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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.

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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.[2] The technical 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.[3] Part 15 intentional radiators, *i.e.*, radio transmitters, are permitted to operate under a set of general emission limits[4] or under provisions that allow higher emission levels in certain frequency bands.[5] Part 15 intentional radiators generally are not permitted to operate in certain sensitive[6] or safety-related frequency bands that are designated as restricted bands,[7] 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.[8] 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

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[2] 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.*

[3] 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.

[4] *See* 47 C.F.R. § 15.209.

[5] *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.

[6] 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.

[7] *See* 47 C.F.R. § 15.205.

[8] 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.

correction factor.[9] 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 rules.[10]

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.[11] 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.[12]

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.[13] 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.[14] Time Domain,[15] NTIA,[16] and the

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

10 *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.

11 *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.

12 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.

13 *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.

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

Department of Transportation[17] submitted GPS interference studies. Qualcomm submitted the PCS study.[18] In response to these studies, the Commission received 22 comments and 16 reply comments, as shown in Appendix D.[19]

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.[20]

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,

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(...continued from previous page)

15 *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.

16 *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.

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

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

19 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.

20 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.

allowing equipment mobility and high data rates to facilitate information sharing.[21] Fantasma noted similar applications for supplying simultaneous video, audio, and Internet use throughout homes, schools, libraries, medical and elder-care facilities, and businesses.[22] AT&T expressed interest in providing high throughput, short-range voice, data and video services on premises and campus environments.[23] 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.[24] Siemens Automotive ZF suggests using UWB technology for forward looking and lane change collision avoidance systems, backup warning systems, and airbag proximity measurements.[25] TDC noted the potential for using UWB devices in dozens of applications.[26]

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.[27] 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.[28] 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.[29]

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.[30] 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.[31] 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.[32] Alloy states that licensing is essential until UWB is found to be non-interfering.[33] MSSI,

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21 Intel reply comments at pg. 3.

22 Fantasma comments at pg. 2.

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

24 National Safe Skies Alliance comments at pg. 1.

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

26 TDC reply comments at pg. 4-19.

27 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.

28 Valeo Electronics comments at pg. 4.

29 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.

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

31 USGPSIC comments at pg. 29-30.

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

33 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.

while a proponent of UWB operation, states that GPRs are inappropriate for unlicensed operation because of their high power level requirements and limited market.[34]

16. Boeing requests that a new rule part be established under which UWB devices would be licensed.[35] 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.[36] 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.[37] 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.[38] 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).[39]

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."[40]

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

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

35 Boeing comments at pg. 13-14.

36 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.

37 Prof. Peha comments at pg. 6.

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

39 Kohler reply comments at pg. 5-6.

40 *See* 47 U.S.C. § 157(a) (1998).

of technical standards and operational restrictions will enable UWB devices to coexist with the authorized 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.[41] 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.[42] 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

[41] *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.

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

may consider whether more flexible standards are appropriate. Within their permitted bands of operation, 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,[43] 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.[44]

  - ***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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[43] 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.

[44] 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.[45] 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.[46] 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., $(f_H+f_L)/2$.[47] 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;[48] 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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45 *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.

46 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.

47 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.

48 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.[49] 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.[50]

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.[51] 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,[52] Kohler,[53] 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."[54] 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.[55] 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.[56]

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.[57] SME and Valeo, for example, requested a fractional bandwidth of around 0.17 and

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49 *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.

50 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.

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

52 Valeo comments at pg. 4.

53 Kohler comments at pg. 4.

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

55 AOPA comments at pg. 4.

56 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.

57 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.[58] Siemens requests that the fractional bandwidth be reduced to 0.15 with a 1 GHz upper bandwidth limit.[59] Bosch requests a fractional bandwidth of 0.15-0.20 and a minimum bandwidth of one to 1.5 gigahertz.[60] ANRO and Kohler request a fractional bandwidth of 0.20.[61] Daimler Chrysler requested an upper bandwidth limit of one gigahertz.[62]

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.[63] 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.[64] 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.[65]

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.[66] 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.[67] TDC also raised concerns that minimal information exists regarding the interference potential and applicable measurement procedures for stepped and swept frequency systems.[68] Endress Hauser and USGPSIC also expressed concerns about permitting the operations of linear sweep systems and chirped systems respectively.[69] 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.[70] CSSIP[71], Krohne[72], Siemens[73] and Valeo[74] specifically requested that stepped frequency or swept frequency systems be

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

59 Siemens comments are pg. 2.

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

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

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

63 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.

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

65 MSSI comments at pg. 15.

66 AOPA reply comments at pg. 10-11.

67 TDC comments at pg. 21.

68 TDC comments at pg. 25.

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

70 ARRL reply comments at pg. 9.

71 CSSIP comments at pg. 1.

72 Krohne comments at pg. 4.

73 Siemens comments at pg. 2.

74 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.[75] 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.[76] 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.[77]

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.[78] 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.[79] 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

[75] Bosch comments at pg. 3.

[76] XSI comments at pg. 8.

[77] AOPA comments at pg. 5.

[78] 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.

[79] 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.[80] 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.[81]

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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80 *See* 47 C.F.R. §15.31(c).

81 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.[82] 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.[83] 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;[84] 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

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82 Our concerns apply to all emissions within the −10 dB bandwidth of the UWB signal, not just at the center frequency.

83 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.

84 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.[85] 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.[86] 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.[87]

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85 ARRL comments at pg. 16.

86 ARINC & ATA comments at pg. 13.

87 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.[88] Sirius requested that GPRs operate exclusively below 2 GHz so as to avoid the DARS frequency band.[89] Aether Wire indicated that the use of frequencies below 1 GHz is optimal for transmitting through walls, pavement, debris, earth, water, snow, etc.[90] The Colorado School of Mines stated that, depending on soil conditions, GPR operation may be in the 100 MHz to 2 GHz region.[91] On the other hand, USGPSIC stated that there is no valid reason why GPRs can not operate above 3 GHz.[92]

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.[93] 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.[94] 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.[95] 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.[96] 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.[97] 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.[98] 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.[99] While Zircon stated that it does not oppose a contact switch in principle it needs an override mechanism to permit a few seconds of

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88 USGPSIC comments at pg. 23-24.

89 Sirius comments at pg. 15.

90 Aether Wire comments at pg. 6.

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

92 USGPSIC reply comments at pg. 10.

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

94 Alloy reply comments at pg. 14.

95 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.

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

97 TDC comments at pg. 11.

98 TDC comments at pg. 26.

99 Zircon comments at pg. 1 and 5.

calibration or to pass closely over uneven surfaces that might not always permit direct contact.[100] XM stated that it is unlikely that imaging systems would pose a significant threat of interference to DARS.[101]

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.[102] 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.[103] 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.[104] 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.[105] 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.[106] 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.[107]

46. Discussion. Based on the record and recommendations from NTIA,[108] 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[109] 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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100 Zircon reply comments at pg. 3.

101 XM reply comments at pg. 6, footnote 8.

102 Nortel comments at pg. 7.

103 Alloy reply comments at pg. 14-16.

104 USGPSIC comments at pg. 23-34.

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

106 TDC comments at pg. 26.

107 Zircon reply comments at pg. 3.

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

109 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.[110] Emission levels from this category

[110] 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[111] and fixed wireless access systems, AT&T on UNII operation, MCHI regarding MSS, and several others.[112] 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.[113] Sirius requested that UWB systems not be permitted to operate below 2.9 GHz, with a possible exception for GPRs and wall imaging systems.[114] 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.[115] MCHI requested that UWB devices, other than certain ground radars, not be permitted below 3 GHz.[116] 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.[117] ARRL requested that non-GPRs be located above 2.5 GHz.[118] XM requested that UWB devices be prohibited from operating below 3 GHz in order to provide protection to DARS.[119] Alloy wants all UWB devices, except GPRs, to operate above 2.7 GHz.[120] ARINC & ATA want UWB operation permitted only above 5.5 GHz and then only outside of the existing restricted bands.[121] ATA and several other industry

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111 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.

112 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.

113 Nortel comments at pg. 6.

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

115 Lockheed Martin comments at pg. 8.

116 MCHI comments at pg. 4.

117 Rockwell comments at pg. 5.

118 ARRL comments at pg. 17.

119 XM comments at pg. 1 and 10.

120 Alloy reply comments at pg. 16.

121 ARINC & ATA reply comments at pg. 7.

representatives stated later that UWB operation must be above 6 GHz.[122] American Trans Air stated that UWB devices should not be permitted to operate in any of the safety-of-life bands.[123] 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.[124]

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.[125] Fantasma indicated that it could operate above 2 GHz.[126] MSSI stated that UWB should initially be allowed above 3.1 GHz.[127] 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.[128] Daimler Chrysler wants to operate its vehicular radar systems with a center frequency at 24.125 GHz.[129]

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.[130] 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.[131] 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.[132] 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.[133] 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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122 ATA *et al ex parte* comments of 6/6/01, 5/18/01.

123 American Trans Air reply comments at pg. 2.

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

125 TDC comments at pg. 11.

126 Fantasma comments at pg. 3.

127 MSSI comments at pg. 2.

128 Valeo Electronics comments at pg. 7.

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

130 XM comments at pg. 10.

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

132 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*.

133 Aether Wire comments at pg. 7.