenna gain such that the minimum separation distance becomes 65 meters when the receiving antenna gain is increased to +6 dBi, *i.e.*, the antenna employed with a base station.

154. Protecting the PCS receiver to a level 6 dB below the thermal threshold of the receiver is not reasonable because it represents the ideal performance of the receiver and is not representative of

[223] At the PRFs commonly employed by UWB transmitters, it is expected that a quasi-peak detector will tend to measure closer to the peak level as opposed to the average level. However, the amateur narrowband receiver would respond to the average level of the UWB emission. This could be considerably less than the peak level. In any event, the devices operating below 1 GHz will be extremely limited in number and scope and should not be a source of interference.

[224] While a 20 dBi Yagi antenna is feasible, such an antenna normally would be mounted high above a roof where it is unlikely that a nearby UWB transmitter would be directly in the main beam.

[225] It should be noted that the PCS frequency bands are not restricted bands. Part 15 devices currently are permitted to transmit in the PCS bands at a level equivalent to –41.25 dBm/MHz EIRP.

typical operating conditions. In practice, PCS receivers will normally receive signals well above the thermal threshold of the receiver. Thus, Motorola's analysis affects receivers operating at the fringe of a reception area. In addition, it is likely that intervening objects would provide significant attenuation to UWB emissions. Thus, we do not believe that Motorola's calculations provide a reasonable representation of the interference potential of UWB to PCS operations.

155. *Sprint PCS, Time Domain Corporation and Telcordia Analyses.* Sprint PCS and TDC jointly submitted two documents. The first was a theoretical model developed by Telcordia Technologies to analyze the impact of UWB on the forward link on a CDMA PCS network. The second summarized tests conducted by Sprint PCS, Time Domain and Telcordia. These tests included laboratory evaluations, over the air transmissions in an anechoic chamber, and field simulations. The over-the-air test conducted in an anechoic chamber demonstrated the following[226]: (1) free space attenuation is appropriate for this type of test; (2) the PCS handset had an antenna gain of –4.6 dBi;[227] (3) the RSSI measured by the handset was 3 dB different from computed values;[228] (4) the measured E/N for the onset of frame errors was 5 dB, consistent with expectations; (5) the handset power varied by 1.5 to 2.5 dB due to antenna polarization and by 12 to 15 dB use to "head loss", *i.e.*, signal blocking by the user; and (6) the effect of UWB IX appears to be the same as Gaussian noise.[229] Much of the data from the open field tests was lost.[230] The available test data employed an RSSI (total forward power received by the handset) of between –92 dBm and –96 dBm. As only a single test cell was activated, no account was taken of potential interference from other nearby cells. The minimum UWB separation distance to avoid interference at that signal level was found to be about 0.35 to 0.56 meters. The call was dropped when the UWB emitter was moved to within about 0.3 meters of the PCS handset.[231] It also was noted that with a fully loaded system this distance range would apply with the RSSI at about 7 dB greater, *i.e.*, at –85 dBm to –89 dBm. Several comments were filed in response to this test.

156. Sprint PCS stated that these tests confirm that a UWB emission at a level 12 dB below the general limits in 47 C.F.R. § 15.209 will cause interference to a PCS CDMA system, resulting in the handset, operating with a PCS received signal of –100 dBm, requesting 50 percent more power when only 2 meters from the UWB transmitter.[232] It added that a separate effect of UWB interference is call blocking such that if between one in twenty and one in five PCS customers are within 2 meters of active UWB transmitters 2 percent to 7.9 percent of calls will be dropped or call attempts will be blocked.[233]

157. On the other hand, TDC believes that the theoretical model of Telcordia does not accurately describe the results of real world open field testing, adding that it is not possible for the PCS receivers to detect UWB emissions even at separation distances less than 1 meter.[234] It stated that the PCS phone performance was dramatically better in an anechoic chamber than in an open field even

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[226] *See* Sprint PCS comments of 9/12/2000 at Attachment 2, pg. 2-3.

[227] In the anechoic chamber test, it appeared that the antenna was optimized for the transmit band rather than the receive band resulting in a measured gain of –4.6 dBi.

[228] Thus, the losses between the antenna and the receiver are greater than those used in the above calculations.

[229] Qualcomm stated that for commercial CDMA receivers it does not matter if the in-band noise has spectral lines or is white spectrum; what matters is total power in a 1.2288 MHz bandwidth. *See* Qualcomm comments of 5/10/01 at pg. 14.

[230] Sprint PCS comments of 9/12/2000 at Attachment 2, pg. 4.

[231] Sprint PCS comments of 9/12/2000 at Attachment 2, pg. 4.

[232] Sprint PCS comments of 4/6/01 at pg. 2.

[233] Sprint PCS comments of 4/6/01 at pg. 2-3.

[234] TDC comments of 4/25/01 at pg. 79.

through the base station was clearly visible to the handset and the propagation path was unobstructed.[235] According to TDC, the model developed by Telcordia predicted that in an anechoic chamber IS-95 cellphones should not experience frame error rates greater than 2 percent at received signals levels as low as –105 dBm; however, in the open field the FER would jump momentarily to as much as 8 percent even when the received signal was as great at –85 dBm. TDC adds that extrapolation from testing suggests that the impact of the UWB emission on PCS might be observable when the PCS signal is marginal, at –95 dBm, and the UWB device is continually transmitting and within 1.5 meters.[236] However, it concluded that this was a conservative estimate since during the open field testing with a PCS received signal level of between –92 dBm and –95 dBm no impact from the UWB emission was seen until the UWB emitter was less than 1 meter from the PCS cellphone.

158. XSI also believes that the earlier Sprint PCS/TDC tests demonstrated that UWB devices would not cause substantial harmful interference to PCS, stating that the claim of interference is based on numerous unrealistic assumptions and conflicting results.[237] XSI stated that it is important to note that the anechoic chamber eliminated all external RF noise and any potential interference due to other CDMA cells or multi-path which it says are the most important factors in understanding potential interference for a PCS network.[238] The test that was performed at an outdoor facility showed that the PCS handset exhibited a rise in traffic channel power and then dropped a call only when a UWB transmitter was moved to within approximately 0.3 meters of the handset.[239] XSI noted that the Sprint model did not consider non-line-of-sight propagation effects, nor did it provide an allowance for interference from other base stations although this effect is shown to be significant, resulting in as much as a 5 dB rise in the effective noise floor.[240] XSI concluded that the live testing by Sprint PCS showed that effects such as interference, noise, and Rayleigh fading were severe enough to mask any effects predicted by the analytical model until the UWB emitter was moved to within approximately 0.3 meters of the PCS handset.[241]

159. We find that the testing in the anechoic chamber permitted the PCS receiver to function properly down to the thermal noise floor of the receiver. Once this equipment was placed outdoors in a simulated environment, the UWB emissions had no significant interference effect except at distances less than one meter. We find that it is extremely unlikely that UWB devices will be located this close to a PCS receiver, particularly given the operating restrictions we are applying to UWB devices. Further, we do not believe it is appropriate to use such a close separation distance as the basis for controlling harmful interference. Any interference at close distances can be easily remedied by moving the devices a short distance apart.

160. *Qualcomm Analysis.* Qualcomm performed a mathematical analysis accompanied by laboratory testing using a PCS simulator. Based on its mathematical analysis, Qualcomm asserts that a PCS mobile unit would need to be at least 24 meters from a UWB transmitter operating at the 47 C.F.R. § 15.209 limit in order not to receive harmful interference. A more detailed discussion of the Qualcomm analysis has been placed in the docket file for this proceeding.

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235 TDC comments of 4/25/01 at pg. 83-84.

236 TDC comments of 4/25/01 at pg. 85.

237 XSI comments of 5/10/01 at pg. 4.

238 XSI comments of 5/10/01 at pg. 5-6.

239 XSI comments of 5/10/01 at pg. 6.

240 XSI comments of 5/10/01 at pg. 7-8.

241 XSI comments of 5/10/01 at pg. 11.

161. We observe that Qualcomm's mathematical analysis is based on defining harmful interference as any UWB emission that is greater than 6 dB below the thermal noise floor of the PCS receiver. While such an analysis can determine if a signal will increase the receiver noise floor in situations where no RF background noise exists, this is not indicative of harmful interference to a communications system. Modifying the antenna gain to –4.6 dBi to reflect the measured data from the Sprint analysis, and using free space to recalculate the minimum separation distance necessary to prevent harmful interference to a PCS system, we find that a UWB transmitter must be 3.2 meters from the PCS receiver if the UWB transmitter operates at the limit in 47 C.F.R. § 15.209 and 0.8 meters if the UWB transmitter operates at 12 dB below the limit in 47 C.F.R. § 15.209, as proposed in the *Notice*. These separation distances are based on worst case conditions as they do not assume that there is additional attenuation of the UWB emissions due to intervening objects, mismatched antenna polarizations, head loss, or other effects. They also assume that the UWB transmitter is operating at its maximum emission limit with the emission directed at the PCS receiver.

162. The laboratory measurements performed by Qualcomm demonstrated that a S/I of about a 6 dB is required to prevent interference to a PCS system. We believe that a PCS received signal level of –96 dBm/1.25 MHz adequately characterizes a low level PCS signal level based on real world applications.[242] Using free space analysis, this PCS signal level and a 6 dB S/I for the UWB emission, we find that the UWB transmitter must be 7.2 meters from the PCS receiver if the UWB transmitter operates at the limit in 47 C.F.R. § 15.209 and 1.8 meters if the UWB transmitter were to operate at 12 dB below the limit in 47 C.F.R. § 15.209. Again, these separation distances are based on worst case conditions as they do not assume that there is additional attenuation of the UWB emissions due to intervening objects, mismatched antenna polarizations, head loss, or other effects. They also assume that the UWB transmitter is operating at its maximum emission limit with the emission directed at the PCS receiver.

163. *Summary of findings of analyses of interference to PCS*. Upon review of the various tests and analyses submitted in the record, we do not believe that UWB devices will present a significant risk of harmful interference to PCS, particularly when evaluated under actual operating conditions instead of in a laboratory environment. Nevertheless, given that we are applying a reduction of at least 12 dB in emissions in the GPS frequency band, which is in close proximity to the PCS band, in an abundance of caution we will require this reduction to extend through the PCS band to 1990 MHz. We do not believe this will have any significant impact on the viability of UWB devices. Further, this will ensure against interference to PCS even under extremely close separation distances.

6. Cisco Analysis of Potential Interference to MMDS

164. Cisco presented mathematical analyses to demonstrate that a single UWB transmitter would cause a significant increase to the noise floor of a MMDS receiver located several hundred meters away. Attachment 2 to its comments addressed UWB peak emissions, and Attachment 3 to its comments addressed UWB average emissions. With regard to peak emissions, Cisco calculated, based on the proposal in the *Notice* for a limit on total peak power, that a UWB transmitter operating with a pulse width of one nanosecond and possessing a 1.5 gigahertz –10 dB bandwidth will have a total peak emission 49.4 dB greater than the average limit. It then calculated that for a UWB system to comply with a 49.4 dB peak to average ratio it must operate with a pulse repetition frequency of 11.5 kHz.[243] As this is less than the 12 MHz bandwidth employed by the MMDS receiver, Cisco calculated that the peak power received by the 12 MHz wide receiver will be 44.1 dB greater than the average UWB received power.

[242] 47 C.F.R. § 24.236 states that the median field strength at any location on the border of the PCS service area shall not exceed 47 dBuV/m. As this is the signal level established in the rules as what is necessary to prevent interference to an adjacent license, it appears likely that PCS systems are designed to operate at this level or higher. For a 50 ohm system, this emission level is equivalent to a received signal level of –96 dBm.

[243] No limit on the peak-to-average ratio was proposed in the *Notice*.

165. We find that in calculating the –10 dB bandwidth of the UWB transmitter Cisco assumed the use of a perfect antenna. It is unlikely that an antenna, which acts as a band-pass filter, would pass all of the energy over a 1.5 gigahertz bandwidth centered on the UWB emission. The actual total peak signal, based on the proposal in the *Notice*, may be lower due to the narrower transmitted bandwidth. Cisco also assumed that the UWB transmitter had to meet a peak-to-average ratio whereas our proposal was to establish an average limit and a peak limit with the latter consisting of two parts: a total peak power based on the bandwidth of the emission and a peak power limit based on a 50 MHz bandwidth. In actual practice, a UWB transmitter will be subject to the average limit or to the peak limit but not both. Systems with low PRFs will be governed by the peak limits and systems with high PRFs will be governed by the average limits.

166. With regard to average power levels, Cisco modeled a 2.5 GHz sinusoidal carrier modulated by a one nanosecond pulse with a PRF of 20 MHz. Cisco then assumed that the UWB transmitter operated at the maximum limit and was pointed directly at a 20 dBi antenna employed by the MMDS receiver. Cisco also assumed that its MMDS operation should be protected to at least a level of 10 dB below the thermal noise floor of the MMDS receiver without adjusting the noise floor for line losses and the receiver noise figure. With free space attenuation, this resulted in Cisco calculating a minimum separation distance of 380 meters. Cisco then assumes that 10 or 100 UWB transmitters all are emitting at the maximum allowable emission limit at 2.5 GHz and are all pointed directly at the MMDS antenna to show how, using free space attenuation, the required separation distances increase to 1.2 km and 3.9 km.

167. We find that the protection of the MMDS receiver to a level 10 dB below the thermal threshold of the receiver is not reasonable.[244] Second, we note that the actual thermal noise floor of the MMDS receiver would be higher than that calculated by Cisco once line losses and the receiver noise figure are included. Unfortunately, these values are not provided by Cisco to permit the calculations to be redone. Third, at the distances employed free space is not a practical method to calculate path loss. At these distances, intervening objects would provide significant attenuation to UWB emissions. Fourth, it is extremely unlikely that the UWB emission could be pointed at the main beam of a high-gain MMDS antenna because such antennas generally are mounted outside on roof tops or on the sides of buildings. Because of this antenna placement, it is highly unlikely that a UWB transmitter would be close to an MMDS station or have its emissions directed within the mean beam of the MMDS receiving antenna. As with the SARSAT and FSS stations, MMDS antennas will not be directed at buildings or other structures that would block reception of the MMDS transmissions. We also note that millions of other RF products, such as spread spectrum transmitters operating in the 2400-2483.5 MHz band under the provisions of 47 C.F.R. § 15.247, already are permitted to place spurious emissions in the MMDS bands at the emission level proposed in the *Notice*. The spread spectrum spurious emissions must be attenuated to–41.25 dBm/MHz,[245] the same level proposed for UWB emissions.

7. XM Analysis of Potential Interference to DARS

168. XM performed an analysis of potential interference to its satellite digital audio radio service operating in the 2332.5 – 2345 MHz band. XM stated that its satellite receiver operates with a received signal of –109 dBm to –90 dBm with a noise figure of 1.2 dB and a thermal noise of –110

244 *See*, for example, *Second Memorandum Opinion and Order* in WT Docket No. 99-168, 16 FCC Rcd. 1239 (2001), at para. 6-8.

245 This is the limit for emissions appearing within the 2483.5-2500 MHz band. The limit on emissions from spread spectrum transmitters appearing within the MMDS band above 2500 MHz is about +16 dBm but may be higher for high gain antennas used with point-to-point spread spectrum systems.

dBm/2 MHz.[246] XM then calculated, using free space, the required separation distances between a UWB device and a DARS receiver in order to ensure that the UWB emissions are below the thermal noise floor of the DARS receiver. At a level of –41.25 dBm/MHz, XM calculated that the UWB device must be 35 meters from the DARS receiver.[247] XM also stated` that the required S/N for its receiver is 3 dB, the I/N is 67 dB and the minimum distance from an interference source must be based on 1 meter. Accordingly, XM requests that the emissions from UWB devices in its 2332.5-2345 MHz band be limited to –70 dBm.

169. As discussed above, harmful interference is not caused to a receiver from a radio signal that is below the thermal noise floor of a victim radiocommunications receiver. If we assume that the UWB signal, emitting at –41.25 dBm/MHz, may not exceed the DARS receiver thermal noise floor of –110 dBm/2 MHz, an attenuation of 71.75 dB is required. Free space at 2340 MHz achieves this attenuation at a separation of around 39 meters. If we take into account the 3 dB loss between XM's circular polarized antenna and the linear polarization expected from UWB operation, the separation drops to 27.9 meters. If only 10 dB of attenuation is applied to the UWB emission, the minimum separation distance decreases to 8.8 meters. This is not an excessive separation distance for a receiving system that generally is expected to be mounted outside of a transportation vehicle or on the roof or side of a building. Under practical operating conditions, there would be further attenuation of the UWB emissions due to the presence of intervening objects, misalignment of the UWB transmitting and DARS receiving antennas, and other factors. Further, the DARS signal normally would be above the minimum received level employed in this calculation. It also is likely that the UWB emissions would be somewhat below the maximum level permitted under the rules. These factors would considerably shorten the calculated interference distance. Vehicle mounted UWB radar systems, which will be located closest to DARS receivers, are being required to operate in a considerably higher frequency band than that used by DARS. This should result in emissions appearing in the DARS band that would be no more of an interference threat than emissions from conventional Part 15 devices.[248] In any event, emissions from the vehicular radar systems would likely be pointed in a direction other than at the DARS antenna. Further, since vehicle manufacturers will provide DARS and UWB radar systems in the same vehicle the vehicle manufacturer would engineer these systems to ensure that there is no mutual interference. We also note that DARS will be supplemented in major metropolitan areas with high powered terrestrial broadcasting stations, further reducing the potential for harmful interference.

8. Summary of Tests and Analyses

170. The protection levels established in this Order primarily are those determined in the NTIA analyses of Government systems. The UWB emissions level NTIA developed for the GPS bands provides a conservative protection level for all of the government and commercial systems operating between 960 MHz and 1610 MHz. We find that the various analyses were generally based on overly conservative and worst case conditions. For example, tests were performed in some cases using UWB signals with characteristics designed to cause the greatest interference effect. While we recognize this could occur, in practice many UWB devices will have emission characteristics that are more benign relative to particular receivers. We also note that several of the analyses seek to protect radiocommunications systems to levels below the receiver thermal noise floor. This is a level of performance that does not generally occur under actual operating conditions due to the presence of other

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246 Referencing the thermal noise to 290°K, the receiver noise level for a 2 MHz bandwidth is –110.97 dBm. A thermal noise referenced to 290°K is appropriate as the omnidirectional antenna employed by the DARS receiver will encompass surrounding terrain.

247 Sirius stated that with a typical noise figure of 2 dB, receiver performance would be degraded by 3 dB at 150 feet for line-of-sight and 25 feet for non-line-of-sight. Sirius comments of 4/25/01 at pg. 3.

248 Due to the extremely wide frequency separation, it is likely that emissions in the DARS band would be considerably lower than the Part 15 emission limits.

sources of radio noise. Further, the fact that the noise floor may increase does not necessarily indicate that harmful interference will occur.

171. Certain of the analyses applied only free space attenuation to determine propagation losses and did not consider the effects of intervening objects. Some commenting parties sought to ensure that no interference would occur at unreasonable separation distances, such a having the victim receiver within one meter of, or co-located with, the UWB transmitter. In some cases additional protection margins were added to further ensure conservative protection levels. We observe that these various studies and analyses have been useful in serving to illuminate the record in this proceeding. However, we do not believe our regulations for controlling interference from UWB devices should be based on a series of worst case assumptions. Instead, we find that the various studies demonstrate conclusively that UWB devices can be permitted under the proper set of standards without causing harmful interference to other radio operations.

E. Emission Limits

1. General

172. Proposal. In order to control harmful interference from UWB devices, appropriate emission limits must be established. The current Part 15 rules are based on the equivalent of a power spectral density, *i.e.*, a field strength limit is specified along with a measurement bandwidth. These emission limits were chosen to protect various classes of receivers from interference at certain separation distances. The radiated limits below 1 GHz are based on measurements employing a quasi-peak detector that effectively provides an average reading with some weighting for peak signal levels. The radiated emissions limits for both intentional and unintentional radiators above 1 GHz are based on measurements using an average detector. However, intentional radiators also are subject to a requirement that the total peak levels of emissions above 1 GHz must be no greater than 20 dB above the average limits.[249] Higher peak levels could lead to an increased risk of interference to certain receivers. For example, if the pulse repetition frequency of the UWB signal is much greater than the bandwidth of a receiver, the emission may appear to be random noise, the effect of which is proportional to the average power in the UWB signal within the receiver's bandwidth. However, if the PRF is much less than the receiver's bandwidth, the UWB signal may appear to the receiver as impulsive noise and the effect would be proportional to the peak power of the UWB signal. In addition, UWB devices spread their emissions over a wide bandwidth as compared to most current intentional and unintentional radiators. As a result, receivers that use wide bandwidths are likely to receive more total energy from UWB devices than from most other existing Part 15 devices.

173. In the *Notice*, the Commission concluded that it is necessary to regulate both the peak and average emission levels above 1 GHz and the quasi-peak emission levels below 1 GHz from UWB transmitters, just as it regulates these emission levels for most other types of Part 15 transmission systems. The impact of UWB signals on a receiver appears to depend on the randomness of the UWB signal and the relationship between the pulse repetition frequency (PRF) of the UWB signal and the bandwidth of the receiver.[250] If the UWB pulses are spaced evenly in time and each pulse is exactly the same (as in many radar systems), then classic communications theory shows that the spectrum consists of narrow spectral lines spaced at the PRF. The impact of these signals on a receiver can be modeled by treating each spectral line as a narrowband conventional signal. This gives rise to one possible way to increase protection to GPS receivers from UWB GPR and through-wall imaging devices. Since repetitive

249 *See* 47 C.F.R. § 15.35(b).

250 This assumes that the UWB signal is far enough from the receiver that it does not overload the receiver causing nonlinear operation. The peak limits being considered in this proceeding will ensure that receiver overloading is not a concern.

identical pulses are often applicable to GPRs and through-wall imaging devices, the Commission noted that it might be possible for designers to select system parameters to avoid GPS signal bands and thus avoid co-channel interference. It also may be possible to space the UWB signal's spectral lines in places within the GPS band where GPS receivers are less sensitive to interference. Comments were requested on whether this technique is applicable to all types of GPRs and through-wall imaging devices and the cost implication of using a stable frequency reference to ensure the PRF creates a signal avoiding the GPS bands.

174. For UWB communications systems, the emitted spectrum depends on the information being sent. If the information is unchanging, such as a steady string of zeroes in the case of digital information, the transmitted signal may become a set of spectral lines that has different interference potential than the noise-like spectrum that would be produced under normal modulation. Depending on exactly where these spectral lines are, the interference potential may increase. This could be avoided by using scrambler technology, often used in digital wireline and optical communications systems, which prevents long strings of unchanging bits. The Commission sought comment on whether it should require such scrambler technology for UWB communications systems or, alternatively, a performance requirement that would show that the transmitted spectrum remains noise-like in the case of unchanging input data.

175. Comments. The comments generally indicated that the proposal to place spectral lines outside of critical frequency bands should not be implemented. For example, as noted by AOPA doppler shifts due to movements of the GPS satellites and to movements of planes would negate any ability to avoid the GPS band.[251] AOPA added that the frequency stability of the circuitry used to generate the PRF would have to be very stable raising cost concerns. A. Peter Annan stated that this is an impractical solution for GPRs that have low PRFs that make it impossible to space the spectral lines far enough apart to avoid the GPS bands.[252] ARRL noted that selecting PRFs to avoid generating signals in certain bands would add a layer of regulatory complexity that could perhaps be better addressed through other means.[253] On the other hand, Aether Wire indicates that it may be possible for its equipment to avoid the GPS L1 and L2 bands by adjusting the spaces between the impulse doublets and between the impulses in each doublet of its transmission, noting that the oscillation would have sufficient stability through the use of temperature stabilization.[254]

176. With regard to scrambler technology, the comments supported requiring UWB signals to be noise-like in certain bands, particularly GPS. AOPA noted that sufficient dithering or scrambling of the interference signal spectral lines in the instantaneous time or frequency domains would decrease the probability of harmful interference but could increase aggregate interference.[255] Aether Wire stated that a UWB system that lacks coding for channelization is severely limited in its capabilities and that such a system it the only one for which scrambler technology is applicable.[256] It added that a performance requirement that shows that the transmitted spectrum remains noise-like in the case of unchanging input data is appropriate.

177. Discussion. We have come to the conclusion that there is no need to establish design criteria for UWB systems, such as specifying where spectral lines may be placed or requiring the

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[251] AOPA comments at pg. 13.

[252] A. Peter Anan comments at pg. 4.

[253] ARRL comments at pg. 14.

[254] Aether Wire comments at pg. 11.

[255] AOPA comments at pg. 13.

[256] Aether Wire comments at pg. 12.

application of scrambler technology. Rather, we believe that we should specify only the emission limits that are necessary to prevent interference to the authorized radio services. It will be up to the manufacturers of UWB devices to determine how they will comply with these standards. A discussion of the emission levels we are adopting follows. As will be noted, we are adopting a requirement to limit the power level of the spectral lines that appear in the GPS frequency bands.

2. Average and Quasi-peak Emission Levels

178. Proposal. The Commission stated in the *Notice* that the Part 15 general emission limits[257] have a long and successful history of controlling interference to other radio operations. However, the general emission limits were never designed to protect against all possibilities of harmful interference. Rather, these limits were designed to protect neighbors from causing interference to each other.[258] These limits were designed as a reasonable compromise to protect the authorized radio services from receiving harmful interference without requiring an analysis of the individual needs of every type of receiver design used in every radio service. The Commission reiterated that it remains committed to protecting the authorized radio services from receiving harmful interference from Part 15 devices, adding that it was especially concerned about protecting radio services used for safety-of-life applications, such as GPS, from such interference. Accordingly, the Commission indicated in the *Notice* that the general emission limits contained in 47 C.F.R. Section 15.209 appear appropriate for UWB operations. These emission limits are already based on a spectral power density, measuring signal level per unit bandwidth.[259] It also proposed that additional protection be provided below approximately 2 GHz for emissions from UWB devices. For emissions from UWB devices other than GPRs and, possibly, through-wall imaging systems, it proposed that emissions that appear below approximately 2 GHz be attenuated by at least 12 dB below the general emission limits. This attenuation below the general emission levels would provide additional protection to the congested spectrum below 2 GHz without affecting the viability of UWB operations. Comments were requested on whether additional attenuation below 2 GHz is necessary. Comments were also sought on whether the proposed reduction in the emission levels should apply to all emissions below 2 GHz or only to emissions below 2 GHz that fall within the restricted bands shown in 47 C.F.R. § 15.205. Comments also were requested on whether UWB devices other than GPRs, and possibly through-wall imaging systems, should be permitted to operate below 2 GHz provided they comply with these reduced emission levels. Finally, the Commission indicated that the emission limits that were proposed in the *Notice* were a reasonable starting point for establishing standards. As equipment continues to be developed and additional experience is gained with this equipment, future changes to the standards would be considered.

179. Comments/Discussion.[260] A considerable number of comments were filed concerning the levels of emissions that should be permitted for UWB transmitters. Most of the comments supported the continued application of quasi-peak limits on radiated emissions below 1000 MHz and of average and

[257] *See* 47 C.F.R. §§ 15.109(a) and 15.209.

[258] While it is possible to establish emission limits that protect a user from his own interference at separation distances on the order of one meter, such limits would significantly add to the cost of all Part 15 devices, including computers, cordless telephones and receivers.

[259] Emissions below 1 GHz are measured using a CISPR quasi-peak detector with a resolution bandwidth of 120 kHz ± 20 kHz. Emissions above 1 GHz are measured using a 1 MHz resolution bandwidth. *See* 47 C.F.R. § 15.35.

[260] Some of the comments continued to propose that UWB devices be subject to the same emission limits as those applied to Class A digital devices. The Commission considered this issue in the *Notice* and declined to propose it. We find no new information in the comments that would cause us to reconsider. *See Notice*, *supra*, at para. 40.

peak limits on radiated emissions above 1000 MHz.[261] NTIA, however, requested that average and peak emission limits apply to all emissions above 960 MHz. Some commenting parties requested that we implement limits on spectral power density.[262] However, the quasi-peak and average limits currently contained in the Part 15 rules already are based on spectral power densities. For example, the quasi-peak limits for emissions between 30 MHz and 1000 MHz are based on the emissions that appear in a 120 kHz ± 20 kHz bandwidth. The emission limits above 1000 MHz are based on the emissions that appear in a 1 MHz bandwidth.[263]

180. There was no concurrence in the comments with regard to the emission limits that should be adopted. The ARRL stated that the Part 15 general emission limits have not been adequate to protect all amateur operations; however, it could, with some reluctance, accept the idea that permitting UWB operation at those levels is not much different in kind from the types of operation permitted under the Part 15 rules.[264] It added that the impact on amateur receivers from UWB signals that are noise-like would be determined by the average power present in the victim receiver bandwidth whereas for UWB signals with low PRFs, the noise may appear as impulse and/or multiple discrete signals within the receiver passband where the peak limit would be more important.[265] Lucent also agreed that the proposed peak and average limits were sufficient for interference protection provided average measurements are clarified.[266] On the other hand, parties such as XM requested that the emission levels in the satellite DARS band be reduced to an EIRP of –100 dBW, about 29 dB below the existing Part 15 emission limit.[267] Parties such as Siemens Automotive and others want the Part 15 emission levels increased at the higher frequencies.[268]

181. With the exception of GPR manufacturers, a few comments requested increases in the Part 15 emission levels for UWB devices. MSSI wished to operate with a one watt peak output into a 6 dBi antenna.[269] While MSSI equated its UWB operation to the regulations for spread spectrum operation, the current rules designate specific frequency bands for spread spectrum operation.[270] Implementation of this same power level for operation in other frequency bands was not supported by the earlier test data or comments. Bosch, Saab, Siemens and Valeo requested that the higher frequency bands be permitted increased signal levels due to increased attenuation.[271] We agree that higher attenuation applies to RF emissions as frequency increases and that this may prove to be an acceptable approach to modifying the Part 15 emission limits. However, we do not believe that initial UWB operations should begin with a power increase.

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[261] *See*, for example, the comments of AOPA at pg. 12, Lucent at pg. 1, and NBAA at pg. 13.

[262] *See*, for example, the comments of AT&T at pg. 6 and Cisco at pg. 6-9.

[263] *See* 47 C.F.R. § 15.35(b).

[264] ARRL comments at pg. 12.

[265] ARRL comments at pg. 14.

[266] Lucent comments at pg. 1.

[267] XM comments at pg. A6 and reply comments at pg. 8.

[268] *See*, for example, Bosch reply comments at pg. 3, SME comments at pg. 3, Siemens comments at pg. 2, and MSSI reply comments at pg. 2.

[269] MSSI reply comments at pg. 2. Also, MSSI comments of 3/22/01 at pg. 4.

[270] *See* 47 C.F.R. § 15.247. The spread spectrum frequency bands are 902-928 MHz, 2400-2483.5 MHz, and 5725-5750 MHz.

[271] Bosch reply comments at pg. 4. Saab comments at pg. 3. Siemens comments at pg. 2. Valeo comments at pg. 5-6. Valeo actually requested a variable limit where the emission would be at thermal noise at 10 meters using free space, a 0 dBi antenna and a 3 dB receiver noise figure.

182. As noted by TDC, the issue of what constitutes reasonable levels of emissions outside of defined bands confronts the Commission every time a new licensed or unlicensed service is proposed.[272] However, several tests and analyses, discussed earlier, have been performed in this proceeding that permit us to determine the appropriate emission limits. As noted earlier, there were only a few instances where UWB systems operating at the limits in 47 C.F.R. § 15.209 demonstrated a clear potential to cause harmful interference to the authorized radio services. In most of these instances, the UWB transmitter and the victim receiver were required to be in extremely close proximity to each other before harmful interference could occur.

183. As discussed earlier, the interference analyses performed by NTIA and others allowed us to determine the emission limits that should be applied to UWB devices operating under various worst case conditions. Based on the limited information in the record and our lack of operation experience with UWB devices, we believe it best to proceed with an abundance of caution in establishing emission limits. The limits we are adopting were coordinated with NTIA, as well as with several other U.S. Government agencies.[273] These limits are an appropriate first step in introducing UWB devices. The following table specifies the average emission limits, in terms of dBm EIRP as measured with a one megahertz resolution bandwidth, that we are implementing for UWB operation.

Table 8 Average Emission Limits Applicable to UWB Operation

Frequency Band (MHz)	Imaging below 960 MHz	Imaging, Mid-Frequency	Imaging, High frequency	Indoor applications	Hand held, including outdoor	Vehicular radar
0.009-960	§15.209	§15.209	§15.209	§15.209	§15.209	§15.209
960-1610	-65.3	-53.3	-65.3	-75.3	-75.3	-75.3
1610-1990	-53.3	-51.3	-53.3	-53.3	-63.3	-61.3
1990-3100	-51.3	-41.3	-51.3	-51.3	-61.3	-61.3
3100-10600	-51.3	-41.3	-41.3	-41.3	-41.3	-61.3
10600-22000	-51.3	-51.3	-51.3	-51.3	-61.3	-61.3
22000-29000	-51.3	-51.3	-51.3	-51.3	-61.3	-41.3
Above 29000	-51.3	-51.3	-51.3	-51.3	-61.3	-51.3

184. Mid-frequency imaging, consisting of through-wall imaging systems and surveillance systems, must operate with the –10 dB bandwidth within the frequency band 1990-10,600 MHz. High frequency imaging systems, equipment that will be operated exclusively indoors, and hand held UWB devices that may operate anywhere, including outdoors and for peer-to-peer applications, must operate with the –10 dB bandwidth within the frequency band 3100-10,600 MHz. All other imaging systems must operate with the –10 dB bandwidth below 960 MHz. Vehicular radar systems must operate with the -10 dB bandwidth within the frequency band 22-29 GHz and with a carrier frequency greater than 24.075 GHz. To further ensure that the operation of these UWB devices does not result in harmful interference, we also are requiring coordination with NTIA through the Commission of the imaging systems. The operators of these devices will be required to provide us with their address, the characteristics of the UWB device, and a detailed record of the areas in which the equipment will be operated. The information submitted to the Commission will be forwarded to NTIA for notification purposes. The operators of UWB imaging systems must complete this coordination and authorization procedure before initial operation of the equipment in a particular area. As noted previously, in emergency situations a

[272] TDC comments at pg. 19.

[273] *See* letter of February 13, 2002, from William Hatch, *supra.*

notification process may be used in lieu of coordination.[274] Further, depending on the specific location it may be necessary for the operators to coordinate day-to-day operations with nearby radio stations within their operating area. The manufacturers of these devices will be required to inform the users of the equipment of these requirements. Because of the tighter emission limits being employed, coordination is not being required for indoor equipment, hand held devices, or vehicular radar systems.

3. Imaging Systems Including GPRs

185. As noted throughout this Report and Order, we are taking a cautious approach to the standards for UWB devices. One method of reducing interference potential is to restrict the applications for using UWB devices and the locations where UWB devices may be operated. These devices will have a low proliferation and would be used infrequently. Further, the primary energy from a GPR is directed into, and absorbed by, the ground. In addition, the energy radiated by the GPR is at a low elevation where it should attenuate rapidly.[275] To ensure that the proliferation remains low, we are restricting the parties that may operate GPRs to law enforcement, fire and emergency rescue organizations, to scientific research institutes, to commercial mining companies, and to construction companies. As used in this Order, law enforcement, fire and emergency rescue organizations refers to parties eligible to obtain a license from the FCC under the eligibility requirements specified in Section 90.20(a)(1) of this chapter. All users of GPRs must be eligible for licensing under Part 90 of our rules, and these users must coordinate with the FCC, which in turn will coordinate with NTIA, before operation.

186. Peter Annan stated that GPRs need special consideration on emission limits with more power needed at lower frequencies, particularly for operation below 250 MHz.[276] He requested that GPRs be permitted to operate at an average power limit of 500 mW below 50 MHz and 20 mW above 250 MHz with a logarithmic progression between these power levels between 50 MHz and 250 MHz. GSSI and Sensors & Software, in extremely late filed comments, requested that GPRs operating with PRFs lower than 500 MHz and at frequencies below 500 MHz be permitted to exceed the 47 C.F.R. § 15.209 limits, up to a maximum level of 95 dBuV/m below 30 MHz.[277] These companies did not indicate how or at what distance the revised emission limit should be measured, but we believe, based on their October 2, 2001, meeting with the staff of our Office of Engineering and Technology, that they desired these limits to be based on an average measurement.

187. Subsequent to the October 10, 2001, filing by GSSI and Sensors and Software, a late filed comment was submitted on October 16, 2001, by Mr. Steven Koppenjan *et al*, identifying themselves as the general chairs of the 6th, 7th, 8th and 9th International Conferences on Ground Penetrating Radar. Mr. Koppenjan *et al* indicated that new GPR products are being developed that will comply with the limits proposed in the *Notice*. They add that pulse compression schemes can provide both low peak-to-average

[274] We note that US Government radio stations may be operated without coordination under emergency circumstances. *See Manual of Regulations and Procedures for Federal Radio Frequency Management*, U.S. Department of Commerce, National Telecommunications and Information Administration, January 2000, at Section 7.3.1. We also note that no similar provision exists that would permit non-Government operation absent appropriate coordination. However, we are implementing a procedure similar to that contained in 47 C.F.R. Section 2.405(a)-(e) to facilitate the emergency operation of UWB imaging devices.

[275] We expect that the emissions would attenuate with distance based on the cube of the inverse distance, not the square as employed with free space propagation.

[276] A. Peter Annan comments at pg. 3-5.

[277] GSSI and Sensors and Software comments of October 10, 2001. The maximum limit was expressed as 20 log (500MHz/testing frequency in MHz) dBuV/m. At, say, 20 MHz, the testing frequency is 9 kHz resulting in a signal level of 94.9 dBuV/m or 55,600 uV/m. The existing limit at 20 MHz is 30 uV/m, as measured at 30 meters with a quasi-peak detector, or 29.5 dBuV/m.

power ratios in the time domain and low spectral power density in compliance with the proposals.

188. Sufficient notice was not provided to the other parties interested in this proceeding to permit us to address a relaxation to the emission limits below 500 MHz. In addition, the request to allow certain GPR devices to operate at higher emissions levels was filed very late, which did not afford an opportunity for analysis by other parties. We also note that GSSI did not provided any interference analysis to support its proposals, other than a statement that existing GPRs have operated benignly with these emission characteristics for 30 years. It appears that the basis of the proposals from GSSI and from Sensors & Software is to accommodate existing equipment designs.[278] It also appears, based on the comment from Mr. Koppenjan *et al*, that it may be possible for GPRs to be designed to comply with the radiated emission limits proposed in the *Notice*. Thus, we are not persuaded that higher emission levels are prudent especially in the early stages of UWB standards development. Such higher limits could overpower the front end of a nearby receiver or result in harmful interference to nearby television broadcast reception.

189. In contrast to GPRs, other types of imaging systems may be used for a variety of applications where the energy is aimed horizontally along the earth. We anticipate that the walls, buildings or other objects against which the imaging system may be placed may absorb most of the energy.[279] However, we recognize that with imaging systems other than GPRs there is an increased risk that some of the energy would not be absorbed and could be radiated in the direction of authorized radio services. Thus, as a cautious approach we are restricting the use of imaging systems. Wall imaging systems may be employed only by law enforcement, fire and emergency rescue organizations, by scientific research institutes, by commercial mining companies, and by construction companies. Only law enforcement, fire or emergency rescue organizations may use through-wall imaging systems. Further, the operators of through-wall and wall imaging systems must be parties that are eligible to obtain licensing under the provisions in Part 90 of our rules. Finally, medical imaging systems may be used only at the direction of, or under the supervision of, a licensed health care practitioner. This will allow the introduction of the compelling uses for UWB imaging systems cited by the commenters, such as for hostage rescue, law enforcement, inspection of building walls and foundations, and detecting objects inside walls when performing construction. At the same time, by limiting the applications for UWB imaging we will minimize the risk of interference by controlling the proliferation of these devices. The applications for UWB imaging systems will be controlled through our equipment authorization program. In addition, the grantees of equipment authorization will be responsible for ensuring that the marketing and distribution of these products is consistent with the restrictions on use.

4. Other Applications

190. While we believe that some of the interference levels characterized by the commenters may not represent real-world situations, we agree that the initial UWB regulations should be implemented cautiously. Accordingly, we are implementing a reduction to the Part 15 general emission levels over certain frequency bands to ensure that our introduction of UWB devices causes the least possible impact to the authorized radio services. We investigated different standards for UWB devices depending on whether they are operated outdoors or indoors. We believe that the combined operating conditions and emissions standards will prevent harmful interference. The operation of UWB devices at the EIRP levels

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278 The only UWB GPRs that have been certified by the Commission are those produced by U.S. Radar. U.S. Radar received a waiver from the Commission, subsequent to extensive coordinated with NTIA, to permit the marketing and use of its product. The marketing or use of any GPR that has not been certified, except under the conditions specified in 47 C.F.R. § 15.211, is in violation of 47 U.S.C. 301 and 302 and is subject to the penalties described in 47 U.S.C. 501-510.

279 Similarly, we believe that medical imaging systems would be used indoors such that intervening walls would attenuate the emissions.

being adopted in this proceeding should provide sufficient attenuation to protect authorized services from harmful interference from UWB systems operating nearby or in elevated locations, such as inside buildings.

191. With regard to GPS, we are particularly concerned about protecting E-911 applications. As noted above, GPS systems can experience harmful interference if they are within a few meters of a UWB system operating at the general limits in 47 C.F.R. § 15.209. The emission limits being adopted in this proceeding within the GPS frequency bands, ranging from 12 to 34 dB below the Part 15 general limits, were found to be more than sufficient to protect GPS from harmful interference. Further, we note that GPS operates in the same frequency region as DME transponders, the ARSR-4, and SARSAT systems.[280] We also note that the emission limits we are applying to the GPS bands are more than sufficient to prevent harmful interference to all Government systems operating in the 960-1610 MHz band.

192. We also concluded from our analysis of the Qualcomm submission that it could be advantageous to provide additional protection to PCS operation in the 1850-1990 MHz band due to its potential use in E-911 applications. The 12 dB of attenuation below the Part 15 general emission limits appears more than sufficient to provide this protection, as described in our discussion of the Qualcomm analyses. We do not believe that additional attenuation is needed for UWB emissions falling in the Cellular Radiotelephone Service bands at 824-849 MHz and 869-894 MHz bands. In the first place, the Part 15 general emission limits for the cellular frequency band, unlike those for the PCS band, are expressed as a quasi-peak limit. The modulation employed by UWB devices will tend to be measured in the cellular band as a peak spectral power density whereas the cellular receiver will respond to the average signal level from the UWB transmitter. This should provide sufficient additional protection to cellular reception. Second, only imaging systems will operate at the low frequency employed for cellular operation. Third, the emissions from cellular transmitters that fall within the band used by the mobile receiver are permitted at a level of –80 dBm, as measured at the antenna connector.[281] This is the level of interference that a cellular mobile transmitter may cause to its own receiver. This also is the level that would be produced by a UWB transmitter, operating at the Part 15 general emission limits, at a separation distance of about 4 meters using free space attenuation with no intervening objects. Thus, the separation distance between a UWB transmitter operating at the general emission limits and a cellular receiver is about the same as that of a UWB transmitter operating at 12 dB below the general emission limits and a PCS receiver. Accordingly, we find that no additional attenuation in the cellular band is required.

193. Based on the above, we are applying a 12 dB reduction below the general emission limits over the frequency range 1610 MHz to 1990 MHz.[282] We also have applied a 10 dB reduction below the general emission limits for emissions between 1990 and 3100 MHz to ensure protection from harmful interference to the U.S. Government operations within this band as well as the operation of DARS and other communications systems operating within this band.

194. One of the largest potential outdoor uses of UWB technology is vehicular radar. However, we do not believe that the proliferation of such devices will result in increased interference

[280] GPS operation occurs at 1164-1215 MHz for the L5 band, 1215-1240 MHz for the L2 band, and 1559-1610 MHz for the L1 band. DME transponders operate at 1025-1150 MHz; the ARSR-4 operates at 1240-1370 MHz; and SARSAT operates at 1544-1545 MHz.

[281] 47 C.F.R. § 22.917(f). This standard originally was established by the cellular industry, working through the Electronics Industry Association, and was published in the Commission's OST Bulletin No. 53, *Cellular System Mobile Station – Land Station Compatibility Specification*, April 1981 at Section 2.2.3.1.1.

[282] As discussed elsewhere in this Order, an additional 8 dB of suppression has been applied to vehicular radar systems and an additional 10 dB has been applied to hand held devices at the request of NTIA.

concerns at the emission levels and frequency range being adopted. We are requiring that the -10 dB bandwidth be between 22-29 GHz and that the center frequency be greater than 24.075 GHz.[283] In addition, there is a high probability that other intervening objects, *e.g.*, other vehicles, will cause the emissions to rapidly attenuate, especially at the higher frequencies. Emissions far removed from the center frequency, *e.g.*, emissions appearing below 10 GHz, should appear similar to spurious emissions from other types of Part 15 devices.[284] Because we are requiring the lower frequency emissions to be attenuated below the Part 15 general emission limits, the interference potential from vehicular radar systems to lower frequency radio systems will be less than the interference potential of conventional Part 15 devices.

195. Our primary interference concern with vehicular radar systems is cumulative interference to passive sensing systems operating in the 23.6 to 24.0 GHz band on low earth orbiting satellites, including meteorological satellites.[285] NTIA indicated that it performed an analysis of the potential interference to EESS passive satellite receivers.[286] NTIA states that a potential for harmful interference to EESS receivers would exist if emissions below 24.0 GHz were permitted at the Part 15 general emission limits. NTIA based its analysis on a 22 to 23 dB antenna discrimination at elevation angles above 30 degrees above the horizon. It concluded that the emissions from vehicular radar systems in the 23.6-24.0 GHz band must be 35 dB below the Part 15 general emission limits at elevation angles greater than 30 degrees above the horizon.[287] NTIA indicated that an attenuation of 25 dB at elevation angles of greater than 30 degrees could be achieved at the present time. NTIA indicated that the radars would be placed on transportation vehicles over a period of time and agreed to allowing a phased-in approach to obtain the additional attenuation. It agreed to permit UWB vehicular radar systems provided these systems attenuate emissions appearing within the 23.6-24.0 GHz band at greater than 30 dB elevation above the horizontal plane by the following amounts below the Part 15 general emission limits: 25 dB by January 1, 2005; 30 dB by January 1, 2010, and 35 dB by January 1, 2014.

196. We believe that the analysis performed by NTIA may be overly conservative.[288] However, to ensure that the cumulative impact of the potentially tens of thousands of transportation vehicles employing these radar devices does not result in harmful interference to the passive satellite receivers we are requiring that the emissions 38 degrees or higher above the horizontal plane in the 23.6-24.0 GHz band from properly installed vehicular radar systems be attenuated by more than 25 dB below

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[283] Part 15 radar systems currently are permitted to operate in the 24.075-24.175 GHz band. *See* 47 C.F.R. § 15.245.

[284] The UWB antenna will act as a band-pass filter. Emissions appearing, say, 20 GHz below a transmitter operating with a center frequency above 24 GHz will be a random collection of cabinet radiation and antenna resonant frequencies.

[285] *See 47 C.F.R. § 2.106.*

[286] *See* letter of February 13, 2002, from William Hatch, *supra.*.

[287] We note that it does not make a difference as to whether this attenuation is achieved through antenna directivity, the suppression of emissions below 24 GHz or some other method.

[288] For example, NTIA did not provide any attenuation of the radiated emissions due to foliage, terrain, buildings, or other vehicles as would be expected at the low elevation angles involved. NTIA also assumed that each vehicle would have four radar transmitters directed towards the satellite, resulting in a 6 dB increase to the received level, with the emissions from these transmitters attenuated, due to antenna directivity, by 21.9 dB at an angle of 33.2 degrees, the lowest LOS elevation angle used in NTIA's analyses. NTIA concluded in its calculations that an additional 10 dB of attenuation is necessary, resulting in an antenna directivity of 31.9 dB at 33.2 degrees above the horizontal plane, of 33.2 dB at 35.2 degrees, or of 40 dB at 90 degrees, depending on which of its four analysis NTIA employed. However, NTIA then required that the antenna directivity be increased to an even tighter margin of 35 dB at an elevation of 30 degrees. NTIA did not provide any justification for its additional protection margin.

the Part 15 general emission limit. The attenuation can be due to antenna directionality, a lowered transmitter power level or whatever combination produces this desired result. For equipment authorized, manufactured or imported on or after January 1, 2005, this attenuation below the Part 15 general emission limit must be increased to 25 dB at 30 degrees or greater elevation. This attenuation at elevations greater than 30 degrees shall increase to 30 dB by January 1, 2010, and to 35 dB by January 1, 2014. We intend to review these standards as additional experience is gained. In addition, we note that this limit on the emissions from a vehicular radar in the vertical direction results in the emissions radiated towards the passive satellite sensors to appear as spurious emissions. Thus, we are exempting Part 15 UWB devices from the provisions contained in US Footnote 246 to the frequency allocation table.[289]

197. We were able to reduce considerably the potential for harmful interference from UWB systems by limiting outdoor devices to imaging and vehicular radar applications. These devices will likely use directional antennas that reduce the probability that a UWB transmitter will be pointed at any particular victim receiver. However, the UWB proponents indicated a desire to provide many other types of UWB systems, especially communications systems. These systems likely would operate at high PRFs with omnidirectional antennas in the lower frequency bands, *e.g.*, with a center frequency lower than 5 to 7 GHz. Further, manufacturers indicated their desire to permit these operations with minimal restrictions on who may use the equipment or on licensing. Indeed, some proponents requested that we establish an emission limit that permits general outdoor operation.

198. XSI, in its *ex parte* filing of October 22, 2001, among others, requested that we prohibit outdoor infrastructure or establish lower emission limits to permit outdoor applications.[290] XSI stated that it would be willing to attenuate the emissions from its UWB communications systems to below the Part 15 general emission limits by 12 dB over the band 2 GHz to 1.6 GHz, 18 dB below 1.6 GHz, and 35 dB in the GPS band with an additional 10 dB in the GPS band for spectral lines. In its *ex parte* filing of November 5, 2001, XSI suggested that the Commission require an additional reduction of 9 to 12 dB in emissions below 3.1 GHz from peer-to-peer devices to provide the same attenuation that would be provided indoor operation due to building shielding.[291]

199. Based on our coordination with NTIA and other concerned U.S. Government agencies, we believe that limited outdoors operation, including general peer-to-peer operations, can be permitted provided the emissions from the UWB devices within the 1610-3100 MHz band and above 10.6 GHz are attenuated by at least 10 dB below the emission levels being permitted for indoor applications. However, we remain concerned that permitting UWB devices to be used outdoors could result in the development of large communications systems that could adversely impact the authorized services. For that reason, we are prohibiting the use of antennas attached to outside structures or any form of fixed outdoor infrastructure. To further prevent use of these products as fixed outdoor systems, we are requiring that these devices be hand held products. Further, to ensure that these products do not emit energy when they are not transmitting information to an associated receiver, we are requiring that hand held UWB devices be designed to cease transmission within ten seconds unless an acknowledgment is received from the associated receiver that the transmission is being received. This acknowledgment of reception must continue to be received by the UWB transmitter at least every ten seconds in order for the UWB transmitter to continue transmission. This will ensure that the UWB device transmits only when it is sending information to an associated receiver. Finally, to further limit the proliferation of these products

289 *See 47 C.F.R. § 2.106.*

290 Prior XSI comments indicated that UWB operation would be restricted to indoor systems. *See*, for example, XSI reply comments at pg. 5 where XSI states that indoors only operation should be required until the Commission has developed a full technical record.

291 NTIA acknowledged building attenuation levels of 9 dB from 960-3000 MHz, 12 dB from 3000-5650 MHz, and 14 dB from 5650-7250 MHz. *See* NTIA Special Publication 01-43, *supra*, at pg. 5-31.

we are prohibiting the use of UWB devices for the operation of toys.[292] We believe that these conditions reflect our desire to proceed cautiously with the introduction of UWB equipment.

200. Except for toys, we are permitting indoor systems to be used for any type of application, including communication systems, provided emissions are not intentionally directed outside, *e.g.*, through a window or doorway to perform an outside function such as the detection of persons about to enter a building. We also are prohibiting the use of fixed outdoor antennas, such as antennas mounted on the side or top of a building, or other outdoors infrastructure. The –10 dB UWB bandwidth, encompassing both the center frequency of operation and the frequency at which the highest radiated emission occurs, must be greater than 3.1 GHz. This will remove the highest emission level components away from the more sensitive radio services operating below this frequency. Building shielding combined with the emission limits being adopted should prevent interference to the authorized services, including the indoor operation of cellular, PCS and GPS systems employed in E-911 applications.[293] However, because indoor systems will be permitted to operate at higher emission levels than outdoor systems, we find that we must adopt a regulation that states that the UWB equipment, by the nature of its design, must be capable of operation only indoors. If a manufacturer were to design a system that permits peer-to-peer operation to function only indoors, we will permit it. An example would be where peer-to-peer operation can occur only when an emission from an associated base station also is detected. A necessity to operate with a fixed indoor infrastructure also may be sufficient to demonstrate indoors only operation. This action is consistent with the method we used with unlicensed PCS to ensure that portable devices were not introduced into areas that had not yet been cleared of existing licensed users.[294]

201. We also note that TDC expressed specific interest in permitting the use of UWB for surveillance systems.[295] These are radar devices that establish a stationary RF perimeter field, similar to that of a half-bubble, that is used for security purposes to detect the intrusion into a designated area by persons or objects. We believe that TDC's request has merit but remain concerned about the potential for the proliferation of these devices. Accordingly, we are requiring the same coordination procedures that we applied to imaging devices. In addition, we are limiting the operation of surveillance systems to law enforcement, fire and emergency rescue organizations, to public utilities and to industrial entities. These parties must be eligible for licensing under Part 90 of our rules.

5. Emission Levels above 1990 MHz

202. We previously discussed the analyses of potential interference to U.S. Government radio operations, amateur operation at 2450 MHz, MMDS operation around 2500 MHz, and satellite DARS at 2320-2345 MHz. The comments also addressed concerns regarding possible harmful interference to several other radio operations. AT&T requests that additional attenuation be provided as high as 2600 MHz to protect possible future 3G operations and also requests that UNII operation at 5 GHz be protected.[296] Lucent also requests additional protection for future 3G systems.[297] Motorola lists several

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[292] This is consistent with our desire to proceed cautiously with the introduction of UWB devices. This is an area that we may wish to readdress in our further review of the UWB standards that is scheduled to occur in the next six to twelve months.

[293] Requiring the equipment to be operated indoors also should provide an effect similar to that of a directional antenna. RF emissions would not be directed skyward due to increased rooftop attenuation. Variable attenuation of the building walls and attenuation by randomly placed objects within the building will reduce the probability that emissions radiated from the building will be pointed in any particular direction.

[294] 47 C.F.R. § 15.307.

[295] *See*, for example, TDC's *ex parte* filing of November 20, 2001.

[296] AT&T comments at pg. 7-8. UNII systems operate under Part 15 and are not entitled to protection from interference. *See* 47 C.F.R. § 15.5.

operations above 2 GHz that should be protected from UWB operations, such as 3G, MDS, WCS, and others, but does not provide any information to demonstrate that UWB devices operating on these frequencies would be a problem.[298]

203. We note that the 10 dB of attenuation below the Part 15 general emission limits that are being provided in the frequency range of 1990-3100 MHz to protect various U.S. Government radio operations appears to be more than sufficient to protect non-Government operations from harmful interference. The only UWB operations not subject to this additional 10 dB of attenuation are through-wall imaging systems used by public safety organizations and surveillance systems employed by public safety organizations and by public utilities and industrial entities. As used in this Order, the reference to public utilities and industrial entities refers to the manufacturers licensees, petroleum licensees or power licensees defined in 47 C.F.R. § 90.7. We believe that the requirement for surveillance systems to operate at the Part 15 general emission limits in combination with the coordination procedures are sufficient to alleviate concerns of harmful interference.

204. Except for imaging devices operating below 960 MHz, through-wall systems, surveillance systems and vehicular radars, all other UWB devices are being required to operate with their –10 dB bandwidth between 3.1-10.6 GHz. Above 3.1 GHz, it appears that the Part 15 general emission limits are sufficient to protect the various authorized radio services from harmful interference. The upper frequency limit of 10,600 MHz provides additional protection to the passive satellite receiving system frequency band at 10,600-10,700 MHz. Only vehicle radar systems are being permitted to operate with their -10 dB bandwidth between 22-29 GHz. Further, as requested by NTIA we are requiring that unwanted emissions from vehicle radar systems be attenuated 20 dB below the Part 15 general limits if they are outside the 22-31 GHz band and 10 dB below the Part 15 general limits if they are in the band 29-31 GHz. The filing from SARA indicated that their equipment could comply with such an emission limit.[299]

6. Dithering and Other Noise-Like Emission Requirements

205. As discussed earlier, the measured level at which interference occurred to a GPS C/A code receiver was 8 dB lower for a CW-like UWB emission than that at which interference occurred from a noise-like UWB emission. This 8 dB difference is in agreement with the international standards, which specify that CW-like emissions necessitate 10 dB of additional interference protection.[300] Because a CW-like emission consists of narrow spectral lines, the standard is specified as the signal level contained within a 700 Hz bandwidth.

206. We concur with the test data and international standards that an additional 10 dB of protection should be provided to GPS emissions from CW-like, narrowband emissions produced by the UWB transmitter. However, we note that a 700 Hz bandwidth setting is not available on the measurement instrumentation, such as a spectrum analyzer. XSI agreed with USGPSIC that this 10 dB of suppression could be demonstrated using a 10 kHz resolution bandwidth.[301] We also agree that a 10 kHz resolution bandwidth could be used to demonstrate that the CW-like emissions are suppressed 10 dB

(...continued from previous page)
[297] Lucent comments at pg. 7.

[298] Motorola comments at pg. 36. While Motorola in its comments requested that UWB systems be required to attenuate emissions 12 dB below the Part 15 general limits, it later requested that 18 dB of attenuation be required but supplied no data to support its request. Motorola reply comments at pg. 2 and 7.

[299] *See*, for example, the *ex parte* comments of December 5, 2001, from DaimlerChrysler and SARA on pg. 14.

[300] Recommendation ITU-R M.1477, *supra*.

[301] XSI comment of 7/25/01responding to the USGPSIC comment of 6/21/01.

below the limits applicable to noise-like emissions.[302] However, we wish to specify the measurement bandwidth as close as possible to the specification employed in the ITU-R recommendation. While a 700 Hz resolution bandwidth is not available, the use of a 1 kHz resolution bandwidth is adequate for this measurement. A CW-like emission will have the same emission level whether it is measured with a 1 kHz, a 10 kHz or a 1 MHz resolution bandwidth. Thus, we are requiring the average emissions appearing within the GPS frequency bands, 1164-1240 MHz and 1559-1610 MHz, when measured with a resolution bandwidth of no less than 1 kHz, to be attenuated by 10 dB below the average limit specified for a 1 MHz resolution bandwidth, *i.e.*, the noise-like emission limit. Specifying the resolution bandwidth for the CW-like measurement as no less than 1 kHz permits noise-like UWB systems to be tested with a wider bandwidth so that testing time may be reduced.[303]

7. Emissions from Incorporated Digital Devices

207. We note that many UWB transmission systems will incorporate digital devices that, by themselves, will radiate RF emissions. We also note that requiring the emissions from these digital devices to comply with some of the reduced levels being adopted in this proceeding may make production infeasible. We see no reason, based on the submissions in this proceeding, that emissions from associated digital circuitry should be required to have any greater attenuation than required under the current rules. To do so may make it technically infeasible or overly expensive to design UWB devices. However, we note that the digital circuitry used with a transmitter for the purpose of enabling the operation of the transmitter is not defined as a digital device but is considered to be part of the transmitter. Thus, this digital circuitry would normally be subject to the emission limits applicable to the transmitter. Under the current rules, emissions from digital circuitry used to enable the operation of the transmitter are not required to be reduced below the general limits in 47 C.F.R. § 15.209. We see no reason to change this existing provision. Accordingly, we are permitting the emissions from digital circuitry used to enable the operation of an UWB device to operate at the limits contained in 47 CFR § 15.209 provided it can be clearly demonstrated that those emissions are due solely to emissions from the digital circuitry and are not intended to be radiated from the antenna. We are not addressing distinctions between Class A and B digital devices as this is not considered in the current regulations. However, if the digital circuitry is used to control additional functions or capabilities, *i.e.*, it complies with the definition in 47 C.F.R. § 15.3(k) for a digital device, that aspect of the digital circuitry may comply with the standards for a Class A digital device or a Class B digital device, as applicable, in accordance with the current rules.

8. Peak Emission Limits

208. Proposal. In the *Notice*, the Commission noted that the peak output level does not directly impact the interference seen by a narrowband receiver. It is the power spectral density of the pulse and the pulse repetition frequency that are important for controlling potential interference. However, a limit on peak emissions is necessary to reduce the potential for UWB emitters to cause harmful interference to radio operations above 1 GHz. The Commission proposed two methods of measuring peak emission levels: 1) the peak level of the emission when measured over a bandwidth of 50 MHz which is comparable to the widest victim receiver that is likely to be encountered, and 2) the

302 If the signal is noise-like, the reduction from a 1 MHz resolution to a 10 kHz resolution bandwidth would cause a 20 dB reduction in the measured signal level.

303 A true CW-like emission will have the same measured emission level regardless of the resolution bandwidth provided only one spectral line is contained within the bandwidth of the measuring instrument. A true noise-like emission will change by 10 dB for every 10 percent change in the measurement bandwidth, *i.e.*, a signal measured to be –30 dBm with a 1 MHz resolution bandwidth will be –60 dBm when measured with a 1 kHz resolution bandwidth. When noise-like and CW-like emissions are mixed, as with most UWB operations, the measured UWB emission will decrease logarithmically with the decrease in resolution bandwidth until the imbedded CW emissions begin to be detected and resolved.

absolute peak output of the emission over its entire bandwidth. Comments were requested on the suitability of these two measurements with regard to the potential for interference from UWB transmitters to wideband receivers used in the licensed radio services.

209. In the case of the first definition of peak level, *i.e.*, the peak signal strength measured over a 50 MHz bandwidth, the Commission proposed to apply a 20 dB limit with respect to the maximum permitted average emission level.[304] This limit is consistent with the limit currently contained in 47 C.F.R. § 15.35(b). It also proposed that the absolute peak limit for the emission over its entire bandwidth be variable based on the amount the –10 dB bandwidth of the UWB emission exceeds 50 MHz. The Commission proposed to use the following formula to calculate the amount that the absolute peak emission level over the entire bandwidth of the UWB emission would be permitted to exceed the Part 15 average emission limit: [20 + 20log$_{10}$(-10 dB bandwidth of the UWB emission in Hertz/50 MHz)] dB with the further stipulation that the absolute peak emission level not be permitted to exceed the average limit by more than 60 dB.[305] This 60 dB limit is comparable with the limit permitted under the waivers recently issued to Time Domain Corporation, U.S. Radar Inc. and Zircon Corporation.[306] Comments were requested on whether wideband receivers used in the licensed services are sensitive to peak signal level in a unit bandwidth, such as the 50 MHz referenced above, or to the total peak emission produced by the USB device, and whether both peak limits are needed to reduce potential interference to the authorized radio services. If only one peak limit is needed, the comments should indicate which limit is appropriate. The Commission indicated that it intended to rely heavily on submitted test data in determining what peak emission standards should apply to UWB products.

210. The Commission requested comments as to whether the higher absolute peak limit will cause increased interference problems, especially using the proposed measurement procedures and the limitations on frequency bands of operation. Comments were requested on the proposed method of varying the absolute peak emission limit and whether other features, such as the excess bandwidth, *i.e.*, the amount of the occupied bandwidth/effective data rate exceeds a specified level such as 10 dB, should be employed in calculating a peak limit.

211. Comments. Several of the comments agreed with our specifying a peak limit over a 50 MHz bandwidth. As stated by AOPA, 50 MHz is ample for current GPS, GLONASS and AMS(R)S receivers which have a front end bandwidth of about 30 MHz.[307] NBAA agreed that a 50 MHz bandwidth is appropriate for protection of the current radio services.[308] AOPA and NBAA noted the possibility that wider bandwidths may be needed in the future if UWB is found to have operational and spectrum efficiency advantages that make it desirable for use in aeronautical communications. Similarly, Valeo Electronics stated that the proposal to measure peak over 50 MHz is appropriate and comparable to the worst case of a likely victim receiver.[309] It also noted that adoption of this standard would make it

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304 The average limit above 1000 MHz, 500 uV/m, as measured at 3 meters, is equivalent to an equivalent isotropically radiated power (EIRP) of –41.25 dBm/MHz. Thus, the proposed peak limit in a 50 MHz band would be 5000 uV/m, as measured at 3 meters, or –21.25 dBm/ 50 MHz EIRP. It appears that several of the commenters mistakenly believed that the Commission proposed to apply a limit to the peak-to-average ratio of the UWB transmission instead of to the peak emission level.

305 This would be equivalent to a total peak EIRP of +18.75 dBm.

306 *See* waivers issued on June 29, 1999, by the Chief, Office of Engineering and Technology. While the waivers stated that the maximum peak-to-average ratio was limited to 30 dB, these ratios were calculated using 10 log$_{10}$[(pulse width) x (pulse repetition frequency)] dB. For conventional pulses, the calculation would have been based on a 20 log$_{10}$ factor, resulting in a maximum 60 dB peak-to-average ratio.

307 AOPA comments at pg. 14.

308 NBAA comments at pg. 15.

309 Valeo Electronics comments at pg. 11.

unnecessary to specify a limit on the total peak signal level. TDC also objected to a limit on total peak signal level as it would be relevant only to receivers that have a bandwidth wide enough to receive the entire UWB transmission.[310] Nortel noted that future software-defined receivers will use wider bandwidths and that a 50 MHz bandwidth would not seem unreasonable in a few years.[311] Bosch also agreed that a 50 MHz bandwidth was a practical standard for a wideband receiver.[312]

212. ANRO requested a limit on the total peak level, noting that peak measurements over a 50 MHz BW would be difficult and citing an uncertainty as to where in the spectrum 50 MHz measurements should be made.[313] On the other hand, Kohler noted that the proposal to establish an absolute peak limit based on the bandwidth of the UWB transmission would encourage manufacturers to employ as wide a bandwidth as possible in order to increase the peak limit and result in greater UWB intrusion into a broader range of frequencies.[314] SiRF Technology, Inc. & Trimble Navigation request that peak power be measured on a "per-nanosecond basis."[315] USGPSIC also requested that peak power be measured on a "per nanosecond basis" believing that otherwise UWB devices would be permitted to emit peak power levels in excess of a megawatt.[316] XSI noted that the calculation by USGPSIC requires the use of an impractical PRF of 1 second and that the average level employed by USGPSIC is 50 dB higher than that proposed in the *Notice* for emissions in the GPS band.[317]

213. The commenters did not agree on the peak signal limit that should be employed. TDC, noting that the absence of peak limits would allow UWB systems operating at low PRFs to emit enormous pulse levels, stated that it was not clear how a 50 MHz measurement bandwidth and a limit of 20 dB above the average limit were indicative of interference potential and that there was no justification provided for these values.[318] TDC later requested that the peak power in a 50 MHz band be limited to 0 dBm EIRP.[319] Kohler notes that its system operates at an average level of –47.3 dBm/MHz and a total peak signal of +7 dBm.[320] XSI stated that its equipment operates with a 5 dB peak to average ratio.[321] CSSIP requested that a peak limit apply below 1000 MHz.[322] This limit, as measured in a 6 MHz bandwidth, would be 20 dB greater than the quasi-peak limit.

214. Discussion. There are two reasons for imposing a peak emission limit on UWB devices.

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310 TDC comments at pg. 34.

311 Nortel comments at pg. 4.

312 Bosch comments at pg. 5.

313 ANRO comments at pg. 2. ANRO also requested peak limits of 2 kW for UWB systems using directional antennas.

314 Kohler comments at pg. 5-6.

315 SiRF Technology, Inc. & Trimble Navigation joint reply comments at pg. 3.

316 USGPSIC comments at pg. 41-42. The USGPSIC stated that this high power would occur from the use of a 1 mW average UWB transmission using a pulse width of 1 nS.

317 XSI reply comments at pg. 6.

318 TDC comments at pg. 32-33.

319 TDC comments of 3/12/01 at pg. 17.

320 Kohler reply comments at pg. 2.

321 XSI reply comments at pg. 5. It appears that the 5 dB peak to average applies to average and peak measurements over the same 1 MHz bandwidth.

322 CSSIP comments at pg. 2. We note that the quasi-peak measurement closely approximates the peak level of a pulsed emission. Accordingly, we see no reason to apply a peak limit on top of a quasi-peak limit.

The first, and most obvious, is to keep from overloading the front end of a nearby victim receiver. For example, the interference protection level for C/A-code GPS receivers from low duty cycle pulse-like emissions is +20 dBm peak pulse power at the receiver input.[323] This is considerably higher than the signal levels we are considering in this proceeding. The second reason is because pulsed emissions with low PRFs have high peak-to-average ratios and victim receivers will respond to the peak signal level produced by the UWB transmitter if their bandwidth is wider than the UWB PRF. Thus, we need to address the potential total peak power that will be received in the bandwidth employed by the victim receiver. The total peak power produced by the UWB device is not relevant to interference potential as there are no receivers employed with the authorized radio services that operate at the bandwidths employed by UWB emissions. For that reason, we are not adopting a limit on total peak power. The comments generally agreed that 50 MHz is about the widest bandwidth that would be employed by victim radio receivers. Thus, there appears to be no reason to measure peak power across a wider bandwidth.

215. The low proliferation, infrequent operation, operation near the ground, rapid attenuation of emitted signals, and general operation in the presence of surrounding objects that would further attenuate the emissions should result in a low interference potential from GPRs and other imaging systems.[324] Vehicular radar systems operate above 24 GHz where the emissions will attenuate rapidly with distance and there is a high probability of intervening objects further attenuating the UWB emissions and reducing the probability of harmful interference. We expect that most indoor and hand held systems would operate at high PRF levels, resulting in potential victim receivers reacting only to the average emission levels produced by the UWB devices. However, some UWB devices may be designed to operate at a low PRF with a resulting high peak-to-average ratio. This could result in the peak power level being a controlling factor in potential interference to other receivers. Accordingly, we believe that a peak limit is needed to ensure that nearby victim receivers are not affected.

216. In the *Notice*, the Commission proposed a peak power limit in a 50 MHz band equal to 20 dB greater than the maximum permitted average limit. The average limit is 500 uV/m, as measured at 3 meters with a 1 MHz resolution bandwidth. This is equivalent to an EIRP of –41.25 dBm/MHz.[325] Thus, the peak power limit proposed in the *Notice* was equivalent to an EIRP of –21.25 dBm/50 MHz. The comments generally did not address interference at the peak limits being considered. Because of this, we performed our own analysis on the effect of peak power to a generic communications receiver.[326] We found that a suitable peak EIRP power limit for a transmitter placed 3 meters away would be –33.7 dBm/MHz. For a transmitter placed 10 meters away, the peak EIRP limit would be –23.3 dBm/MHz. We also note that the peak limit needs to be applied at only one location, *i.e.*, centered on the frequency at which the highest level emission occurs.[327]

217. As noted in the section on Measurement Procedures, we find that peak measurements based on a 50 MHz (resolution) bandwidth may not be feasible. The widest readily available resolution bandwidth that can be employed for peak measurements is 3 MHz. Consequently, we prepared a comparison of the differences in peak-to-average ratios, based on an average signal measured with a 1 MHz resolution bandwidth (RBW), as the PRF of the UWB emission and the RBW of the measuring

323 NTIA Special Publication 01-45, *supra*, at pg. 4-3.

324 We also note that many GPRs and imaging systems will operate below 1000 MHz where they are subject to a quasi-peak emission limit. The quasi-peak emission limit should closely approximate the peak levels produced by these devices.

325 There is a direct correlation between EIRP and field strength. Field strength in dBuV/m at 3 meters equals EIRP (in dBm) plus 95.2.

326 Our initial analysis of the effect on a QPSK system has been placed in the docket file for this proceeding.

327 The bandwidth of the measuring instrument would be centered on this frequency.

instrument are varied.[328] These graphs, shown in Appendix E to this Report and Order, compare emissions from conventional pulsed transmissions and dithered (Gaussian) pulsed transmissions.

218. As shown in the graph, the peak EIRP signal level of –21.25 dBm/50 MHz [329] that was proposed in the *Notice* results in non-dithered pulsed emissions being average-limited if the PRF is greater than 11.11 MHz and all dithered UWB emissions being peak-limited.[330] If the RBW is reduced to 3 MHz, the relationship is based on a 20 log factor resulting in a decrease in the peak level allowed with a 50 MHz RBW by 24.44 dB. This results in an allowable peak level of –45.69Bm/3 MHz, a level that is 4.44 dB lower than the permissible average limit with a 1 MHz RBW. Reducing this further to measurement with a 1 MHz RBW lowers the permissible peak level to –55.23 dBm/MHz, 14 dB below the average limit. In actual practice, we would not specify a peak level lower than the average limit. It should be noted that a conventional pulsed modulated emission would not have a peak emission higher than the average limit at PRFs greater than the RBW employed divided by 0.45.

219. Based on the above, we believe that our proposal to permit a peak emission within a 50 MHz RBW of only –21.25 dBm EIRP is too conservative. We believe that the peak emission level of 0 dBm/50 MHz, equivalent to 58 mV/m at 3 meters, requested by TDC would not result in harmful interference problems to communications systems. This level translates to a peak EIRP of –24.44 dBm/3 MHz or 3.6 uW/3 MHz, or to a peak field strength of 3.46 mV/m at measured at 3 meters with a 3 MHz RBW. This peak level is 16.8 dB higher than the average level determined with a 1 MHz RBW and is 3.2 dB lower than the peak limit permitted under the current Part 15 rules. [331] It results in dithered and non-dithered UWB emissions being average-limited for PRFs greater than 1 MHz and peak-limited for PRFs below 1 MHz.

220. Our conversion from a 50 MHz resolution bandwidth to a 3 MHz resolution bandwidth is based on the worse case assumption that changes in the peak levels changes follow the square of the change in the resolution bandwidth. That is, the change in the allowable peak limit at 50 MHz to a peak limit at 3 MHz was based on 20 log (3/50) dB. We recognize that this could penalize some UWB operations, particularly those operating with PRFs greater than around 6.7 MHz. According, we are adopting a peak limit based on a sliding scale dependent on the actual resolution bandwidth employed in the measurement. The peak EIRP limit being adopted in this Report and Order is 0 dBm when measured with a resolution bandwidth of 50 MHz and 20 log (RBW/50) dBm when measured with a resolution bandwidth ranging from 1 MHz to 50 MHz. RBW is the resolution bandwidth, in megahertz, actually employed. The minimum resolution bandwidth that may be employed is 1 MHz; the maximum resolution bandwidth that may be employed is 50 MHz.

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[328] The formulas needed to perform this analysis are contained in NTIA Special Publication 01-43, *supra*, at pg. D-1 through D-2.

[329] This equates to a 20 dB peak-to-average level for the 50 MHz RBW curve.

[330] "Average-limited" means that the average emission level will be the determining standard on whether the equipment complies with the standards. If the emissions from the device meet the average limit, they will also meet the peak limit. "Peak-limited" is the counter to this where if the device meets the peak limit, it will also comply with the average limit. However, it must be noted that the graphs are based on ideal pulse characteristics. Because of extraneous emissions, *e.g.*, emissions from an associated digital device, antenna effects, different pulse shapes, and other factors it remains necessary to specify both peak and average emissions.

[331] The peak limit above 1000 MHz is 5 mV/m. This is equivalent to –21.25 dBm EIRP. *See* 47 C.F.R. §§ 15.33(b) and 15.209. However, it must be remembered that the peak limit in the current Part 15 rules is based on the total peak emission level and not on a peak level over a specified bandwidth.

9. AC Power Line Conducted Limits

221. In the *Notice*, the Commission proposed to retain the existing limit in 47 CFR Section 15.207 for controlling the amount of energy permitted to be conducted onto the AC power lines as a reasonable starting point for establishing standards until additional experience can be gained with this equipment.[332] None of the comments objected to retaining the existing Part 15 limits on RF energy conducted onto the AC power lines.[333] We concur and are adopting a limit of 250 uV over the frequency range of 450 kHz to 30 MHz, as proposed in the *Notice*.

10. Summary of Emission Limits Being Adopted in this Report and Order

222. As stated in the *Notice*, the establishment of emission limits requires a firm understanding of the characteristics of UWB signals, their impact on victim receivers, and the minimum separation distance between UWB devices and victim receivers; almost any transmitter will cause interference if it is too close to a receiver.[334] We have attempted to apply the data submitted in the various comments, tests and analyses to determine what emission limits are acceptable for UWB operation. Our task was to determine limits based on reasonable, real-world applications and not just on the results of laboratory measurements conducted in anechoic chambers. While such measurements are necessary to determine if further investigations are necessary or additional caution should be applied, they demonstrate the possible performance capabilities of products in the absence of other RF noise sources. In some cases, we have adjusted the levels determined from the various analyses to reflect our desire and the desire of NTIA to proceed cautiously.[335]

223. The limits we are adopting in this proceeding are considerably lower in some frequency ranges than the current Part 15 levels. While these limits may prove to be lower than what is necessary, we believe that such caution is needed in the early stages of UWB implementation. Once additional experience is gained with this equipment and a better understanding develops regarding operating frequency and allowable emissions levels, we may be able to revisit these limits. In the interim, the following summarizes the emission limits being adopted in this Report and Order.

224. Based on the proceeding discussion, we are adopting the following emission limits for UWB devices:

- Coordinated GPRs, wall imaging and through-wall imaging systems may operate with the –10 dB bandwidth below 960 MHz at the Part 15 general emission limits provided emissions in the 960-1610 MHz band are attenuated below the general limits by 24 dB; narrowband emissions in the GPS bands are attenuated below the general limits by 34 dB; emissions in the 1610-1990 MHz are attenuated below the general limits by 12 dB; and emissions above 1990 MHz are attenuated below the general limits by 10 dB. There are usage restrictions and a labelling requirement.

- Coordinated through-wall imaging systems and surveillance systems may operate with the –

332 The Commission proposed to modify the AC power line conducted emission limits in 47 C.F.R. § 15.207. *See Notice of Proposed Rule Making* in ET Docket No. 98-80, 64 Fed. Reg. 62159, November 16, 1999, http://www.fcc.gov/Bureaus/Engineering_Technology/Notices/1999/fcc99296.wp.

333 *See*, for example, the comments of ARRL at pg. 16, A. Peter Annan at pg. 7, and TDC at pg. 34. While Mr. Annan's comments address conducted limits applicable to digital devices, UWB devices are intentional radiators though they also may contain digital circuitry.

334 *Notice*, *supra*, at para. 32.

335 *See* letter of February 13, 2002, from William Hatch, supra.

10 dB bandwidth within the band 1990 MHz to 10,600 MHz at the Part 15 general emission limits provided emissions below 960 MHz do not exceed the general limits; emissions in the 960-1610 MHz band are attenuated below the general limits by 12 dB; narrowband emissions in the GPS bands are attenuated below the general limits by 22 dB; emissions in the 1610-1990 MHz band are attenuated below the general limits by 10 dB; and emissions above 10,600 MHz are attenuated below the general limits by 10 dB. There are usage restrictions and a labelling requirement.

- Coordinated GPRs, wall imaging and medical imaging systems may operate with the –10 dB bandwidth within the band 3100 MHz to 10,600 MHz at the Part 15 general emission limits provided emissions below 960 MHz do not exceed the general limits; emissions in the 960-1610 MHz band are attenuated below the general limits by 24 dB; narrowband emissions in the GPS bands are attenuated below the general limits by 34 dB; emissions in the 1610-1990 MHz band are attenuated below the general limits by 12 dB; emissions in the 1990-3100 MHz band are attenuated below the general limits by 10 dB; and emissions above 10,600 MHz are attenuated below the general limits by 10 dB. There are usage restrictions and a labelling requirement.

- Indoor-only systems may operate with the –10 dB bandwidth within the band 3100 MHz to 10,600 MHz provided emissions below 960 MHz do not exceed the general limits; emissions in the 960-1610 MHz band are attenuated below the general limits by 34 dB; narrowband emissions in the GPS bands are attenuated below the general limits by 44 dB; emissions in the 1610-1990 MHz band are attenuated below the general limits by 12 dB; emissions in the 1990-3100 MHz band are attenuated below the general limits by 10 dB; and emissions above 10,600 MHz are attenuated below the general limits by 10 dB. There is a labelling requirement.

- Hand held systems may operate with the –10 bandwidth within the band 3100 MHz to 10,600 MHz provided emissions below 960 MHz do not exceed the general limits; emissions in the 960-1610 MHz band are attenuated below the general limits by 34 dB; narrowband emissions in the GPS bands are attenuated below the general limits by 44 dB; emissions in the 1610-1990 MHz band are attenuated below the general limits by 22 dB; emissions in the 1990-3100 MHz band are attenuated below the general limits by 20 dB; and emissions above 10,600 MHz are attenuated below the general limits by 20 dB.

- Vehicular radar systems may operate with the -10 dB bandwidth within the 22-29 GHz and with the center frequency and the frequency at which the maximum emission occurs both located above 24.075 GHz provided emissions below 960 MHz do not exceed the general limits; emissions in the 960-1610 MHz band are attenuated below the general limits by 34 dB; narrowband emissions in the GPS bands are attenuated below the general limits by 44 dB; emissions in the 1610-22,000 MHz band and in the band above 31 GHz are attenuated below the general limits by 20 dB; and emissions between 29 GHz and 31 GHz are attenuated below the general limits by 10 dB.

225. For all UWB devices, emission limits below 960 MHz are based on the use of a CISPR quasi-peak detector and average emissions above 960 MHz are based on the use of an RMS average detector with a 1 MHz resolution bandwidth. For systems operating above 960 MHz, there is a limit on the peak emission level contained within a 50 MHz bandwidth centered on the frequency, f_M, at which the highest radiated emission occurs. That limit is 0 dBm EIRP. A different resolution bandwidth of between 1 MHz and 50 MHz may be employed for the peak measurement provided the peak EIRP level does not exceed 20 log (RBW/50) dBm where RBW is the resolution bandwidth in megahertz. Only one peak

measurement, centered on f_M, is required. If the UWB transmitter connects to the AC power lines, there is a quasi-peak limit of 250 uV over the frequency range of 450 kHz to 30 MHz.[336]

F. Cumulative Impact

226. Proposal. While the Commission indicated that further testing and analysis is desirable on this issue, it stated in the *Notice* that it appeared that cumulative impact is negligible at the power levels and with the modulation types being proposed, especially when compared to the interference potential from a single land mobile transmitter. Thus, the Commission believed that only the closest transmitter placing an emission on the frequency of concern would be of importance, obviating the need for additional attenuation to compensate for cumulative effects. However, it added that the cumulative impact of several UWB devices might be different depending on their individual emission and transmission characteristics. For example, how does the cumulative impact of those UWB transmitters that emit a line spectrum compare to those that have a high level of random pulse positioning or dithering and may appear as Gaussian noise?[337] Further, what is the relationship between pulse repetition frequency and the cumulative impact of a number of UWB devices? The Commission noted that the emission limits were established based on the potential interference from a single Part 15 device and do not take into account cumulative effects that could occur if a number of devices are located closely together. Comments and test data were requested along with relevant input from the Commission's Technical Advisory Council.

227. Comments. There was no agreement among the comments. It is obvious that emissions from multiple UWB transmitters are additive to some extent. As the UWB emissions become more noise like, they tend to add directly, as would be expected with noise emissions. This was demonstrated in the University of Texas tests using multiple UWB transmitters.[338] Other commenting parties have advanced various mathematical models of UWB system configurations to demonstrate whether the major impact is caused by the closest UWB emitter or is caused by the cumulative effect of all surrounding emitters.

228. XSI argued that there is little cumulative effect from multiple UWB devices even when they are concentrated in a small area.[339] XSI added that UWB devices could not add over distances greater than about 10 meters because of poor indoor propagation.[340] XSI noted that devices located within about 10 m of each other share a common RF channel and so must reduce power, duty cycle, or both to avoid mutual interference. As stated by Aether Wire, a local network of UWB devices will generally have only one device transmitting at any time.[341] Similarly, Sprint PCS stated that many types of UWB devices will not transmit continuously, but rather will transmit burst or packets as necessary.[342] Sprint PCS added that in that case it would not be realistic to sum interference contributions from multiple UWB transmitters that normally would not all be transmitting simultaneously.

229. Motorola stated that it expected that the UWB devices closest to the victim receiver

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336 This limit could change in the future based on the *Notice of Proposed Rule Making* in ET Docket No. 98-80, *supra*.

337 Most UWB transmitters produce a line spectrum while those employing high levels of random pulse positioning can appear more as Gaussian noise. For the former devices, the emission only appears as noise depending on the settings of the measurement instrumentation.

338 *See* TDC submission of 3/9/01, *supra*.

339 XSI *ex parte* response of 7/25/01 at pg. 3-4 and 5-6.

340 XSI was promoting an indoor-only system.

341 Aether Wire comments at pg. 12.

342 Sprint PCS comments at Attachment 1, pg. 1-2.

would dominate due to typical path losses.[343] Its Monte Carlo analysis demonstrated that the vast majority of the time more than 90 percent of the interference is coming from the closest one to five UWB transmitters. Thus, Motorola concluded that even with 1000 surrounding transmitters the effect of cumulative interference was not as severe as the effect from the closest transmitters. Motorola's analysis found that a cumulative effect was more prevalent where the victim receiver was a base station with no nearby UWB transmitters. Under this condition, it took a considerably greater number of transmitters to contribute 90 percent of the interference power, using UWB emission contributions from as far away as 600 m.[344] As stated by AT&T, the important issue is how many transmitters operating simultaneously within a specified range will cause an additive power problem.[345]

230. NTIA employed a mathematical analysis using successive, equally spaced rings containing UWB emitters with their energy maximized in the direction of the victim receiver to demonstrate that high concentrations of UWB transmitters could result in cumulative interference.[346] However, XSI demonstrated that if only one UWB transmitter was placed within the inner ring used in NTIA's analysis the emission from that single UWB transmitter would dominate the signal at the victim receiver.

231. DOD provided mathematical analyses of possible cumulative interference from UWB operation to its SEEK Skyhook radar system, operating at 3.15 GHz and at 3.23 GHz.[347] The SEEK Skyhook is a surveillance radar positioned 12,000 feet above mean sea level operating with a range of 278 km at an altitude of 3660 meters. It currently is used to detect low flying aircraft for drug interdiction at Cudjoe Key, Florida and operates with a narrow 40 dBi antenna tilted at –1.5 degrees. Based on these specifications, DOD calculated the ground area illuminated by the radar antenna and the distance to the center of that range to determine how many UWB emitters could be permitted per square kilometer based on I/N levels ranging from –3 dB to –10 dB.[348] It concluded that a UWB emission level of –53 dBm covers most of the interference situations it analyzed and that mitigating factors from UWB antenna patterns, intermittent operation, building attenuation, and obstacle attenuation would permit a higher signal level.

232. ARRL stated that while more distant radiators would create less noise, this would be offset by the fact that there are more of them seen by the victim receiver.[349] It added that the large antennas used by amateur operators at UHF and higher frequencies would see a cumulative effect when overlooking urban areas. ARRL added that a single UWB emitter may dominate if the interference extended only for tens of meters, but as demonstrated by Motorola the interference could extend for hundreds of meters.[350] TDC argued that the closest UWB transmitter would produce the greatest impact as signals from more distant devices would be subsumed by the noise floor.

233. Discussion. We agree with ARRL that a single UWB emitter will dominate if the

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343 Motorola comments at pg. 10 and 20-21.

344 Motorola comments at pg. 26-27.

345 AT&T comments at pg. 6.

346 NTIA Special Publication 01-43, *supra*, at pg. 5-1 through 5-34 and B-1 through B-27.

347 Filing of U.S. Department of Defense submitted 10/1/00, Attachment 1.

348 We believe that the power levels being permitted for UWB operation would need to be considerably higher in order to transverse the hundreds of kilometers necessary to cause interference to the DOD SEEK Skyhook radar system.

349 ARRL comments at pg. 13-14.

350 ARRL reply comments at pg. 8.

interference extends for only a few tens of meters. Earlier in this Report and Order, we demonstrated that the interference impact of a single UWB device is on the order of "tens of meters" or less with the exception of a few sensitive receivers that operate at the noise floor and employ high gain antennas, such as the ARSR-4 system.[351] The ARSR-4 would not be particularly prone to cumulative interference as it views only a narrow ground segment at any given time.[352] Systems prone to receiving cumulative interference are those that employ high gain receiving antennas directed over large geographical areas. Examples are airborne systems and receivers located on orbiting satellites. Wide coverage area cellular and PCS base stations also may experience some cumulative impact although it should be considerably less than that received by airborne receivers.

234. We have implemented considerable restraints on the technical and operational standards for UWB equipment to ensure that cumulative interference will not occur. Primarily, we have limited outdoor applications to imaging, hand held and vehicle radar systems. The directional antennas employed by imaging and vehicle radar systems make it unlikely that the maximum emission components would be directed towards a victim receiver. Thus, directional antennas prevent the occurrence of multiple UWB emitters from producing equally received emission levels even if they are equally distant from the victim receiver. Also, the majority of the UWB radar devices being authorized direct their emissions into the ground or horizontally, away from airborne or satellite receivers. In addition, limiting the applications to systems that operate at ground level[353] ensures that the emissions attenuate more rapidly with distance and have a higher probability of obstructions between the UWB transmitter and the victim receiver. Most of the imaging UWB devices will operate only infrequently and will be far apart such that it is unlikely they will cause any cumulative effect. We also implemented constraints on the frequency bands in which the equipment is permitted to operate. Limiting devices to operate above certain frequency bands ensures that the maximum emissions will not occur in lower frequency bands where greater propagation may occur. Finally, we required UWB devices to operate at reduced emission levels between 960 MHz and 1990 MHz or higher, significantly reducing the range over which the UWB emissions in this band can be detected. All of these features combine to ensure that UWB systems will not result in a cumulative interference problem. While it is possible that indoor UWB devices, operating in an omnidirectional mode, could be sufficiently concentrated in a small area to cause a cumulative effect, XSI, Sprint PCS and others have already demonstrated that these devices will not operate simultaneously.[354] It is more likely that any high concentration of UWB devices operating indoors would be an interlinked system with a low overall duty cycle so as to avoid mutual interference.

G. Measurement Procedures

235. In the *Notice*, we proposed to continue to employ quasi-peak measurements for emissions below 1 GHz and average and peak measurements for emissions above 1 GHz, as under the current rules.[355] Quasi-peak measurements provide a weighted average over a specified measurement bandwidth while average measurements above 1 GHz are based on the use of a 1 MHz resolution bandwidth ("RBW"). Comments were sought regarding the specific measurement procedures that should be

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[351] Interference to systems such as the ARSR-4 has been sufficiently addressed through the emission limits being adopted in this proceeding.

[352] The directional signal characteristics of the UWB systems also will reduce the number of UWB devices "visible" to the ARSR-4 receiver.

[353] We expect that most handheld devices would be operated indoors or at ground level.

[354] As noted earlier, it will appear to outdoor receivers that indoor UWB systems are operating with directional antennas due to variable attenuation from building walls and randomly placed obstacles within the building.

[355] *See* 47 C.F.R. §§ 15.35(b) and 15.209(d). There are also certain rule sections that specify the application of a total peak power limit over a wider bandwidth. *See*, for example, 47 C.F.R. §§ 15.247(b) and 15.255(e).

employed.

1. Quasi-peak and Average Measurements

236. For measuring average emissions, we proposed in the *Notice* that spectrum analyzer video averaging with a video bandwidth ("VBW") of no greater than 10 kHz or less than 10 Hz be used in conjunction with peak hold to determine the average level as a function of frequency. Alternative techniques that can be shown to give comparable or more accurate results would be considered. Comments were requested on applying the measurement procedures specified in HP Application Note 150-2. Under this note, if there was no dithering of the pulse position or pulse position modulation, the average level of the fundamental and harmonic emissions would be measured using a spectrum analyzer adjusted to produce a line spectrum with the VBW equal to or greater than the RBW. This requires that the RBW be less than, or equal to, 0.3 times the pulse repetition frequency. The level of the highest line in the emission line spectrum being measured would be the average level. If the dithering or pulse position modulation could not be turned off, the emission would be measured with the spectrum analyzer settings adjusted to obtain a true pulse spectrum. A pulse desensitization correction factor, based on the calculations provided in HP Application Note 150-2, would be added to the measurement to obtain a peak level, and the average would be calculated using the duty cycle factor in dB.

237. Comments. Quasi-peak and average emission measurements are well understood, and ANSI[356] and others have established appropriate measurement procedures. ANRO, Bosch and Zircon supported the proposed average measurement techniques.[357] There were, however, several requests for variations from our measurement procedures. NTIA requested that we apply an average limit based on an RMS average rather than a logarithmic average, such as would be obtained from a spectrum analyzer employing a low video bandwidth.[358] It stated that the average logarithm is largely insensitive to energy contained in low duty cycle, high amplitude signals. It added that no single average detector function adequately describes the interference effects of UWB signals but the RMS average better quantifies this. NTIA also wished to apply the average emission limits above 960 MHz instead of 1000 MHz.[359]

238. On the other hand, Lucent requested that the VBW employed for an average measurement be greater than 10 Hz because of the possibility of burst transmissions.[360] Lucent was concerned that a 10 Hz VBW, approximating averaging over a 100 millisecond period, would result in too low a measured value, permitting the actual radiated emission to exceed our average limits. Lucent requested that the VBW be set no lower than 10 kHz or that an undefined “correction factor” be applied when the transmitter operating time was less than the averaging time of the measurement. Metricom requested that average measurements be made using a RBW of 50 MHz, just like the peak measurements.[361] A narrower VBW would be employed to average the emission.

239. Most of the comments were directed not towards the actual measurement instrumentation

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356 American National Standards Institute (ANSI) ANSI C63.4-1992, *Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz*, is specified in the Part 15 regulations as the measurement procedure applicable to Part 15 devices. *See* 47 C.F.R. § 15.31(a)(6).

357 ANRO comments at pg. 2; Bosch comments at pg. 5; Zircon comments at pg. 4.

358 *See* NTIA Report 01-383, *supra*, at pg. 6-18 through 6-25 and A-1 through A-21. *See*, also, NTIA Special Publication 01-43, *supra*, at pg. 2-1 through 2-2.

359 One of the U.S. Government frequency bands starts at 960 MHz, not at 1000 MHz.

360 Lucent comments at pg. 3. Burst transmissions are extremely short transmission intervals that have a low average emission level.

361 Metricom comments at pg. 5.

settings but to the test setup itself. With regard to GPRs, A. Peter Annan expressed concern that GPRs may not be perfectly coupled with the ground, suggesting that the GPRs be measured while suspended in the air and 20 to 40 dB be subtracted from the results.[362] Mr. Annan also requested that GPRs operating below 250 MHz be measured with a resistive load substituted for the antenna. CSSIP requested that GPRs be measured with the antennas in contact with, or in close proximity to, the ground using a suitable media of dry sand, freshwater, salty-water or concrete made from specified materials.[363] An *ex parte* filing by Sensors & Software and GSSI requested the use of a concrete slab, at least 8 inches thick, the size of the GPR transducer and installed over 12 inches of gravel, be used as the absorptive material for a GPR.[364] No metal or fiberglass reinforcing bar would be used in this base material.

240. TDC also suggested several provisions for the test set-up for UWB measurements.[365] TDC requested that we permit measurements at 1 meter due to the need for the measured emission to be at least 10 dB above the noise level of the spectrum analyzer for accuracy purposes. Bosch suggested the use of a corrugated horn antenna for measuring emissions above 1 GHz as these antennas have a fixed phase center and may be used over a wide bandwidth.[366]

241. Discussion. There is no apparent difficulty in performing measurements of quasi-peak or average emission levels. Such procedures are well documented in the current FCC test procedures and the application notes published by spectrum analyzer manufacturers. There are, however, a few areas where we need to provide clarification of the measurement procedures. A measurement procedure applicable to UWB devices is attached as Appendix F. The following discussion provides the reasons for several of the features we are including in these procedures.[367]

242. We concur with NTIA's request that logarithmic averaging not be permitted for UWB average measurements. We currently do not permit a logarithmic average to be employed for any Part 15 measurements with one exception: if the peak-to-average ratio of an emission is low and the measured emission is well below our limits, we have permitted the use of logarithmic averaging in order to facilitate measurements. While we normally perform measurements of emissions from Part 15 devices with the detector on the spectrum analyzer set in the linear mode[368], we recognize that the test data and analyses in this proceeding were performed based on RMS average emission levels. In keeping with our conservative approach to implementing UWB operation, we are adopting NTIA's suggestion to specify the average emission limits in terms of RMS average. A 1 MHz resolution bandwidth would be employed with an RMS detector and an averaging time of 1 millisecond or less. Appendix F also describes an alternative method that can be used to measure RMS average emission levels using spectrum analyzers that do not have an RMS detector. We also are implementing NTIA's request to begin RMS average emission limits, based on the use of a 1 MHz resolution bandwidth, beginning at 960 MHz.

243. We do not agree with Lucent that a minimum VBW of 10 kHz needs to be established[369] or that a "correction factor" needs to be applied to average emission measurements of short burst

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[362] A. Peter Annan comments at pg. 7-8.

[363] CSSIP comments at pg. 2.

[364] Sensors & Software and GSSI *ex parte* filing of 10/10/01.

[365] TDC comments at pg. 36-42 and reply comments at pg. 59.

[366] Bosch comments at pg. 5.

[367] We noted under the discussion on emission limits the need to test for narrowband emission levels in the GPS frequency bands and the test procedure that would be applied.

[368] Linear averaging can be accomplished by using appropriate video averaging or by trace averaging.

[369] It is not necessary to specify a video bandwidth with an RMS detector.

transmissions. Lucent has not provided any information to demonstrate why the application of a 10 Hz VBW, representing an averaging period of 100 milliseconds, to a burst UWB transmission would result in a higher interference potential. We agree that burst transmissions would have a low average measurement because of their short period of operation. However, the peak levels we are establishing would limit such transmissions. A UWB system with a high peak-to-average ratio would be peak-limited, resulting in the measured average emission level being well below our limits. We also reject the proposal by Metricom to employ a 50 MHz RBW for average measurements. Metricom did not provide any justification as to why such a large RBW is necessary for average measurements. It appears that Metricom wanted the use of a wider RBW, without a corresponding increase in permitted signal level, solely to reduce the levels of the radiated emissions. We also note that measurement equipment employing such a wide RBW is not commonly available in laboratory environments, and we are unsure about the repeatability of measurements made using such equipment.

244. In most cases, measurements will follow the procedures specified in 47 C.F.R. §15.31(a)(6). However, we believe that the measurement procedures applied to UWB devices also should address the manner in which the equipment is designed to be operated. For example, through-wall imaging systems are intended to transmit through a wall that may not dissipate much of the energy. Thus, these systems may be tested with a ½ inch section of gypsum board in front of the transmitting antenna. No attenuating material would be employed in front of medical imaging systems, vehicle radar systems, indoor systems, or hand held devices.[370] On the other hand, GPRs and wall imaging systems are designed to dissipate their transmitted energy into the ground or other structure into which they are radiating. Testing these devices over a ground plane would cause the transmitted energy to be reflected back into the air. Thus, we agree with CSSIP, Sensors & Software and GSSI that GPRs and wall imaging systems should be tested over an absorptive material. We are specifying that the transmitted emission from a GPR or a wall imaging system is to be directed towards 20 inches of dry sand. We believe that the use of dry sand will be easier to establish than a concrete/gravel test bed and would not contain the discontinuity at 8 inches as would occur with the concrete/gravel interface. This dry sand bed shall be at least the width and length of the GPR or wall imaging system being tested. Further, no ground plane shall be located under this dry sand bed. GPRs shall be suspended above this material at the height above ground at which the equipment is intended to operate. Wall imaging systems shall be suspended above this material at the separation distance at which they are intended to operate from a wall. Recognizing that the use of this absorptive material will prevent the use of a turntable, measurements must be taken at a sufficient number of radials to ensure that the measured emission levels are maximized.

245. Because of the lack of ground plane material in the test bed used for GPRs and wall imaging systems, we are establishing a test procedure than may be used for any UWB device as an option to using a ground plane. We will permit RF absorptive material, such as that found in an anechoic chamber, to be employed between the equipment under test and the measuring instrumentation. However, if this absorptive material is used 4.7 dB must be added to the obtained measurement results to simulate the effect of an additive signal reflected from the ground plane. In addition, measurements may be made at a closer distance, as requested by TDC, following the existing procedures in 47 C.F.R. § 15.31(f). However, measurements may not be made in the near field.

2. Peak Measurements

246. Proposal. In the *Notice*, we recognized that the measurement of peak power based on a 50 MHz measurement bandwidth can not be performed with normal commercial EMC test equipment. We noted that microwave receivers designed for radar interception and analysis are available with such characteristics and have costs comparable to normal EMC test equipment. Further, the IF output of a

[370] The type of material in front of these transmitters, if any, could vary. Thus, no attempt was made to categorize this material.

microwave receiver that uses a wide bandwidth, *e.g.*, 50 MHz, could be analyzed using a conventional oscilloscope in order to measure the peak level of the waveform in the time domain. Comments were sought on the feasibility of this testing technique as well as its utility as a model for the interference potential of peak UWB levels. As we are not adopting a standard for total peak power, there is no need to discuss a corresponding measurement procedure.[371] Similarly, there is no need to reiterate the discussion on antennas suitable for extreme bandwidth measurements.

247. Comments/Discussion. Several of the comments responded to the systematic problems of measuring a peak emission level over a 50 MHz bandwidth. TDC supplied a detailed measurement procedure for accomplishing this.[372] We appreciate the efforts of the commenting parties. Unfortunately, upon reflection we do not believe that peak measurements employing a 50 MHz bandwidth are practical using currently available equipment. As has become obvious from the comments, there are considerable difficulties maintaining phase accuracy over a 50 MHz bandwidth making calibration of the setup of the test bed and the measurements of the radiated emissions difficult. Further, the choice of the variable-frequency filter used to perform measurements over a 50 MHz bandwidth is extremely critical. It is unlikely that measurements over a 50 MHz bandwidth would be repeatable from one test site to another.

248. Siemens suggested measuring the peak emission level using the maximum RBW available on the instrumentation and calculating the peak emission at 50 MHz.[373] Valeo proposed a method of integrating a measurement from a spectrum analyzer over 50 MHz.[374] As stated by Fantasma, the existing rules employing a 1 MHz RBW are simple and straight forward.[375] While USGPSIC argued against the use of a spectrum analyzer, stating that spectrum analyzers sample at too low a rate to capture the peak power of UWB signals[376], we believe that a spectrum analyzer can provide a realistic view of the peak emission level as it would be viewed by a receiver employing a similar bandwidth.

249. We believe that there is a simpler method of measuring peak emission levels in a manner that also takes into account the interference potential of the equipment. In order to perform a peak measurement on a spectrum analyzer, the VBW must be at least as large as the RBW. The largest VBW on a spectrum analyzer is about 7 MHz. Thus, the widest RBW that could be employed is 3 MHz. However, there are several receivers used by the authorized radio services that employ greater bandwidths. Thus, the concern is how to ensure that peak measurements performed with a 3 MHz RBW will protect receivers that employ a wider bandwidth from harmful interference.

250. Appendix E attached to this Report and Order demonstrates the theoretical peak-to-average relationship of a pulsed emission and a dithered emission that appears like Gaussian noise as the PRF is varied. In these graphs, the average is based on measurements performed with a 1 MHz RBW. The peak measurements are based on measurements performed with a RBW of 1 MHz, 3 MHz and 50 MHz. As can be seen, the major differences between changes in RBW are not based on a 10 log relationship. Rather, they are based on a 20 log relationship.[377] We established a peak emission limit of 0 dBm as measured over a 50 MHz bandwidth. Under these conditions, reducing the RBW from 50 MHz

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371 The comments noted considerable difficulties in attempting to measure total peak output levels. *See*, for example, TDC comments at pg. 42-43.

372 TDC reply comments at Appendix C.

373 Siemens comments at pg. 1.

374 Valeo comments at pg. 12.

375 Fantasma reply comments at pg. 9.

376 USGPSIC comments at pg. 45, footnote 81.

377 The worst case comparison occurs when the PRF is less than RBW/0.45.

to 3 MHz results in an attenuation of the peak limit of 20 log (3/50) or –24.44 dBm.[378] Reducing the allowed peak limit to an EIRP of –24.44 dBm when measured with a 3 MHz RBW ensures that the emission would be no greater than 0 dBm if it was measured with a 50 MHz RBW. Peak measurements using a spectrum analyzer with a 3 MHz RBW are relatively straight-forward and can be performed using existing measurement procedures. It also is expected that these measurements should be reproducible between different measurement sites. For these reasons, we are adopting a peak measurement procedure employing a 3 MHz resolution bandwidth. This measurement must be performed centered on the frequency of emission on which appears the highest average level emission.

251. As stated earlier, our conversion from a 50 MHz resolution bandwidth to a 3 MHz resolution bandwidth is based on the worse case assumption that changes in the peak levels changes follow the square of the change in the resolution bandwidth. That is, the change in the allowable peak limit at 50 MHz to a peak limit at 3 MHz was based on 20 log (3/50) dB. We also recognized that this could penalize some UWB operations, particularly those operating with PRFs greater than around 6.7 MHz. To compensate for this, peak limits were established based on a sliding scale that is dependent on the actual resolution bandwidth employed in the measurement. The peak EIRP limit is 20 log (RBW/50) dBm when measured with a resolution bandwidth between 1 MHz and 50 MHz.[379] RBW is the resolution bandwidth in megahertz actually employed. This bandwidth must be centered on the frequency at which the highest radiated emission occurs.

252. We intend to employ at our laboratory a measurement procedure using a 3 MHz resolution bandwidth. However, we will permit responsible parties to test their UWB products using different resolution bandwidths ranging from 1 MHz to as high as 50 MHz. The use of a higher resolution bandwidth may be particularly helpful for measuring a system operating at a higher PRF. If a resolution bandwidth greater than 3 MHz is employed, the application for certification filed with the Commission must contain a detailed description of the test procedure, calibration of the test setup, and the instrumentation employed in the testing.

3. Frequency Range of Measurement

253. Proposal. For impulse systems, the Commission proposed that the center frequency of the emission bandwidth, as determined by the –10 dB points, should be used as the reference for determining the upper frequency range over which emissions should be measured.[380] Noting that the emission spectrum will change depending on the specific measurement procedures employed, *e.g.*, the use of average versus peak measurements, comments were requested on any specific measurement procedures that should be employed to determine the center frequency. For a carrier modulated system, the Commission proposed that the carrier frequency should continue to be used as the reference for determining the upper frequency range over which emissions should be measured. However, the Commission expressed concern that a manufacturer could employ a low frequency carrier with an extremely narrow pulse or a narrow pulse impulse system could be used with a low frequency antenna, resulting in emissions extending far beyond the tenth harmonic, the normal upper range of measurement. Accordingly, comments were requested on whether a different method of determining the frequency measurement range should be employed, *e.g.*, a system based on pulse rise time and width. In addition, it was noted that the lower frequency range of measurements would continue to be determined by the lowest

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378 If peak measurements were to be performed using a 1 MHz bandwidth, the peak limit would be decreased by 20 log (1/50) or to an EIRP of –34 dBm.

379 This may be converted to a peak field strength level at 3 meters using E(dBuV/m) = P(dBm EIRP) + 95.2.

380 While several references to the –20 dB emission points were made in the comments for defining UWB emissions, we believe that the –10 dB emissions points are more appropriate for determining the center frequency as it is unlikely that the –10 dB points would be below the noise floor of a spectrum analyzer.

radio frequency generated in the device. Comments were requested on whether the pulse repetition frequency, pulse dithering frequency, modulating frequency or other factors would permit the investigation of a low enough frequency range to address possible amplification of the emitted signal due to antenna resonances below the fundamental emission.

254. Comments/Discussion. There were no pertinent comments regarding the proposed frequency range over which measurements should be performed. Valeo stated that the measurement ranges are appropriate as referenced to the carrier or center frequency.[381] Our primary concern is that a sufficient frequency range be investigated to ensure that the emitted signals are no greater than the limits contained in Part 15 so that harmful interference is not caused to other users of the spectrum

255. UWB operation is unique with regard to the possible range of emissions that could be radiated from the transmitter. The generated pulse could result in a fundamental emission that is several gigahertz wide. Similarly, the side lobes also could be several gigahertz wide with the amplitude of the secondary lobe(s) only attenuated slightly below the level of the fundamental emission. It is the resonant frequency of the antenna employed with the UWB transmitter that determines the relative amplitudes of the radiated emissions.[382] The antenna can be resonant on several frequencies over a wide range both low and high. Thus, it is difficult to precisely state a frequency range of measurement.

256. We would rather proceed cautiously for these initial standards. We believe that the frequency range over which radiated emissions are investigated should include at least the fundamental emission and the secondary lobe regardless of the center frequency. This can be accomplished by requiring that the emissions be measured up to at least the center frequency added to three divided by the width of the pulse in seconds. Of course, we recognize that there is no need to require the emissions to be measured beyond 200 GHz, as could otherwise be required for extremely short pulses.[383] On the other hand, we do not wish to overburden equipment manufacturers with extensive measurement ranges that may not be necessary. Accordingly, we believe that we can compromise by establishing the following parameters. The radio spectrum produced by a UWB transmitter shall be investigated from the lowest frequency generated within the device, without going below 9 kHz, up to the frequency range shown in 47 C.F.R. § 15.33(a) or to the center frequency added to three divided by the pulse width in seconds, whichever is higher. The frequency range in 47 C.F.R. § 15.33(a) shall be based on the center frequency unless a higher frequency, *e.g.*, a carrier frequency, is generated within the UWB device. There is no requirement to measure emissions beyond 40 GHz provided the center frequency is less than 10 GHz; beyond 100 GHz if the center frequency is at or above 10 GHz and below 30 GHz; or beyond 200 GHz if the center frequency is at or above 30 GHz.[384]

H. Prohibition Against Class B, Damped Wave Emissions

257. The rules prohibit the use of Class B, damped wave emissions.[385] This prohibition stems from a similar International Telecommunication Union regulation and is a throwback to the days when

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381 Valeo comments at pg. 13.

382 Pulse shaping also could affect the characteristics and levels of the radiated emissions.

383 With the exception of radar transmitters operating between 76-77 GHz, 200 GHz is the current upper range of measurements for Part 15 transmitters. *See* 47 C.F.R. § 15.33(a).

384 At this time, we are not adopting regulations that would permit UWB systems to operate with a center frequency greater than 30 MHz. However, we see no reason not to adopt a general standard for the frequency range of measurement.

385 *See* 47 C.F.R. §§ 2.201(f) and 15.5(d).

spark gap transmitters were employed.[386] There is no longer a clear definition of a Class B, damped wave emission.[387] The Commission proposed to eliminate the prohibition against Class B, damped wave emissions indicating that this prohibition does not appear to be relevant at the power levels being proposed for UWB transmissions. These levels appear to be low enough to prevent harmful interference to other users of the spectrum. Further, unlike conventional damped wave transmissions it is likely that the receivers associated with UWB transmitters would attempt to recover as much of the transmitted bandwidth as possible for information processing purposes.

258. Comments. Few comments were filed in response to this proposal. TDC agreed with our proposal stating that the prohibition against damped wave emissions does not appear relevant to the current UWB technologies.[388] On the other hand, USGPSIC objected to removing the prohibition against employing damped wave emissions stating that there is no assurance that all future UWB applications will employ low power levels.[389] USGPSIC stated that it is prudent to retain the prohibition until a regulatory environment can be established that ensures stability of the national information infrastructure.

259. Discussion. The objection from USGPSIC has no technical basis. The regulations being adopted address the emission limits from UWB devices, ensuring that these devices will not operate at power levels that could cause harmful interference to the authorized radio services. Accordingly, our original supposition has been satisfied, and we are eliminating the prohibition against damped wave operation for UWB devices.

I. Other Matters

1. Operation of Wide Bandwidth Systems under the Existing Rules

260. Proposal. In the *Notice*, we proposed specific regulations regarding the frequency of operation and emission levels that would apply to UWB devices. We expressed concern that UWB manufacturers would wish to operate their products under a combination of both the UWB regulations and the existing Part 15 regulations in 47 C.F.R. §§ 15.217-15.255. This would result in a transmitter that has an extremely wide bandwidth attempting also to operate under standards that were developed for narrowband operation. An example would be a UWB device that operates at 5800 MHz attempting to demonstrate compliance with 47 C.F.R. § 15.245 over the frequency range 5785-5815 MHz while demonstrating compliance with the UWB emission limits outside of that frequency band. To prevent this method of cross-rule operation, the Commission proposed to amend 47 C.F.R. § 15.215(c) to state that intentional radiators operated under the provisions of 47 C.F.R. §§ 15.217-15.255 or Subpart E of the current regulations must be designed to ensure that the main lobe or the necessary bandwidth, whichever is less, is contained within the frequency bands designated in those rule section under which the equipment is operated. The requirement to contain the fundamental emission within one of the specified frequency bands would include the effects from frequency sweeping, frequency hopping and other modulation techniques that may be employed as well as the frequency stability of the transmission over

386 *See* Chapter II, Article 5, Section 8 of the Radio Regulations of the International Telecommunication Union.

387 The term "damped waves (Type B)" was last defined in Article 5, Section 1 of the 1938 version of the ITU regulations as "[w]aves composed of successive series of oscillations the amplitude of which, after obtaining a maximum, decreases gradually, the wave trains being keyed according to a telegraph code." A more modern version of the term "damped wave" is defined in the IEEE Standard Dictionary of Electrical and Electronic Terms, IEEE Std 100-1972, as "[a] wave in which, at every point, the amplitude of each sinusoidal component is a decreasing function of time."

388 TDC comments at pg. 44.

389 USGPSIC comments at pg. 47-48.

variations in temperature and supply voltage. If a frequency stability were not specified, the regulation would continue to recommend that the fundamental emission be kept within at least the central 80 percent of the band in order to minimize the possibility of out-of-band operation.

261. Comments. Interlogix expressed concern on how to compute the necessary bandwidth and measurements of the fundamental lobe.[390] It requested that the determination of whether an emission was contained within one of the frequency bands specified in 47 C.F.R. § 15.217-15.255 should be based on the 20 dB bandwidth of the emission. Bosch requested that higher emission levels be permitted for UWB devices if the emission is located in one of the ISM bands.[391] TDC requested that we not prohibit dual mode devices provided each mode of operation qualifies separately under the pertinent regulations.[392] Valeo and SARA also requested the ability for dual mode operation.[393] In addition, Delphi and SARA requested that higher UWB emissions be permitted if the emissions are located in the ISM bands.[394]

262. Discussion. We agree with Interlogix that the 20 dB bandwidth of an emission is an appropriate method of determining if an emission is operating within one of the frequency bands specified in 47 C.F.R. §§ 15.217-15.255 and are adopting this suggestion.[395] We also agree that dual mode operation is not prohibited provided each mode of operation can be distinguished and demonstrated to comply separately under the pertinent regulations.[396] However, we see no basis for permitting emissions from UWB devices to exceed the standards being adopted in this proceeding simply because the emissions happen to appear in an ISM band. There are a significant number of other radio services and devices operating within the ISM bands, some of which are allocated spectrum for this purpose. Examples include Location Monitoring Service systems in the 915 MHz band, Amateur Radio Service and land mobile systems operating in the 2450 MHz band, and police radar systems operating in the 24.125 GHz band. These are authorized radio services and are protected against harmful interference from the operation of Part 15 devices, regardless of whether they are located within ISM bands. The commenting parties have not provided information demonstrating that their products could operate without causing harmful interference to these authorized services. Even so, we are not persuaded that higher emission limits for UWB operation are prudent at this time. Once we have gained additional experience with the operation of UWB devices and their interference potential, additional changes to the rules could be considered.

2. Transition Provisions

263. In the *Notice*, we proposed that the regulations being adopted in this Report and Order become effective 60 days from its date of publication in the Federal Register. USGPS objected to our

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390 Interlogix comments at pg. 4-5 and reply comments at pg. 2. We note that Interlogix redesigned its equipment in order to be certified under the provisions of 47 C.F.R. § 15.249.

391 Bosch comments at pg. 5 and reply comments at pg. 5.

392 TDC comments at pg. 44-45.

393 Valeo comments at pg. 4; SARA *ex parte* filing of 11/14/01.

394 Delphi comments at pg. 17-18; SARA *ex parte* filing of 11/14/01. The "ISM" bands refer to the frequency bands under 47 C.F.R. § 18.301, *e.g.*, the bands on which operation is permitted under 47 C.F.R. §§ 15.245-15.249.

395 Any emissions appearing outside of the specified frequency band must continue to meet the emission limits even if those limits require an attenuation of greater than 20 dB. For example, a spread spectrum system operating at 2400-2483.5 MHz under 47 C.F.R. § 15.245 must attenuate emissions in the 2483.5-2500 MHz band by significantly greater than 20 dB. We are using the 20 dB bandwidth only to determine that the emission is contained within the specified band.

396 We do not believe that a specific regulation is required for this interpretation.

proposal, stating that it is premature to permit the regulations to become effective within 60 days of publication in the Federal Register.[397] USGPSIC added that additional proposals are needed, and that these would be major rule changes requiring congressional review.

264. We recognize that this proceeding is considered to be a major action and that the effective date is delayed for 60 days under the Contract with America Advancement Act of 1996.[398] This provides Congress with sufficient time to review our decisions, if it so desires. Absent adoption of a petition for stay or a court-order stay of this proceeding, we see no justification for delaying further the effective date.

3. Existing Waivers

265. The Commission has issued four waivers to permit the manufacture of UWB devices. Three of the waivers were issued on June 25, 1999. TDC was issued a waiver for UWB systems that would be used by public safety personnel for high resolution imaging of persons and objects behind walls or under debris. Zircon was issued a waiver for UWB radar systems that would be used by the construction industry to detect objects hidden inside walls or other building materials. U.S. Radar was issued a waiver for ground penetrating radar systems. A fourth waiver was issued on August 6, 2001, to Kohler Co. to permit it to market UWB toilet ventilating devices. These waivers were scheduled to terminate upon the effective date of the Report and Order in this proceeding.

266. On August 16, 2001, Kohler filed a request to permit it to continue to market its product under the waiver until one year from the effective date of this Report and Order. Kohler, noting that the adopted rules may be different than those under which the waiver was granted, cited the time necessary to redesign its product, to test the redesigned device and to modify its tooling. We sympathize with Kohler's concerns and believe that these problems also would affect other companies marketing equipment under a waiver. Accordingly, we are extending the cut-off dates of the waivers issued to Time Domain Corp., to U.S. Radar, to Zircon, and to Kohler for a period of one year from the effective date of this Report and Order.

4. Miscellaneous Issues

267. *Further Notice of Proposed Rule Making*. A number of parties requested that the Commission issue a further notice of proposed rule making before adopting final rules.[399] They argue, generally, that the *Notice* was inadequate because it did not include the text of the proposed rules. They also claim that the Commission must update the proposals to take into account the information contained in the various test reports filed in the record. As stated by ARRL, the *Notice* included no proposed rules, listed a few generalized tentative conclusions about UWB, and was more akin to a Notice of Inquiry.[400] Contrary to these comments, Fantasma and XSI asserted that each regulatory measure was contemplated in the *Notice* and can be implemented without a further notice of proposed rule making.[401]

268. It is true that the *Notice* did not include the precise language of the rules we are adopting today. However, the Commission did provide a general picture of what it intended to do and that is

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397 USGPSIC comments at pg. 48-52.

398 *See* 5 U.S.C. §§ 801 *et seq*.

399 *See*, for example, ATA *et al* late filed comments of 3/27/01, and MSSI late filed comments of 10/9/01. MSSI rescinded its request in an *ex parte* filing of 11/12/01.

400 ARRL comments at pg. 3.

401 Fantasma late filed comments of 4/2/01; XSI late comments of 4/12/01 and *ex parte* filing of 7/25/01.

legally adequate under the Administrative Procedure Act.[402] In *California Citizens Band Association* v. *U.S.*, 375 F 2d 43, 48-49 (9th Cir. 1967), *cert. denied*, 389 U.S. 844 (1967), the court held that the Administrative Procedure Act "...does not require an agency to publish in advance every precise proposal which it may ultimately adopt as a rule. ...[A] notice of rulemaking is sufficient if it provides a description of the subjects and issues involved." Similarly, the court in *Forester* v. *Consumer Product Safety Com'n*, 559 F 2d 774, 787 (D.C. Cir. 1977) held that "Section 553(b) does not require that interested parties be provided precise notice of each aspect of the regulations eventually adopted. Rather, notice is sufficient if it affords interested parties a reasonable opportunity to participate in the rulemaking process..." Additional legal citations were provided by Fantasma in its filing of April 2, 2001, and by XSI in its filing of April 12, 2001.

269. Several hundred comments have been filed in this proceeding, including comments on the various technical reports and analyses. It is clear from this record that the commenters well understood the regulations under consideration for amendment and the scope of proposed changes under consideration. We find that there is sufficient information in the record to make initial decisions at this time that provide for the introduction of UWB technology based on standards that are extremely conservative in protecting radio services against harmful interference. We recognize, however, that as this technology develops and we gain experience with the potential interference of UWB devices, it is appropriate to reexamine these rules. Accordingly, within the next six to twelve months we intend to review the standards for UWB devices and issue a further rule making to explore more flexible technical standards and to address the operation of additional types of UWB operations and technology. In the meantime, we plan to expedite enforcement action for any UWB products found to be in violation of the rules we are adopting and will act promptly to eliminate any reported harmful interference from UWB devices.

270. *Delphi and Other Automotive Radar Systems*. Delphi requested that we include its radar system operating at 24.125 GHz under our provisions for UWB operation.[403] Delphi indicated that it operates at 17 GHz and at 24.125 GHz and uses several different modulation types, including swept frequency modulation. However, it is the 24.125 GHz system operating with a pseudo-noise direct sequence binary phase shift key waveform that Delphi requested for inclusion. This system transmits in the restricted band below 24 GHz at the limit in 47 C.F.R. § 15.209. SARA also has expressed interest in a similar technology.[404] We find that the SARA and Delphi systems, excluding the swept frequency modulated system, fall under the definition being adopted in this proceeding and that no further action is necessary.

5. Other Matters

271. *Operation in the PCS Bands*. Sprint objected to the basic concept of UWB operation, stating that the Commission does not have a legal right to convert Sprint's licenses into non-exclusive licenses and to require Sprint PCS to share its spectrum with others, much less share it for free.[405] Sprint PCS added that it spent over $3 billion for exclusive PCS licenses and that Commission authorization of new users constitutes breach of contract and an unlawful modification of licenses for which the

402 *See* 5 U.S.C. 553.

403 *See* Delphi comments, reply comments and *ex parte* filings of 4/24/01, 6/07/01, 7/13/01, and 9/20/01.

404 SARA *ex parte* filing of 11/14/01. SARA also expressed concern regarding the residual carrier emission produced by its homodyne receiver. This issue will be addressed upon such time as the equipment is submitted for authorization under our certification procedure. However, we note that the levels of radiated emissions due to the local oscillator of a receiver operating above 960 MHz is not addressed under Part 15, other than the requirement that the emissions not cause harmful interference to other radio operations. *See* 47 C.F.R. § 15.101(b).

405 Sprint reply comments at pg. 13-14 and comments of 4/25/01 at pg. 8.

Government would be liable for damages.[406] However, no such contractual exclusivity exists. This spectrum is not, and has never been, exclusive to Sprint or to any other licensee or user. While Sprint PCS has been provided some exclusivity in operating licensed PCS systems within specified geographic areas, Part 15 transmitters currently are permitted to operate within the PCS and cellular frequency bands at considerably higher emission levels than those being adopted in this Report and Order.[407] In addition, there are countless other devices that emit radio emissions within these bands. In any event, we have not in this proceeding permitted any UWB devices to deliberately emit in the PCS bands. Much as we have done for other RF devices, we have simply established limits on out-of-band and spurious emissions from UWB devices that are designed to reduce the probability that harmful interference would be caused.

272. *Exemption of Unlicensed PCS Transmitters from the Restricted Bands*. Under the current rules, unlicensed PCS transmitters operating under Subpart D of Part 15 are not subject to the restricted band provisions in 47 C.F.R. § 15.205. The cross-reference in Subpart D to other applicable Part 15 regulations, as specified in 47 C.F.R. § 15.309, does not include Subpart C of Part 15 or any of the individual regulations contained in that subpart. Thus, 47 C.F.R. § 15.205, which is contained in Subpart C, does not apply to unlicensed PCS transmitters.[408] We are taking the opportunity provided by this Report and Order to clarify this current standard in our amendment to 47 C.F.R. § 15.205. As this amendment to the rules only clarifies an existing regulation, prior notice and comment are unnecessary.[409]

273. *U.S. Government Operation of UWB Devices*. When the Part 15 regulations were amended in 1989,[410] the Commission opened several frequency bands for unlicensed operation even though those bands were allocated for exclusive operation by the U.S. Government. The Commission took this action following an informal agreement with NTIA that similarly permitted it to operate equipment in exclusive non-government bands under the same Part 15 standards.[411] We will continue this policy, permitting the U.S. Government to operate in non-government frequency bands and in shared frequency bands under the Part 15 standards. Accordingly, as a condition of their use of these bands U.S. Government specifications for UWB devices operated by the U.S. Government agencies in non-government or in shared frequency bands must conform to the standards and operating conditions that are being adopted in this Order.[412] We believe that this will result in a greater number of UWB devices operating under the same parameters, facilitating our studies to readdress the appropriateness of the UWB standards within the next six to 12 months.

V. PROCEDURAL MATTERS

274. Paperwork Reduction Act of 1995 Analysis. This Report & Order contains modified information collection subject to the Paperwork Reduction Act of 1995 (PRA), Public Law 104-13. It will be submitted to the Office of Management and Budget (OMB) for review under Section 3507(d) of the PRA. OMB, the general public, and other Federal agencies are invited to comment on the modified

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406 Sprint PCS comments of 4/6/01 at pg. 2.

407 *See* 47 C.F.R. § 15.231.

408 Unlicensed PCS transmitters operate in the bands 1910-1930 MHz and 2390-2400 MHz. The exemption from the restricted bands only affects the limits for some of the unwanted emissions. The unwanted emissions are required to comply with the limits in 47 C.F.R. §§ 15.321(d) and 15.323(d), as appropriate.

409 *See* 47 U.S.C. 553(b)(B).

410 *See First Report and Order* in GEN Docket No. 87-389, 4 FCC Rcd. 3493 (1989).

411 *See Manual of Regulations and Procedures for Federal Radio Frequency Management*, U.S. Department of Commerce, National Telecommunications and Information Administration, January 2000, at Sections 7.8 and 7.9.

412 The operation in non-government bands of UWB devices that are not in compliance with the technical and administrative provisions contained in this Order is not permitted without the concurrence of the FCC.

information collection contained in this proceeding.

275. Final Regulatory Flexibility Certification. The Regulatory Flexibility Act of 1980, as amended (RFA)[413] requires that a regulatory flexibility analysis be prepared for rulemaking proceedings, unless the agency certifies that "the rule will not have a significant economic impact on a substantial number of small entities."[414] The RFA generally defines "small entity" as having the same meaning as the terms "small business," "small organization," and "small governmental jurisdiction."[415] In addition, the term "small business" has the same meaning as the term "small business concern" under the Small Business Act.[416] A small business concern is one which: (1) is independently owned and operated; (2) is not dominant in its field of operation; and (3) satisfies any additional criteria established by the Small Business Administration (SBA).[417]

276. In this First Report and Order, we are amending Part 15 of our rules to permit the marketing and operation of new products incorporating ultra-wideband ("UWB") technology. UWB devices operate by employing very narrow or short duration pulses that result in very large or wideband transmission bandwidths. UWB devices have the capability to provide for significant benefits for public safety, businesses and consumers. With appropriate technical standards, UWB devices can operate on spectrum occupied by existing radio services without causing interference, thereby permitting scarce spectrum resources to be used more efficiently.

277. We note that the Aircraft Owners and Pilots Association (AOPA) along with the National Business Aviation Association (NBAA) commented that the impact on small entities could not be estimated at this time.[418] They added that their constituency substantially consists of small entities, comprising individuals and small businesses that are aircraft owners and operators. AOPA and NBAA expressed concern that there would be a severe and lengthy impact to aeronautical operations should the UWB standards prove to be inadequate to protect aeronautical communications, navigation and surveillance functions. However, as demonstrated in our analyses of the interference studies on GPS there should be no impact to aeronautical radio operations from UWB devices operating under the technical limits and operational requirements we are adopting. Therefore, we find that our action will have no negative impact on this industry and in fact will have a positive impact. Further, as noted in the text we currently are limiting the expansion of UWB, out of an abundance of caution, until such time as we gain additional experience. Thus, we expect that our actions do not amount to a significant economic impact at this time. Accordingly, we certify that the rules being adopted in this Report and Order will not have a significant economic impact on a substantial number of small entities.

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413 The RFA, *see* § 5 U.S.C. S 601 *et. seq*., has been amended by the Contract With America Advancement Act of 1996, Pub. L. No. 104-121, 110 Stat. 847 (1996) (CWAAA). Title II of the CWAAA is the Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA).

414 5 U.S.C. § 605(b).

415 5 U.S.C. § 601(6).

416 5 U.S.C. § 601(3) (incorporating by reference the definition of "small business concern" in Small Business Act, 15 U.S.C. S § 632). Pursuant to 5 U.S.C. § 601(3), the statutory definition of a small business applies "unless an agency, after consultation with the Office of Advocacy of the Small Business Administration and after opportunity for public comment, establishes one or more definitions of such term which are appropriate to the activities of the agency and publishes such definition(s) in the Federal Register."

417 Small Business Act, § 15 U.S.C. S 632.

418 AOPA comments at pg. 16-17; NBAA comments at pg. 17.

278. We will send a copy of the First Report and Order, including a copy of this final certification, in a report to Congress pursuant to the Congressional Review Act.[419] In addition, the First Report and Order and this certification will be sent to the Chief Counsel for Advocacy of the Small Business Administration, and will be published in the Federal Register.[420]

VI. ORDERING CLAUSES

279. IT IS ORDERED that Part 15 of the Commission's Rules and Regulations IS AMENDED as specified in Appendix D, effective 60 days after publication in the Federal Register. This action is taken pursuant to Sections 4(i), 302, 303(e), 303(f), 303(r), 304 and 307 of the Communications Act of 1934, as amended, 47 U.S.C. Sections 154(i), 302, 303(e), 303(f), 303(r), 304 and 307.

280. IT IS FURTHER ORDERED that the waivers issued on June 25, 1999, to Time Domain Corporation, to U.S. Radar Inc., and to Zircon Corp. and the waiver issued on August 6, 2001, to Kohler Co. to permit the manufacture and marketing of their UWB devices remain in effect until one year from the effective date of this Report and Order.

281. IT IS FURTHER ORDERED that the Commission's Consumer and Governmental Affairs Bureau, Reference Information Center, SHALL SEND a copy of this *Report and Order*, including the Final Regulatory Flexibility Analysis, to the Chief Counsel for Advocacy of the Small Business Administration.

282. For further information regarding this *Report and Order*, contact John A. Reed, Office of Engineering and Technology, (202) 418-2455, jreed@fcc.gov.

FEDERAL COMMUNICATIONS COMMISSION

Marlene H. Dortch
Secretary

[419] *See* 5 U.S.C. § 801(a)(1)(A)

[420] *See* 5 U.S.C. § 605(b).

APPENDIX A
Commenting Parties

Parties filing comments:

1. Aeronautical Radio, Inc. & the Air Transport Association of America, Inc.
2. Aether Wire & Location, Inc.
3. Aircraft Owners and Pilots Association
4. Alzheimer's Association, Coastal Carolina Chapter
5. Alzheimer's Association, Middle Mississippi Chapter
6. The Amyotropic Lateral Sclerosis Association, Keith Worthington Chapter
7. The Amyotropic Lateral Sclerosis Association, Western Ohio Chapter
8. A. Peter Annan
9. ANRO Engineering, Inc.
10. Senator Bill Armistead, Alabama State Senate
11. Arc of Tennessee
12. ARRL, The National Association for Amateur Radio
13. Arthur D. Little, Inc.
14. The Associated General Contractors of America
15. Assistance of Independent Living, Inc.
16. Astatula Police Department (Florida)
17. AT&T Wireless Services, Inc.
18. Ball & Associates
19. Berwyn Fire Department (Illinois)
20. A/Prof. Marek Bailkowski, University of Queensland
21. Boeing Company
22. Burbank Fire Department
23. Centre for Sensor Signal and Information Processing
24. Cisco Systems, Inc.
25. Colingo, Williams, Heidelberg, Steinberger & McElhaney, P.A. (2)
26. Comprehensive Cancer Institute
27. Thomas J. Cooper
28. Congressman Bud Cramer, *et al.*
29. Daniel Group
30. Decatur Police Department, Criminal Investigation Division (Alabama)
31. Delphi Automotive Systems Corporation
32. Deutsche Bank Securities Inc.
33. William E. N. Doty
34. Dulac Fire Protection District 4-A (Louisiana)
35. DVP Incorporated
36. Endress + Hauser GmbH & Co.
37. Envoy Corporation
38. Fairlawn Fire Department (Ohio)
39. Fantasma Networks, Inc.
40. Farmington Department of Public Safety (Michigan)
41. Federal Law Enforcement Wireless Users Group
42. Federal Republic of Germany, Liaison Office for Defense Materiel USA/Canada
43. Florida Adult Day Care Association
44. Gordon E. Fornell
45. Charles Alton Forsberg
46. Fraternal Order of Police
47. Frontier Capital, LLC
48. Garmin International, Inc.

49. General Electric Company
50. Globe Fire Department (Arizona)
51. Golf-Domain
52. Groveland Police Department (Florida)
53. The Heart Center, P.C.
54. Helena Fire Department (Montana)
55. Hewlett-Packard Company
56. Houma Police Department (Louisiana)
57. Houston Police Department (Texas)
58. Representative Mike Hubbard, Alabama House of Representatives
59. Iberia Parish Council on Aging, Inc. (Louisiana)
60. Intelligent Automation, Inc.
61. Interlogix, Inc.
62. International Association of Fire Chiefs
63. International Brotherhood of Electrical Workers
64. Irmo Fire District (South Carolina)
65. Jore Corporation
66. Joseph Decosimo and Company
67. Kohler Co.
68. Krohne America Inc.
69. L-3 Communications
70. Laborers' International Union of North America
71. Leesburg Fire Department (Florida)
72. Lockheed Martin Corporation
73. Lockheed Martin Information Systems
74. Los Angeles County Sheriff's Department (California)
75. Senator Trent Lott
76. Lucent Technologies Inc.
77. M/A-COM
78. Maricopa County Emergency Management (Arizona)
79. McNeese State University
80. Metricom, Inc.
81. Metro Area Agency on Aging (W. Virginia)
82. Mobile Communications Holdings, Inc.
83. Moose Hill Enterprises, Inc.
84. Motorola, Inc.
85. Multispectral Solutions, Inc.
86. National Alliance for the Mentally Ill, Illinois
87. National Alliance for the Mentally Ill, Kansas
88. National Alliance for the Mentally Ill, South Dakota
89. National Association of Broadcasters
90. National Business Aviation Association, Inc.
91. National Safe Skies Alliance
92. National Telecommunications and Information Administration
93. National Thoroughbred Racing Association
94. National Volunteer Fire Council
95. Noro-Moseley Partners (2)
96. Nortel Networks Inc.
97. Ohio Statewide Independent Living Council
98. OnScene, Inc.
99. Plymouth Township Police Department (Michigan)
100. Professor Jon M. Peha, Carnegie Mellon University

101. Qualcomm Incorporated
102. Rainbow/PUSH Coalition
103. Redwood City Fire Department (California)
104. Richards Lighting
105. Roane County Committee on Aging, Inc. (W. Virginia)
106. Robert Bosch Gmbh
107. Rockwell Collins, Inc.
108. Saab Marine Electronics
109. San Mateo County, Office of the Sheriff (California)
110. Satellite Industry Association
111. James J. Schaffer
112. Professor Robert Scholtz, University of Southern California
113. Science Applications International Corporation
114. Senior Citizens, Inc.
115. Senior Companion Program, Van Buren Community Development and Services Board (Tennessee)
116. Senator Jeff Sessions, U.S. Senate
117. Siemens Automotive
118. Siemens Corporation
119. Sierra Monolithics, Incorporated
120. Singing River Hospital (Mississippi)
121. Sioux Falls Fire Rescue (South Dakota)
122. SiRF Technology, Inc.
123. Sirius Satellite Radio Inc.
124. Sony Corporation
125. South Dakota Coalition of Citizens with Disabilities
126. Sprint
127. Sprint Corporation
128. Staenberg Private Capital, LLC
129. Stanford University, Department of Aeronautics and Astronautics
130. STEP Inc.
131. Stephens Inc.
132. Steven T. Suess
133. Tacoma-Pierce County Chamber of Commerce (Washington)
134. Tallahassee Senior Center (Florida)
135. Congressman Billy Tauzin, *et al.*
136. Tennessee Disability Coalition
137. Terrebonne Parish Sheriff's Office (Louisiana)
138. Time Domain Corporation
139. Peter W. Torode
140. Tri-City Fire District (Arizona)
141. UCI
142. University of Mississippi, Office of the Chancellor
143. Upper East Tennessee Human Development Agency, Inc.
144. U.S. Department of Justice, Federal Bureau of Prisons
145. U.S. Department of the Navy, Office of the Assistant Secretary
146. U.S. Department of Transportation
147. U.S. GPS Industry Council
148. Valeo Electronics
149. Virginia Task Force One
150. Virtual Education, Inc.
151. Wakefield Police Department (Massachusetts)

152. Congressman Curt Weldon
153. West Virginia Department of Health and Human Resources
154. Wheeling Jesuit University, Office of Law Enforcement Technology Commercialization (West Virginia)
155. Lt. Governor Steve Windom, State of Alabama
156. Wireless Communications Association International, Inc. ("WCA")
157. XM Radio Inc.
158. XtremeSpectrum, Inc.
159. Zircon Corporation

Parties filing reply comments:

1. Aeronautical Radio, Inc. and the Air Transport Association of America, Inc.
2. Aerospace Industries Association
3. Aerospace States Association (ASA)
4. Aircraft Owners and Pilots Association (AOPA)
5. Alliance for Telecommunications Industry Solutions (ATIS)
6. Alloy LLC
7. American Association of People with Disabilities
8. American Telemedicine Association
9. American Trans Air, Inc.
10. Apple Valley Fire Protection District, California
11. ARRL, The National Association for Amateur Radio
12. AT&T Wireless Services, Inc.
13. Aviation Management Associates, Inc. (AMA)
14. Clovis Firefighters' Association
15. Colorado School of Mines, Department of Geophysics
16. Community Technology Centers' Network (CTCNet)
17. Computer & Communications Industry Association (CCIA)
18. Consortium for School Networking (CoSN)
19. Consumers Union and the Consumer Federation of America
20. Council of Chief State School Officers (D.C.)
21. Daimler Chrysler Research and Technology North America
22. Dain Rauscher Wessels
23. Delphi Automotive Systems Corporation
24. Disability Rights Education and Defense Fund, Inc.
25. Dr. William E. English
26. Fantasma Networks, Inc.
27. Fraternal Order of Police (Albuquerque, New Mexico)
28. Garmin International, Inc.
29. Dr. Jim Grigsby
30. Hays Medical Center (Kansas)
31. Iberia Medical Center (Louisiana)
32. Intel Corporation
33. Interagency GPS Executive Board (IGEB)
34. Interlogix Inc.
35. IPEG Corporation
36. iTelehealth, Inc.
37. Kohler Co.
38. Krohne, Inc.
39. Lockheed Martin Corporation (2)
40. Lucent Technologies Inc.

41. M/A-COM
42. Motorola, Inc.
43. Multispectral Solutions, Inc.
44. National Alliance for the Mentally Ill, Tennessee
45. National Association of County and City Health Officials
46. National Business Aviation Association, Inc.
47. National Catholic Educational Association
48. National Safe Skies Alliance
49. National Spectrum Managers Association
50. NAV Canada, SatNav
51. NovAtel Inc.
52. Robert Bosch Gmbh
53. Rockwell Collins, Inc.
54. Rural Wisconsin Health Cooperative
55. Rush Advanced Technology & International Health
56. Satellite Industry Association (SIA)
57. SBK Capital, LLC
58. Nancy J. Sharp
59. Don Siegelman, Governor, State of Alabama
60. SiRF Technology, Inc. & Trimble Navigation Limited
61. Sirius Satellite Radio Inc.
62. Sprint
63. Sprint PCS
64. STMicroelectronics (ST)
65. Stroud Engineering Services, Inc.
66. Time Domain Corporation (2)
67. United States Catholic Conference
68. U. S. Department of Defense
69. U. S. Department of Transportation
70. U. S. GPS Industry Council
71. University NAVSTAR Consortium
72. University of Arkansas for Medical Sciences, Rural Hospital Program
73. Verizon Telephone Companies
74. Dr. John Michael Williams
75. John A. Williamson, Sr.
76. Steve Windom, Lieutenant Governor, State of Alabama
77. Worldcom, Inc.
78. XM Radio Inc.
79. XtremeSpectrum, Inc.
80. Zircon Corporation

Appendix B
Comments in Response to NTIA's Study of Potential Interference to non-GPS Systems

Parties filing comments:

1. Aeronautical Radio, Inc. and the Air Transport Association of America, Inc. (ARINC/ATA)
2. AT&T Wireless Services, Inc. (AT&T)
3. Cingular Wireless LLC (Cingular)
4. Fantasma Networks, Inc. (Fantasma)
5. Federal Law Enforcement Wireless Users Group (FLEWUG)
6. Nickolaus E. Leggett
7. Lockheed Martin Corporation (LMC)
8. Multispectral Solutions, Inc. (MSSI)
9. National Association of Broadcasters (NAB)
10. Dr. Gary R. Olhoeft
11. Rockwell Collins, Inc.
12. Sirius Satellite Radio Inc. (Sirius)
13. Sprint Corporation
14. 3Com Corporation
15. Time Domain Corporation
16. U.S. GPS Industry Council

Parties filing reply comments:

1. AT&T Wireless Services, Inc. (AT&T)
2. Fantasma Networks, Inc. (Fantasma)
3. Multispectral Solutions, Inc. (MSSI)
4. Sirius Satellite Radio Inc. (Sirius)
5. Time Domain Corporation
6. XM Radio Inc.
7. XtremeSpectrum, Inc.

Appendix C
Comments in Response to Studies of Potential Interference to GPS Systems and to PCS

Parties filing comments:

1. Aeronautical Radio, Inc. and The Air Transport Association of America, Inc. (ARINC/ATA)
2. ANRO Engineering, Inc. (ANRO)
3. ARRL, The National Association for Amateur Radio (ARRL)
4. The Boeing Company (Boeing)
5. Centre for Sensor Signal and Information Processing (CSSIP)
6. Conexant Systems Inc.
7. Geophysical Survey Systems, Inc. (GSSI) (x2)
8. The Ground Penetrating Radar Circle of Finland
9. Johns Hopkins University Applied Physics Laboratory
10. Lockheed Martin Corporation (LMC)
11. Motorola, Inc.
12. Nokia, Inc.
13. Sirius Satellite Radio Inc. (Sirius) (x2)
14. Dr. Lee Slater
15. Sprint Corporation (Sprint)
16. Sprint Spectrum (Sprint PCS)
17. Dr. Ben K. Sternberg
18. Technos, Inc.
19. Time Domain Corporation (TDC)
20. U.S. GPS Industry Council
21. Dr. David L. Wright
22. XtremeSpectrum, Inc. (x2)

Parties filing reply comments:

1. Aeronautical Radio, Inc. and The Air Transport Association of America, Inc. (ARINC/ATA)
2. Dr. A. Peter Annan
3. ARRL, The National Association for Amateur Radio (ARRL)
4. Cingular Wireless
5. Common Ground Alliance
6. Geophysics Community
7. Interagency GPS Executive Board (IGEB)
8. Johns Hopkins University Applied Physics Laboratory
9. Mercedes-Benz USA (MBUSA)
10. Qualcomm Incorporated
11. Sirius Satellite Radio, Inc.
12. Society of Exploration Geophysicists (SEG)
13. Time Domain Corporation (TDC)
14. U.S. GPS Industry Council
15. XM RadioInc.
16. XtremeSpectrum, Inc.

Appendix D
Changes to the Regulations

Title 47 of the Code of Federal Regulations, Part 15, is amended as follows:

1. The authority citation for Part 15 continues to read as follows:

AUTHORITY: 47 U.S.C.154, 302, 303, 304, 307 and 544A.

2. Section 15.35 is amended by revising paragraph (b) to read as follows:

Section 15.35 Measurement detector function and bandwidth.

* * * * *

(b) Unless otherwise stated, on any frequency or frequencies above 1000 MHz the radiated limits shown are based upon the use of measurement instrumentation employing an average detector function. When average radiated emission measurements are specified in the regulations, including emission measurements below 1000 MHz, there also is a limit on the radio frequency emissions, as measured using instrumentation with a peak detector function, corresponding to 20 dB above the maximum permitted average limit for the frequency being investigated unless a different peak emission limit is otherwise specified in the rules, *e.g.*, see Sections 15.255, 15.509 and 15.511. Unless otherwise specified, measurements above 1000 MHz shall be performed using a minimum resolution bandwidth of 1 MHz. Measurements of AC power line conducted emissions are performed using a CISPR quasi-peak detector, even for devices for which average radiated emission measurements are specified.

* * * * *

3. Section 15.205 is amended by adding a new subparagraph (d)(6), to read as follows:

Section 15.205 Restricted bands of operation.

* * * * *

(d)(6) Transmitters operating under the provisions of Subparts D or F of this Part.

* * * * *

4. Section 15.215 is amended by revising (c) and by removing paragraph (d), to read as follows:

Section 15.215 Additional provisions to the general radiated emission limitations.

* * * * *

(c) Intentional radiators operating under the alternative provisions to the general emission limits, as contained in Sections 15.217 *et seq.* and in Subpart E of this part, must be designed to ensure that the 20 dB bandwidth of the emission is contained within the frequency band designated in the rule section under which the equipment is operated. The requirement to contain the 20 dB bandwidth of the emission within the specified frequency band includes the effects from frequency sweeping, frequency hopping and other modulation techniques that may be employed as well as the frequency stability of the transmitter over expected variations in temperature and supply voltage. If a frequency stability is not specified in the regulations, it is recommended that the fundamental emission be kept within at least the central 80% of the permitted band in order to minimize the possibility of out-of-band operation.

5. Part 15 is amended by adding a new Subpart F, to read as follows:

SUBPART F – ULTRA-WIDEBAND OPERATION

Section 15.501 Scope.

This subpart sets out the regulations for unlicensed ultra-wideband transmission systems.

Section 15.503 Definitions.

(a) UWB Bandwidth. For the purpose of this subpart, the UWB bandwidth is the frequency band bounded by the points that are 10 dB below the highest radiated emission, as based on the complete transmission system including the antenna. The upper boundary is designated f_H and the lower boundary is designated f_L. The frequency at which the highest radiated emission occurs is designated f_M.

(b) Center frequency. The center frequency, f_C, equals $(f_H + f_L)/2$.

(c) Fractional bandwidth. The fractional bandwidth equals $2(f_H - f_L)/ (f_H + f_L)$.

(d) Ultra-wideband (UWB) transmitter. An intentional radiator that, at any point in time, has a fractional bandwidth equal to or greater than 0.20 or has a UWB bandwidth equal to or greater than 500 MHz, regardless of the fractional bandwidth.

(e) Imaging system. A general category consisting of ground penetrating radar systems, medical imaging systems, wall imaging systems through-wall imaging systems and surveillance systems. As used in this subpart, imaging systems do not include systems designed to detect the location of tags or systems used to transfer voice or data information.

(f) Ground penetrating radar (GPR) system. A field disturbance sensor that is designed to operate only when in contact with, or within one meter of, the ground for the purpose of detecting or obtaining the images of buried objects or determining the physical properties within the ground. The energy from the GPR is intentionally directed down into the ground for this purpose.

(g) Medical imaging system. A field disturbance sensor that is designed to detect the location or movement of objects within the body of a person or animal.

(h) Wall imaging system. A field disturbance sensor that is designed to detect the location of objects contained within a "wall" or to determine the physical properties within the "wall." The "wall" is a concrete structure, the side of a bridge, the wall of a mine or another physical structure that is dense enough and thick enough to absorb the majority of the signal transmitted by the imaging system. This category of equipment does not include products such as "stud locators" that are designed to locate objects behind gypsum, plaster or similar walls that are not capable of absorbing the transmitted signal.

(i) Through-wall imaging system. A field disturbance sensor that is designed to detect the location or movement of persons or objects that are located on the other side of an opaque structure such as a wall or a ceiling. This category of equipment may include products such as "stud locators" that are designed to locate objects behind gypsum, plaster or similar walls that are not thick enough or dense enough to absorb the transmitted signal.

(j) Surveillance system. A field disturbance sensor used to establish a stationary RF perimeter field that is used for security purposes to detect the intrusion of persons or objects.

(k) EIRP. Equivalent isotropically radiated power, *i.e.*, the product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna. The EIRP, in terms of dBm, can be converted to a field strength, in dBuV/m at 3 meters, by adding 95.2. As used in this subpart, EIRP refers to the highest signal strength measured in any direction and at any frequency from the UWB device, as tested in accordance with the procedures specified in Sections 15.31(a) and 15.523 of this chapter.

(l) Law enforcement, fire and emergency rescue organizations. As used in this subpart, this refers to those parties eligible to obtain a license from the FCC under the eligibility requirements specified in Section 90.20(a)(1) of this chapter.

(m) Hand held. As used in this subpart, a hand held device is a portable device, such as a lap top computer or a PDA, that is primarily hand held while being operated and that does not employ a fixed infrastructure.

Section 15.505 Cross reference.

(a) Except where specifically stated otherwise within this subpart, the provisions of Subparts A and B and of Sections 15.201 through 15.204 and Section 15.207 of Subpart C of this part apply to unlicensed UWB intentional radiators. The provisions of Sections 15.35(c) and 15.205 do not apply to devices operated under this subpart. The provisions of Footnote US 246 to the Table of Frequency Allocations contained in Section 2.106 of this chapter does not apply to devices operated under this subpart.

(b) The requirements of Subpart F apply only to the radio transmitter, *i.e.*, the intentional radiator, contained in the UWB device. Other aspects of the operation of a UWB device may be subject to requirements contained elsewhere in this chapter. In particular, a UWB device that contains digital circuitry not directly associated with the operation of the transmitter also is subject to the requirements for unintentional radiators in Subpart B of this chapter. Similarly, an associated receiver that operates (tunes) within the frequency range 30 MHz to 960 MHz is subject to the requirements in Subpart B of this chapter.

Section 15.507 Marketing of UWB equipment.

In some cases, the operation of UWB devices is limited to specific parties, *e.g.*, law enforcement, fire and rescue organizations operating under the auspices of a state or local government. The marketing of UWB devices must be directed solely to parties eligible to operate the equipment. The responsible party, as defined in Section 2.909 of this chapter, is responsible for ensuring that the equipment is marketed only to eligible parties. Marketing of the equipment in any other manner may be considered grounds for revocation of the grant of certification issued for the equipment.

Section 15.509 Technical requirements for low frequency imaging systems.

(a) The UWB bandwidth of an imaging system operating under the provisions of this Section must be below 960 MHz.

(b) Operation under the provisions of this section is limited to the following:

(1) GPRs and wall imaging systems operated by law enforcement, fire and emergency rescue organizations, by scientific research institutes, by commercial mining companies, or by construction companies.

(2) Through-wall imaging systems operated by law enforcement, fire or emergency rescue organizations.

(3) Parties operating this equipment must be eligible for licensing under the provisions of Part 90 of our rules.

(4) The operation of imaging systems under this section requires coordination, as detailed in Section 15.525 of this chapter.

(c) An imaging system shall contain a manually operated switch that causes the transmitter to cease operation within 10 seconds of being released by the operator. In addition, it is permissible to operate an imaging system by remote control provided the imaging system ceases transmission within 10 seconds of the remote switch being released by the operator.

(d) The radiated emissions at or below 960 MHz from a device operating under the provisions of this section shall not exceed the emission levels in Section 15.209 of this chapter. The radiated emissions above 960 MHz from a device operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of 1 MHz:

Frequency in MHz	EIRP in dBm
960-1610	-65.3
1610-1990	-53.3
Above 1990	-51.3

(e) In addition to the radiated emission limits specified in the above table, UWB transmitters operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of no less than 1 kHz:

Frequency in MHz	EIRP in dBm
1164-1240	-75.3
1559-1610	-75.3

(f) There is a limit on the peak level of the emissions contained within a 50 MHz bandwidth centered on the frequency at which the highest radiated emission occurs, f_M. That limit is 0 dBm EIRP. It is acceptable to employ a different resolution bandwidth, and a correspondingly different peak emission limit, following the procedures described in Section 15.521 of this chapter.

(g) Imaging systems operating under the provisions of this section shall bear the following or similar statement, as adjusted for the specific provisions in paragraph (b) of this section, in a conspicuous location on the device:

> Operation of this device is restricted to law enforcement, fire and rescue officials, scientific research institutes, commercial mining companies, and construction companies. Operation by any other party is a violation of 47 U.S.C. § 301 and could subject the operator to serious legal penalties.

Section 15.511 Technical requirements for mid-frequency imaging systems.

(a) The UWB bandwidth of an imaging system operating under the provisions of this section must be contained between 1990 MHz and 10,600 MHz.

(b) Operation under the provisions of this section is limited to the following:

(1) Through-wall imaging systems operated by law enforcement, fire or emergency rescue organizations.

(2) Fixed surveillance systems operated by law enforcement, fire or emergency rescue organizations or by manufacturers licensees, petroleum licensees or power licensees as defined in Section 90.7 of this chapter.

(3) Parties operating under the provisions of this section must be eligible for licensing under the provisions of Part 90 of our rules.

(4) The operation of imaging systems under this section requires coordination, as detailed in Section 15.525 of this chapter.

(c) A through-wall imaging system shall contain a manually operated switch that causes the transmitter to cease operation within 10 seconds of being released by the operator. In addition, it is permissible to operate an imaging system by remote control provided the imaging system ceases transmission within 10 seconds of the remote switch being released by the operator.

(d) The radiated emissions at or below 960 MHz from a device operating under the provisions of this section shall not exceed the emission levels in Section 15.209 of this chapter. The radiated emissions above 960 MHz from a device operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of 1 MHz:

Frequency in MHz	EIRP in dBm
960-1610	-53.3
1610-1990	-51.3
1990-10600	-41.3
Above 10600	-51.3

(e) In addition to the radiated emission limits specified in the above table, UWB transmitters operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of no less than 1 kHz:

Frequency in MHz	EIRP in dBm
1164-1240	-63.3
1559-1610	-63.3

(f) There is a limit on the peak level of the emissions contained within a 50 MHz bandwidth centered on the frequency at which the highest radiated emission occurs, f_M. That limit is 0 dBm EIRP. It is acceptable to employ a different resolution bandwidth, and a correspondingly different peak emission limit, following the procedures described in Section 15.521 of this chapter.

(g) Imaging systems operating under the provisions of this section shall bear the following or similar statement, as adjusted for the specific provisions in paragraph (b) of this section, in a conspicuous location on the device:

Operation of this device is restricted to law enforcement, fire and rescue officials, public utilities, and industrial entities. Operation by any other party is a violation of 47 U.S.C. § 301 and could subject the operator to serious legal penalties.

Section 15.513 Technical requirements for high frequency imaging systems.

(a) The UWB bandwidth of an imaging system operating under the provisions of this section must be contained between 3100 MHz and 10,600 MHz.

(b) Operation under the provisions of this section is limited to the following:

(1) GPRs and wall imaging systems operated by law enforcement, fire or emergency rescue organizations, by scientific research institutes, by commercial mining companies, or by construction companies.

(2) Medical imaging systems used at the direction of, or under the supervision of, a licensed health care practitioner.

(3) Parties operating GPRs or wall imaging systems must be eligible for licensing under the provisions of Part 90 of our rules.

(4) The operation of imaging systems under this section requires coordination, as detailed in Section 15.525 of this chapter.

(c) An imaging system shall contain a manually operated switch that causes the transmitter to cease operation within 10 seconds of being released by the operator. In addition, it is permissible to operate an imaging system by remote control provided the imaging system ceases transmission within 10 seconds of the remote switch being released by the operator.

(d) The radiated emissions at or below 960 MHz from a device operating under the provisions of this section shall not exceed the emission levels in Section 15.209 of this chapter. The radiated emissions above 960 MHz from a device operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of 1 MHz:

Frequency in MHz	EIRP in dBm
960-1610	-65.3
1610-1990	-53.3
1990-3100	-51.3
3100-10600	-41.3
Above 10600	-51.3

(e) In addition to the radiated emission limits specified in the above table, UWB transmitters operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of no less than 1 kHz:

Frequency in MHz	EIRP in dBm
1164-1240	-75.3
1559-1610	-75.3

(f) There is a limit on the peak level of the emissions contained within a 50 MHz bandwidth centered on the frequency at which the highest radiated emission occurs, f_M. That limit is 0 dBm EIRP. It is acceptable to employ a different resolution bandwidth, and a correspondingly different peak emission limit, following the procedures described in Section 15.521 of this chapter.

(g) Imaging systems, other than medical imaging systems, operating under the provisions of this section shall bear the following or similar statement in a conspicuous location on the device:

> Operation of this device is restricted to law enforcement, fire and rescue officials, scientific research institutes, commercial mining companies, and construction companies. Operation by any other party is a violation of 47 U.S.C. § 301 and could subject the operator to serious legal penalties.

Section 15.515 Technical requirements for vehicular radar systems.

(a) Operation under the provisions of this section is limited to UWB field disturbance sensors mounted in terrestrial transportation vehicles. These devices shall operate only when the vehicle is operating, *e.g.*, the engine is running. Operation shall occur only upon specific activation, such as upon starting the vehicle, changing gears, or engaging a turn signal.

(b) The UWB bandwidth fo a vehicular radar system operating under the provisions of this section shall be contained between 22 GHz and 29 GHz. In addition, the center frequency, f_C, and the frequency at which the highest level emission occurs, f_M, must be greater than 24.075 GHz.

(c) Following proper installation, vehicular radar systems shall attenuate any emissions within the 23.6-24.0 GHz band that appear 38 degrees or greater above the horizontal plane by 25 dB below the limit specified in paragraph (d) of this chapter. For equipment authorized, manufactured or imported on or after January 1, 2005, this level of attenuation shall be 25 dB for any emissions within the 23.6-24.0 GHz band that appear 30 degrees or greater above the horizontal plane. For equipment authorized, manufactured or imported on or after January 1, 2010, this level of attenuation shall be 30 dB for any emissions within the 23.6-24.0 GHz band that appear 30 degrees or greater above the horizontal plane. For equipment authorized, manufactured or imported on or after January 1, 2014, this level of attenuation shall be 35 dB for any emissions within the 23.6-24.0 GHz band that appear 30 degrees or greater above the horizontal plane. This level of attenuation can be achieved through the antenna directivity, through a reduction in output power or any other means.

(d) The radiated emissions at or below 960 MHz from a device operating under the provisions of this section shall not exceed the emission levels in Section 15.209 of this chapter. The radiated emissions above 960 MHz from a device operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of 1 MHz:

Frequency in MHz	EIRP in dBm
960-1610	-75.3
1610-22,000	-61.3
22,000-29,000	-41.3
29,000-31,000	-51.3
Above 31,000	-61.3

(e) In addition to the radiated emission limits specified in the above table, UWB transmitters operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of no less than 1 kHz:

Frequency in MHz	EIRP in dBm
1164-1240	-85.3

1559-1610	-85.3

(f) There is a limit on the peak level of the emissions contained within a 50 MHz bandwidth centered on the frequency at which the highest radiated emission occurs, f_M. That limit is 0 dBm EIRP. It is acceptable to employ a different resolution bandwidth, and a correspondingly different peak emission limit, following the procedures described in Section 15.521 of this chapter.

Section 15.517 Technical requirements for indoor UWB systems.

(a) Operation under the provisions of this section is limited to UWB transmitters employed solely for indoor operation.

(1) Indoor UWB devices, by the nature of their design, must be capable of operation only indoors. The necessity to operate with a fixed indoor infrastructure, *e.g.*, a transmitter that must be connected to the AC power lines, may be considered sufficient to demonstrate this.

(2) The emissions from equipment operated under this section shall not be intentionally directed outside of the building in which the equipment is located, such as through a window or a doorway, to perform an outside function, such as the detection of persons about to enter a building.

(3) The use of outdoor mounted antennas, *e.g.*, antennas mounted on the outside of a building or on a telephone pole, or any other outdoors infrastructure is prohibited.

(4) Field disturbance sensors installed inside of metal or underground storage tanks are considered to operate indoors provided the emissions are directed towards the ground.

(5) A communications system shall transmit only when the intentional radiator is sending information to an associated receiver.

(b) The UWB bandwidth of a UWB system operating under the provisions of this section must be contained between 3100 MHz and 10,600 MHz.

(c) The radiated emissions at or below 960 MHz from a device operating under the provisions of this section shall not exceed the emission levels in Section 15.209 of this chapter. The radiated emissions above 960 MHz from a device operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of 1 MHz:

Frequency in MHz	EIRP in dBm
960-1610	-75.3
1610-1990	-53.3
1990-3100	-51.3
3100-10600	-41.3
Above 10600	-51.3

(e) In addition to the radiated emission limits specified in the above table, UWB transmitters operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of no less than 1 kHz:

Frequency in MHz	EIRP in dBm
1164-1240	-85.3
1559-1610	-85.3

(f) There is a limit on the peak level of the emissions contained within a 50 MHz bandwidth centered on the frequency at which the highest radiated emission occurs, f_M. That limit is 0 dBm EIRP. It is acceptable to employ a different resolution bandwidth, and a correspondingly different peak emission limit, following the procedures described in Section 15.521 of this chapter.

(g) UWB systems operating under the provisions of this section shall bear the following or similar statement in a conspicuous location on the device or in the instruction manual supplied with the device:

> This equipment may only be operated indoors. Operation outdoors is in violation of 47 U.S.C. § 301 and could subject the operator to serious legal penalties.

Section 15.519 Technical requirements for hand held UWB systems.

(a) UWB devices operating under the provisions of this section must be hand held, *i.e.*, they are relatively small devices that are primarily hand held while being operated and do not employ a fixed infrastructure.

(1) A UWB device operating under the provisions of this section shall transmit only when it is sending information to an associated receiver. The UWB intentional radiator shall cease transmission within 10 seconds unless it receives an acknowledgement from the associated receiver that its transmission is being received. An acknowledgment of reception must continued to be received by the UWB intentional radiator at least every 10 seconds or the UWB device must cease transmitting.

(2) The use of antennas mounted on outdoor structures, *e.g.*, antennas mounted on the outside of a building or on a telephone pole, or any fixed outdoors infrastructure is prohibited. Antennas may be mounted only on the hand held UWB device.

(3) UWB devices operating under the provisions of this section may operate indoors or outdoors.

(b) The UWB bandwidth of a device operating under the provisions of this Section must be contained between 3100 MHz and 10,600 MHz.

(c) The radiated emissions at or below 960 MHz from a device operating under the provisions of this section shall not exceed the emission levels in Section 15.209 of this chapter. The radiated emissions above 960 MHz from a device operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of 1 MHz:

Frequency in MHz	EIRP in dBm
960-1610	-75.3
1610-1900	-63.3
1900-3100	-61.3
3100-10600	-41.3
Above 10600	-61.3

(d) In addition to the radiated emission limits specified in the above table, UWB transmitters operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of no less than 1 kHz:

Frequency in MHz	EIRP in dBm
1164-1240	-85.3

1559-1610	-85.3

(e) There is a limit on the peak level of the emissions contained within a 50 MHz bandwidth centered on the frequency at which the highest radiated emission occurs, f_M. That limit is 0 dBm EIRP. It is acceptable to employ a different resolution bandwidth, and a correspondingly different peak emission limit, following the procedures described in Section 15.521 of this chapter.

Section 15.521 Technical requirements applicable to all UWB devices.

(a) UWB devices may not be employed for the operation of toys. Operation onboard an aircraft, a ship or a satellite is prohibited.

(b) Manufacturers and users are reminded of the provisions of Sections 15.203 and 15.204 of this chapter.

(c) As noted in Section 15.3(k) of this chapter, digital circuitry that is used only to enable the operation of a transmitter and that does not control additional functions or capabilities is not classified as a digital device. Instead, the emissions from that digital circuitry are subject to the same limits as those applicable to the transmitter. If it can be clearly demonstrated that an emission from a UWB transmitter is due solely to emissions from digital circuitry contained within the transmitter and that the emission is not intended to be radiated from the transmitter's antenna, the limits shown in Section 15.209 of this chapter shall apply to that emission rather than the limits specified in this section.

(d) Within the tables in the above rule sections, the tighter emission limit applies at the band edges. Radiated emission levels at and below 960 MHz are based on measurements employing a CISPR quasi-peak detector. Radiated emission levels above 960 MHz are based on RMS average measurements over a 1 MHz resolution bandwidth. The RMS average measurement is based on the use of a spectrum analyzer with a resolution bandwidth of 1 MHz, an RMS detector, and a 1 millisecond or less averaging time. If pulse gating is employed where the transmitter is quiescent for intervals that are long compared to the nominal pulse repetition interval, measurements shall be made with the pulse train gated on. Alternative measurement procedures may be considered by the Commission.

(e) The frequency at which the highest radiated emission occurs, f_M, must be contained within the UWB bandwidth.

(f) Imaging systems may be employed only for the type of information exchange described in their specific definitions contained in Section 15.503 of this chapter. The detection of tags or the transfer or data or voice information is not permitted under the standards for imaging systems.

(g) When a peak measurement is required, it is acceptable to use a resolution bandwidth other than the 50 MHz specified in this subpart. This resolution bandwidth shall not be lower than 1 MHz or greater than 50 MHz, and the measurement shall be centered on the frequency at which the highest radiated emission occurs, f_M. If a resolution bandwidth other than 50 MHz is employed, the peak EIRP limit shall be 20 log (RBW/50) dBm where RBW is the resolution bandwidth in megahertz that is employed. This may be converted to a peak field strength level at 3 meters using E(dBuV/m) = P(dBm EIRP) + 95.2. If RBW is greater than 3 MHz, the application for certification filed with the Commission must contain a detailed description of the test procedure, calibration of the test setup, and the instrumentation employed in the testing.

(h) The highest frequency employed in Section 15.33 of this chapter to determine the frequency range over which radiated measurements are made shall be based on the center frequency, f_C, unless a higher frequency is generated within the UWB device. For measuring emission levels, the spectrum shall be investigated from the lowest frequency generated in the UWB transmitter, without going below 9 kHz, up to the frequency range shown in Section 15.33(a) of this chapter or up to f_C + 3/(pulse width in seconds), whichever is higher. There is no requirement to measure emissions beyond 40 GHz provided f_C is less than 10 GHz; beyond 100 GHz if f_C is at or above 10 GHz and below 30 GHz; or beyond 200 GHz if f_C is at or above 30 GHz.

(i) The prohibition in Sections 2.201(f) and 15.5(d) of this chapter against Class B (damped wave) emissions does not apply to UWB devices operating under this subpart.

(j) Responsible parties are reminded of the other standards and requirements incorporated by reference in Section 15.505 of this chapter, such as a limit on emissions conducted onto the AC power lines.

Section 15.523 Measurement procedures.

Measurements shall be made in accordance with the procedures specified by the Commission.

Section 15.525 Coordination requirements.

(a) UWB imaging systems require coordination through the FCC before the equipment may be used. The operator shall comply with any constraints on equipment usage resulting from this coordination.

(b) The users of UWB imaging devices shall supply detailed operational areas to the FCC Office of Engineering and Technology who shall coordinate this information with the Federal Government through the National Telecommunications and Information Administration. The information provided by the UWB operator shall include the name, address and other pertinent contact information of the user, the desired geographical area of operation, and the FCC ID number and other nomenclature of the UWB device. This material shall be submitted to the following address:

Frequency Coordination Branch., OET
Federal Communications Commission
445 12th Street, SW
Washington, D.C. 20554

ATTN: UWB Coordination

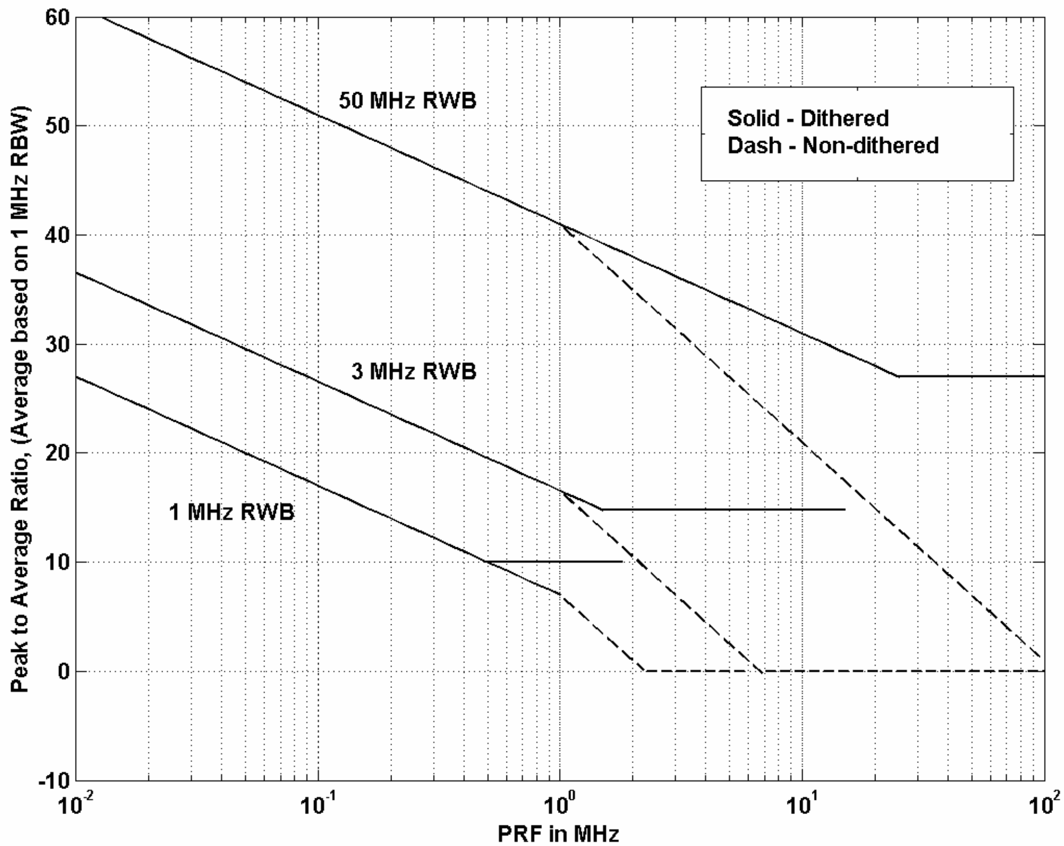
(c) The manufacturers, or their authorized sales agents, must inform purchasers and users of their systems of the requirement to undertake detailed coordination of operational areas with the FCC prior to the equipment being operated.

(d) Users of authorized, coordinated UWB systems may transfer them to other qualified users and to different locations upon coordination of change of ownership or location to the FCC and coordination with existing authorized operations.

(e) The NTIA/FCC coordination report shall include any needed constraints that apply to day-to-day operations. Such constraints could specify prohibited areas of operations or areas located near authorized radio stations for which additional coordination is required before operation of the UWB equipment. If additional local coordination is required, a local coordination contact will be provided.

(f) The coordination of routine UWB operations shall not take longer than 15 business days from the receipt of the coordination request by NTIA. Special temporary operations may be handled with an expedited turn-around time when circumstances warrant. The operation of UWB systems in emergency situations involving the safety of life or property may occur without coordination provided a notification procedure, similar to that contained in Section 2.405(a)-(e) of this chapter, is followed by the UWB equipment user.

APPENDIX E
Peak in a Specific Bandwidth vs. Average in a 1 MHz Bandwidth vs. PRF



APPENDIX F
Measurement Procedures

This appendix is intended to provide general guidance for compliance measurements of UWB devices. The procedures herein are based on the Commissions current understanding of UWB technology. Modifications may be necessary as measurement experience is gained.

Except as otherwise described herein, measurements shall be made in accordance with the procedures specified in Section 15.31(a)(6) of Title 47 of the Code of Federal Regulations.

(1) Ground penetrating radars (GPRs) and wall imaging systems shall be tested under conditions that are representative of actual operating conditions. UWB devices intended for these types of application shall be compliance tested with the transducer at an operationally representative height above a twenty-inch thick bed of dry sand. The use of this medium, particularly for larger GPRs (e.g., those that are towed behind vehicles), will likely preclude the use of a turntable in the measurement procedure. For these cases, directionality gradients shall be analyzed and measurements shall be performed at a sufficient number of radials around the equipment under test to determine the radial at which the field strength values of the radiated emissions are maximized.

(2) Field strength measurements of through-wall imaging systems may be made with a ½” thick gypsum or drywall board placed between the UWB device antenna and the measurement system antenna.

(3) RMS average field strength measurements, required for all frequencies above 960 MHz, shall be made using techniques to obtain true RMS average. This can be accomplished by using a spectrum analyzer that incorporates a RMS detector. The resolution bandwidth of the analyzer shall be set to 1 MHz, the RMS detector selected, and a video integration time of 1 ms or less is to be used. If the transmitter employs pulse gating, in which the transmitter is quiescent for intervals that are long compared to the nominal pulse repetition interval, all measurements shall be made while the pulse train is gated on. Alternatively, a true RMS level can be measured using a spectrum analyzer that does not incorporate a RMS detector. This approach requires a multiple step technique beginning with a peak detection scan of the UWB spectrum with a RBW of 1 MHz and a VBW of no less than 1 MHz. The resulting trace is to be used to identify the frequency and bandwidth of the five highest peaks in the spectrum. The analyzer is then to be placed in a “zero span” mode, with a RBW of 1 MHz, a video bandwidth equal to or greater than 1 MHz, and a detector selected that does not distort or smooth the instantaneous signal levels (e.g., a “sample” detector). With these settings, a minimum of ten independent instantaneous points, representing the highest amplitude readings, are to be obtained during the time that a pulse is present, in each 1 MHz frequency bin across the bandwidth of each of the five highest peaks identified in the previous step. Note that when the PRF of the device under test is less than the measurement bandwidth of 1 MHz, a significant number of samples may be required to ensure that a minimum of 10 samples with the pulse present are obtained. The data obtained from these measurements must then be post-processed to determine true RMS average power levels. The post-processing of the data can be performed manually or with the aid of appropriate software.

(4) On any frequency or frequencies below or equal to 960 MHz, the field strength shall be measured with equipment employing a CISPR quasi-peak detector function and related measurement bandwidths, unless otherwise specified.

(5) In the frequency bands 1164-1240 MHz and 1559-1610 MHz, average radiated field strength measurements shall be made with a resolution bandwidth of no less than 1 kHz, using techniques as described previously for determining true RMS average power levels.

(6) Peak radiated emission measurements shall be made using a spectrum analyzer with a 3 MHz resolution bandwidth and no less than a 3 MHz video bandwidth. The analyzer should be used in a maximum-hold trace mode. The peak power level expressed in a 3 MHz bandwidth and the frequency at which this level was measured shall be reported in the application for certification. A different resolution bandwidth between 1 MHz and 50 MHz may be employed with appropriate changes to the standard. If a resolution bandwidth greater than 3 MHz is employed, a detailed description of the test procedure, calibration of the test setup, and the instrumentation employed in the testing must be submitted to the Commission. It is recommended that measurements using a resolution bandwidth greater than 3 MHz be coordinated with the Commission's laboratory staff in advance of the submission for certification.

(7) Field strength measurements may be performed without the use of a ground plane; however, a factor of 4.7 dB must be added to the measurement results thus obtained.

(8) To the extent practicable, the device under test should be measured at the distance specified in the appropriate rule section. However, in order to obtain an adequate signal-to-noise ratio in the measurement system, radiated measurements may have to be made at distances less than specified. In these cases, measurements may be performed at a distance other than what is specified, provided: measurements are not made in the near field of the measurement or device under test antenna, except where it can be shown that near field measurements are appropriate due to the characteristics of the device; and, it can be demonstrated that the signal levels necessitated a measurement at the distance employed in order to be accurately detected by the measurement equipment.

(9) To the maximum extent possible, field strength measurements should be performed with the equipment under test positioned as it is intended to be used in actual operating conditions.

(10) Radiated field strength measurements must be made using the antenna to be employed with the UWB device under test. The measurement antenna must be sufficiently broad band to cover the frequency range of the measurements, and the use of multiple measurement antennas may be required. All measurement antennas used must be accurately calibrated and must demonstrate low phase dispersion over the frequency range of measurement. The orientation of the measurement antenna shall be varied to determine the polarization that maximizes the measured field strength.

(11) The spectrum to be investigated should include at least the fundamental emission and the secondary lobe regardless of the center frequency. In order to accomplish this, the frequency spectrum shall be investigated from the lowest frequency generated within the device, without going below 9 kHz, up to the frequency range shown in Section 15.33(a) of the FCC rules or up to an upper frequency defined by adding three divided by the pulse width in seconds to the center frequency in Hz, whichever is greater. The frequency range in Section 15.33(a) is based on the center frequency unless a higher frequency, *e.g.*, a carrier frequency, is generated within the device. There is no requirement to measure emissions beyond 40 GHz provided the center frequency is less than 10 GHz; beyond 100 GHz if the center frequency is at or above 10 GHz and below 30 GHz; or beyond 200 GHz if the center frequency is at or above 30 GHz.

SEPARATE STATEMENT OF
COMMISSIONER MICHAEL J. COPPS

February 14, 2002

RE: Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems (ET Docket No. 98-153)

I believe that ultra-wideband ("UWB") technologies are destined to play a significant role across America's communications landscape. UWB devices will save firefighters' and policemen's lives, prevent automobile accidents, assist search-and-rescue crews in seeing through the rubble of disaster sites, enable broadband connections between our home electronics, and allow exciting new forms of communications in the years ahead. Indeed, the U.S. Government already uses UWB extensively to make our soldiers, airport runways, and highway bridges safer, and so much more is on the horizon.

But opinion differs greatly on the interference effect of the widespread use of UWB technologies by the public. If interference does occur, it could conceivably affect critical government and non-government spectrum users. Our national defense and several safety-of-life systems depend on bands that have the potential to be impacted by UWB devices.

Because the effects of widespread use of UWB are not yet fully known, and interference could impact critical spectrum users, I will support, albeit somewhat reluctantly, the ultra-conservative ultra-wideband step we take today. The limits we place on UWB are designed to reduce the interference risks associated with the technology to levels far, far below those placed on technologies that place energy into narrower portions of the spectrum. These limits are intentionally at the extreme end of what FCC engineers – the best spectrum engineers in the country – believe necessary. They were agreed to because of the unique and novel impact of this technology, and should not be taken as precedent for any other interference dispute – involving other Part 15 devices, government bands, or other new technologies.

I strongly support the Commission's decision to initiate a further NPRM within 6 to 12 months. My hope is that we can phase in this exciting new technology with some sense of urgency, proceeding through the conduct of expeditious step-by-step authorizations from the Commission for applications that are waiting in line. We owe it to our citizens and our businesses to determine, just as quickly as we prudently can, whether we can loosen the ultra-conservative restrictions we put in place today. So I urge all parties, especially our government colleagues, to start collecting data immediately so we can have as much data as possible, including information about their own use of UWB and how UWB effects their other uses of the spectrum, in a timely manner.

Delay, even when advisable, still has costs. If we find that our rules are too restrictive and we fail to correct them promptly, the price may be that the United States loses its leadership role in ultra-wideband. The technology could easily move overseas, where, I wager, would-be competitors are only too eager to get a step ahead of the USA. Let's be cognizant, too, of the need to proceed so as to inflict minimal harm on U.S. commercial interests. Some companies may be seriously inhibited by the limitations being announced. We should not expect that they can afford to stand patiently by while testing and approval proceeds at glacial pace. I hope that all of us, whether in government or the private sector, will approach our nation's deployment of ultra-wideband with the sense of urgency that it so clearly merits.

Finally, I want to welcome Ed Thomas to the FCC. He started with ultra-wideband – a trial by fire! I look forward to working with you. I also want to thank Julie Knapp and the whole OET team for their dedication and hard work on this item. Lots of weekends and late nights went into this Order. Thank you.

SEPARATE STATEMENT OF COMMISSIONER
KEVIN J. MARTIN

RE: Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, First Report and Order (ET Docket No. 98-153).

Spectrum management decisions are always complex and challenging. In an environment where the amount of unencumbered spectrum is decreasing while demand continues to grow, it is even more critical we make interference and sharing decisions that do not waste this precious natural resource. Inevitably, we will depend more and more on sharing the spectrum currently available to avoid such waste. Sharing decisions are made particularly difficult in the context of the "fiefdom" mentality that seems to characterize players who fervently guard their spectrum "turf," regardless of whether additional use can be accommodated. Unfortunately, the result is often unrealized potential that can never be recaptured.

I am excited that ultrawideband technology, which operates at powers 10,000 times lower than PCS handsets, will allow us to take sharing to new levels, and help avoid such waste. These sophisticated applications can potentially co-exist with spectrum users in any frequency, while promising a host of exciting military, public safety, medical and consumer uses. Firefighters, police officers and emergency personnel can make use of this technology to detect and image objects that are behind walls, buried underground or even inside the human body. Automotive applications such as collision avoidance and improved airbag mechanisms will have a direct consumer safety impact. Consumers also stand to benefit from enhanced laptops, phones, video recorders, and personal digital assistants that can wirelessly send and receive streams of digital video, audio and data.

Most importantly, ultrawideband challenges the notion that use of particular frequencies or bands is necessarily mutually exclusive. In defiance of our traditional allocation paradigm that often forces us to pick "winners and losers" in the face of competing demands, this technology seems to allow more winners all around.

I am disappointed that we did not, at this time, adopt more flexible limits that may have allowed for even more widespread use of this technology. I look forward to re-examining the technical parameters established in this order once we have more data that will address the interference concerns expressed by NTIA.

I am optimistic that future technological developments will provide the Commission with more such opportunities to insist on increasingly efficient use of current spectrum. Ultimately, the amount of available spectrum and our ability to use it is perhaps limited only by technology. Today, however, we must act rationally to make the best choices within the spectrum constraints that face us now.