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March 12, 2001

HAND DELIVERED
Magalie R. Salas, Esq.
Secretary
Federal Communications Commission
445 12th Street, SW, Room TW-B204
Washington, D.C. 20554

Re: Ultra-Wideband Transmission Systems
ET Docket 98-153

Dear Ms. Salas:

Enclosed are the original and nine copies of the Reply Comments of XtremeSpectrum, Inc., for filing in the above-referenced docket.

Kindly date stamp and return the enclosed extra copy of the Comments.

If there are any questions about this filing, please call me at the number above.

Respectfully submitted,

Mitchell Lazarus
Counsel for XtremeSpectrum, Inc.

ML:deb

Enclosures

cc: Service List
John McCorkle, XtremeSpectrum, Inc.
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Before the
Federal Communications Commission
Washington DC 20554

In the Matter of	)	
	)	
Revision of Part 15 of the Commission's Rules	)	ET Docket 98-153
Regarding Ultra-Wideband Transmission	)	DA 01-171
Systems	)	

Reply Comments of XtremeSpectrum, Inc.

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March 12, 2001

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Revision of Part 15 of the Commission's Rules	)	ET Docket 98-153
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Systems	)	

Reply Comments of XtremeSpectrum, Inc.

XtremeSpectrum, Inc. hereby files these Reply Comments in response to Public Notice DA 01-171 in the above-captioned proceeding;[1] NTIA Special Publication 01-43;[2] and the first-round Comments filed in response to the Public Notice. ***IMPORTANT***: The attached *XtremeSpectrum, Inc. Technical Statement on NTIA Report* is not an appendix, but an integral part of these Reply Comments.

XtremeSpectrum conducts research in ultra-wideband communications systems, and intends to become a manufacturer once the Commission authorizes certification of such systems.

These comments address only communications systems. XtremeSpectrum takes no position on ultra-wideband radar applications.

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[1] *Comments Requested on Test Data Submitted by the National Telecommunications and Information Administration Regarding Potential Interference from Ultra-Wideband Transmission Systems*, DA 01-171 (released Jan. 24, 2001).

[2] Lawrence K. Brunson *et al.*, *Assessment of Compatibility Between Ultrawideband Devices and Selected Federal Systems*, NTIA Special Publication 01-43 (U.S. Dep't of Commerce January 2001) (NTIA Report). *See also* William A. Kissick, ed., *The Temporal and Spectral Characteristics of Ultrawideband Signals*, NTIA Report No. 01-383 (U.S. Dep't of Commerce January 2001).

A. Summary.

UWB opponents cite the NTIA Report as proving interference from UWB, or at least as justifying additional delays before UWB is authorized. UWB advocates instead point to alleged errors in the Report, and seek to dismiss its conclusions.

XtremeSpectrum offers a different reading. The Report shows how to design UWB systems that avoid harmful interference to other users. As it happens, the Report provides detailed, quantitative support for the technical rules that XtremeSpectrum proposed earlier in this proceeding. **Application of those proposed rules, together with factors NTIA acknowledged but did not apply, produces UWB emission levels below those required to meet NTIA's protection criteria for all types of victim receivers.**

Any other result would be surprising. If the UWB opponents' reading of the NTIA analysis were correct, we would expect ongoing, persistent interference from the tens of millions of unlicensed transmitters and digital devices already operating. Yet that does not occur; and the limits XtremeSpectrum proposes for UWB devices are lower than for other Part 15 equipment. The Commission can be fully confident that the showings of non-interference in the attachdd Statement, and summarized below, will be borne out in practice.

B. The NTIA Report Provides Guidance for Designing Non-Interfering UWB Systems.

XtremeSpectrum commends NTIA for its analysis. NTIA has provided the Commission, the UWB industry, and other users of the spectrum with an excellent starting point for assessing and preventing interference from UWB. Predicably, however, the NTIA Report has generated diametrically opposite reactions.

Opponents of UWB have seized on the Report as variously proving interference into other systems,[3] requiring draconian bandwidth limitations,[4] or justifying further delay in UWB deployment.[5]

Conversely, UWB proponents have criticized the Report as overly conservative and failing to apply real-world mitigation factors,[6] accumulating worst-case assumptions that overstate the interference risk,[7] or using an irrelevant test methodology.[8]

Both sets of views miss the Report's most important lesson. To be sure, opponents are doubtless correct that some hypothetical UWB implementations may cause some level of detectable impact on some types of receivers. And UWB advocates are correct that the NTIA Report did not (and could not have) considered in equal detail all types of UWB systems, all potential mitigating factors, and all types of potential victim receivers.

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[3] *See* Sprint (NTIA results confirm harmful interference into PCS systems); Lockheed Martin (NTIA results show potential for interference into fixed satellite earth stations).

[4] *See* Rockwell Collins (opposes operation below 5.15 GHz); Federal Law Enforcement Wireless Users Group (concerned about UWB operation below 3.1 GHz). Multispectral Solutions, a UWB manufacturer, also takes this position.

[5] *See* Aeronautical Radio (NTIA results confirm need for more testing); AT&T Wireless Services (NTIA results do not address ubiquitous commercial radio systems); Cingular (Commission should launch further notice of proposed rulemaking).

[6] *See* Time Domain.

[7] *See* Fantasma Networks.

[8] *See* 3Com.

But the NTIA Report has value far beyond fueling both sides of the debate. Properly read, it provides a possible means of resolving the debate: the Report suggests criteria for designing UWB systems that do not cause harmful interference to other users of the spectrum.

Earlier in the proceeding, XtremeSpectrum proposed a UWB emission mask and other constraints that are somewhat more conservative than those in the Commission's Notice.[9] At the time, XtremeSpectrum calculated that these constraints would eliminate harmful interference to other users, while still permitting commercially viable UWB devices. The NTIA Report now bears out those calculations. **Application of the constraints proposed by XtremeSpectrum, together with factors NTIA acknowledged but did not apply, produces UWB emission levels below those required to meet NTIA's protection criteria for all types of victim receivers.**

XtremeSpectrum proposed -- and the NTIA data support -- the following limitations on UWB communications systems:

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[9] *Compare* Reply Comments of XtremeSpectrum, Inc. at 3-5 (filed Oct. 27, 2000) *with Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, 15 FCC Rcd 12086 at para. 39 (2000).

1. ***Field strength*** (at boundaries, the lower limit applies):[10]

above 2.7 GHz:	500 uV/m at 3m ([11])
2-2.7 GHz:	6 dB below 500 uV/m
1.6-2 GHz:	12 dB below 500 uV/m
at and below 1.6 GHz:	18 dB below 500 uV/m.

2. ***Peak-to-average ratio***: 20 dB maximum across any bandwidth. This value is more conservative than those in the Commission's proposal, which range up to 60 dB.[12] (XtremeSpectrum's own implementation requires only 5 dB.) Experience may permit the peak-to-average limits to be relaxed further.

3. ***Indoor operation only***. The NTIA data confirm that this constraint on UWB communications systems is necessary for adequate protection to other users, at least initially.

---

[10] The attenuations listed were originally intended to protect the following services, among others:

2-2.7 GHz:	WCS and DARS at 2305-2360 MHz; MMDS at 2150-2162 & 2500-2690 MHz
1.6-2 GHz:	PCS at 1850-1990 MHz
below 1.6 GHz:	GPS at 1227.6, 1381.05, and 1575.42 MHz.

[11] This field strength corresponds to Sections 15.209 (maximum emissions in bands not otherwise specified) and 15.109 (Class B digital devices).

[12] The Commission proposed these limits:

(1) over a bandwidth of 50 MHz: 20 dB

(2) over the entire occupied bandwidth: [20 + 20log[10](-10 dB occupied bandwidth in Hertz/50 MHz)] dB, but not to exceed 60 dB. The 60 dB limit will control for any occupied bandwidth over 5 GHz.

Notice at para. 43.

C. The NTIA Analysis Did Not Apply Mitigating Factors.

The NTIA report acknowledged, but did not incorporate into its analyses, several factors that tend to reduce the interfering effect of UWB operations. As we show below, these factors taken together virtually eliminate the risk of UWB interference.

- ***Standard for harmful interference*.** The Commission's Rules prohibit a Part 15 user from causing "harmful interference,"[13] defined as "[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service . . . ."[14] NTIA instead applied protection criteria at which an inteferer would raise the receiver's theoretical noise floor by 0.5-1.0 dB. In most cases this is a much more sensitive standard than harmful interference.

  Nonetheless, the attached Statement shows that UWB systems can attain even NTIA's protection criteria, under the constraints set out above.

- ***Indoor operation*.** UWB communications systems will generally be operated indoors. XtremeSpectrum suggests a rule provision that limits their operation to indoors.[15] All of the victim receivers studied by NTIA are outdoors. NTIA agrees with us that exterior building walls add 9 dB attenuation up to about 3 GHz, and 12-14 dB at higher frequencies, but NTIA did not take this protection onto account.

- ***Outdoor propagation effects*.** Throughout its analysis, NTIA assumed either free-space propagation or a smooth-earth model. Neither of these is realistic. As shown in the attached Statement, the literature supports significant correction factors:

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13 47 C.F.R. Secs. 15.5(b), (c).

14 47 C.F.R. Sec. 2.1.

15 *Cf.* 47 C.F.R. Sec. 15.407(e) (limiting U-NII devices at 5.15-5.25 GHz to indoor operation).

irregular terrain	4.5-24.5 dB
foliage	10 dB
suburban (<1 km)	15 dB
suburban (>1 km)	20 dB
urban (< 1 km)	20 dB
urban (>1 km)	40 dB

- ***Multiple emitters***. NTIA's free-space and smooth-earth models overstate the aggregate effect of multiple emitters, because they overestimate the effect of more distant emitters. Application of the above propagation characteristics shows that all of the federal systems NTIA considered can meet their respective protection criteria with UWB densities of 1,000 emitters per km^2, and all but a few can tolerate 10,000 emitters per km^2. NTIA's analysis assumed densities as high as 10,000 emitters per km^2. In the 1300 km radius circle used to analyze the SARSAT uplink system, this totals more than 50 billion emitters -- a hopelessly unrealistic number. Densities on the order of a few hundred emitters per km^2 would be more realistic,[16] and these are safe for all federal systems.

  In addition, UWB transmitters operating as a system must coordinate their transmissions to avoid interfering with one another. In a wireless network, each transmitter must operate at well below 100% duty cycle, thus further reducing their aggregate effect.

The attached Statement, as summarized in the following section, shows that application of these factors (except aggregation), together with common-sense consideration about each type of victim receiver, results in UWB emission levels well below the NTIA protection criteria for all types of receivers. The aggregation analysis shows that the interference from multiple emitters does not accumulate.

16 *See* Fantasma Networks at 19-20.

D. A Closer Look at Victim Receivers Yields a Greater Certainty of Protection Against UWB Interference.

We consider in turn each type of victim receiver addressed in the NTIA Report, taking into account (1) the emission mask and other restrictions proposed by XtremeSpectrum; (2) the mitigating factors listed above; and (3) other real-world considerations that affect the various receivers. **This is only a summary. For details, please see the attached Statement, particularly Figures 6 and 7 on page 15.**

In each case, the analysis shows that the UWB signal falls below the protection levels specified by NTIA (and much farther below levels that would constitute harmful interference).

Any other result would be surprising. After all, the proposed UWB emission levels are extremely low. If the NTIA analysis were complete as it stands, we would expect ongoing interference from the tens of millions of unlicensed transmitters and digital devices already operating. Yet the Commission has never published a report of harmful interference from operation of any Part 15 device at the current limits. The Commission can be fully confident that the showings of non-interference below will be borne out in practice.

- ***Microwave Landing System (MLS)***. The aircraft-mounted MLS receiver is used during landing approaches. NTIA calculates that UWB emissions will exceed protection levels only within a range of 160 meters. But this can occur only during the final approach, when the aircraft altitude is under 100 meters. The aircraft is then necessarily over or very close to the airport, certainly within 1 km of the MLS transmitter. At that short range the MLS receiver is operating at a high signal-to-noise ratio, not near its noise floor, and the low-level UWB signal is completely irrelevant.

- ***Next Generation Weather Radar (NEXRAD)***. NTIA predicts that a UWB emitter at 2 meters height exceeds protection levels by 0.47 dB. The analysis did not account for the fact that UWB and NEXRAD signals are polarized linearly and circularly, respectively. Correcting for this discrepancy inserts 3 dB coupling loss, which brings UWB under the protection levels.

At 30 meters height, an interfering UWB emitter must be in a building (which adds another 12 dB attenuation) and must also be in the main lobe of the antenna. But the radar beam is only 16 meters wide at 1 km, and so would be blocked by the building. In practice these devices must be sited well away from structures that could obstruct the beam and expose occupants to hazardous RF radiation levels. As a result there is no realistic way to place a UWB device in the main antenna lobe.

- ***4 GHz Fixed Satellite Earth Station***. At 2 meters height, building penetration losses bring UWB emissions below NTIA protection levels.

  At 30 meters height, the analysis is similar to that for NEXRAD. If the earth station has a UWB emitter in its main lobe, UWB interference will be insignificant compared to blockage from the building in which the UWB device is operating.

- ***SARSAT Local User Terminal (LUT)***. These terminals access low-earth-orbit satellites. With building penetration losses and the emission mask proposed above, the UWB signal remains below NTIA protection levels at all satellite elevations down to within 2 degrees of the horizon. At the horizon, the UWB emitter theoretically exceeds protection levels by 0.7 dB, but in practice the LUT would be blocked by the structure housing the UWB source. In addition, both the UWB source and the LUT would be blocked by intervening foliage, buildings, and terrain.

- ***Maritime Radio-Navigation Radar***. If the radar is directed more than 2 degrees away from any landmass, the received UWB signal is lowered by at least 25 dB, bringing it far below the protection criterion. If the radar is directed at land, the amplitude of the return signal far exceeds any possible UWB emission.

- ***ARSR-4 (Long-Range Search Radar) and ASR-9 (Airport Surveillance Radar)***. At 2 meters height, building penetration losses and the emission mask proposed above bring emissions below NTIA protection levels. At 30 meters height, the NEXRAD analysis applies. UWB interference will be insignificant compared to blockage from the building that houses the UWB device.

- ***DMT Transponder (Ground Station)***. At heights of either 2 or 30 meters, building penetration losses and the emission mask proposed above bring emissions below NTIA protection levels.

CONCLUSION

Taken as a whole, the NTIA Report confirms that UWB systems operating under an appropriate emissions mask and an indoor-only restriction will not exceed the NTIA-specified protection criteria for any of the federal systems studied, much less cause harmful interference to those systems.

Respectfully submitted,

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March 12, 2001

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XtremeSpectrum, Inc. Technical Statement on NTIA Report

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March 12, 2001

Table of Contents

1. Introduction

The NTIA's Special Publication 01-43 documents analytical approaches and testing intended to assess the compatibility of UWB devices and selected federal telecommunications systems. There are a number of additional factors representing real-world conditions that are mentioned in the report and subsequent comments, but which are not included in the report's core analysis. When augmented with these factors, the analytical approaches and testing support the conclusion that UWB devices can coexist with current federal systems, much as digital consumer electronics devices do, and provide significant public benefits without imposing harmful effects on existing systems.

The Commission can stand on this body of evidence to confidently issue an initial set of rules that would allow near-term operation of UWB devices, while further investigation is made into relaxing the limits to provide additional services and benefits of UWB to consumers without doing undue harm to existing services.

As part of these comments, XtremeSpectrum is proposing a set of limits that are more restrictive than Section 15.209 emission limits in order to provide additional protection to devices operating at or below 2.7 GHz. Because it is not physically possible to have a sharp cut-off (i.e., a "brick-wall") at a single frequency, our suggested spectral mask was derived by looking at the worst case interference that might occur to existing licensed systems, and by taking into consideration that the slope of the cut-off should not be so steep as to cause ringing in potential UWB systems.

Many of the mitigating factors related to the aggregation of UWB emissions (such as building attenuation, indoor-to-outdoor wall attenuation, urban & forest path-loss models) are in fact well understood. The propagation of RF signals has been extensively studied and reported on in the literature in academic and commercial research that includes field measurements as well as modeling. The NTIA in its report identifies a few references to some of this work and presents specific values to quantify the effects. We offer additional references for propagation modeling and apply them in particular to each of the potential "victim" systems. The analysis must take into account the actual operational environment of each of the systems as well as that of the UWB devices. This includes, but is not limited to, the placement geometry, the duty factors, the fact that UWB communications systems will be used predominantly indoors over very short distances so that it is, essentially, self-limiting in the density of users, and the fact that power control will be used on UWB devices for both battery life and minimization of near-far problems. By using realistic models and operational scenarios, we provide quantitative support to show that for each system analyzed, the concerns reported by the NTIA are overstated.

2. The NTIA Analysis Approach and the Lack of any Distinction Between "Harmful Interference" and "Interaction"

The stated objective of the NTIA Special Publication 01-43 is to determine those "maximum EIRP and minimum separation distances that will ensure compatibility between UWB devices and other telecommunications services".[1]

[1] NTIA report, page 1-4.

As noted in many of the comments already submitted regarding the NTIA report, one fundamental issue undermining the analysis is that the NTIA did not attempt to distinguish between the potential for UWB devices to *interact* with federal telecommunications systems and the potential for UWB devices to actually cause *harmful interference*.[2] Instead, the NTIA established for each system a "protection criterion" that would be used as a basis to recommend limitations on UWB device emission levels. In many cases, these criteria were selected as the levels at which an interferer would cause a 0.5-1.0 dB rise in the theoretical noise floor of the receiver. In no case, however, was it demonstrated that exceeding any of these protection criteria would actually cause any system to function unacceptably in typical usage scenarios. In fact, many of the comments submitted[3] have documented numerous factors that would indicate that most of these protection criteria did not take into account usage factors (both those of UWB devices and those of the victim systems), and as a result were too restrictive.

Nonetheless, the core analysis approach, though neglecting important and acknowledged terms, was appropriately framed and computed. We applaud the effort made in this work. Indeed, many of the Comments also support the NTIA's computational format, and simply add into the NTIA's core analysis the neglected terms mentioned in the NTIA's report. In addition to these terms, XtremeSpectrum would like to add a few additional insights that will be described in a later section. Without the cumulative effect of all the missing terms included, however, *the analysis leads to misleading results*. Therefore, *the NTIA's conclusions cannot be supported*, even though the computational approach of the core analysis is correct.

3. Propagation Effects

In the analyses contained in the report, propagation effects are modeled either using free-space propagation (e.g. the MLS analysis) or using the smooth-earth Irregular Terrain Model (ITM), which is based on a model known in the literature as the Longley-Rice model. This model is used over a wide range of frequencies but has a fundamental limitation in that it does not model many environmental factors that are known to affect propagation. These shortcomings were well understood by the authors of the report. There was significant detail in the report about environmental factors that are well known to affect RF propagation, including specific correction factors that could be applied to account for each effect, taken from the literature. Some of these are listed here along with the corrections factors listed by the authors:[4]

1. Building penetration (9 dB for 960-3000 MHz, 12-14 dB for higher frequencies)
2. Foliage (10 dB)
3. Irregular terrain (4.5-24.5 dB)
4. Urban/Suburban environment (Urban: 20/40 dB for ranges under/over 1 km, Suburban: 15/30 db for ranges under/over 1 km)

All of these factors have been well studied, and there is much information in the literature to indicate what effect they might have on propagation losses. For example, a number of other studies have shown that losses through foliated areas, across irregular terrain, and in urban environments do not obey the typical free space predictions. The NTIA acknowledges this in 01-

[2] See, for example, Comments of 3Com Corporation Concerning NTIA's Compatibility Report or Comments of Time Domain Corporation

[3] See comments of Fantasma Networks, 3Com Corporation or Time Domain Corporation, for example.

[4] NTIA Report 01-43, section 5.6.

43 section 5.6, and even provides typical numbers for additional attenuation from a number of the effects. However, foliage effects are not enumerated. Tamir[5] did much of the early work in propagation in forested regions, but his work was generally restricted to frequencies at or below 200 MHz. More recently, others have extended models and performed experiments at higher frequencies. Ulaby, Whitt, and Dobson[6] showed approximately 9 dB of foliage loss through single canopy at a 40° incidence (60° grazing) angle at 1600 MHz. Tavakoli, Sarabandi, and Ulaby[7,8] have examined vegetation effects at 1.5 GHz and 4.75 GHz for shallow incidence angle and both horizontal and vertical incident waves. Their theory compares well with their measurements and shows average values of attenuation of 23.4 dB for vertical polarization, and 2.5 dB for horizontal polarization at 1.5 GHz. However, at 4.75 GHz, the horizontal polarization has less of an advantage with 17.7 dB of attenuation compared to 29 dB of attenuation in the vertical mode. Kovács, *et al.*[9] performed measurements and developed empirical path loss models for a number of frequency bands including 900 and 1900 MHz. They found a loss in addition to the propagation loss of $1/R^{4.3}$ in these frequency bands for typical Danish forested areas that include hills and valleys. Li *et al.*[10] derive an equation based on a number of propagation modes through the forest that accounts for frequency and foliage density for frequencies between 200 and 2000 MHz. The loss is:

$$L = 32.4 + 20 \log \mathit{distance(km)} + 20 \log \mathit{frequency(MHz)} + 20 \log (E_{air}/E_{total})$$

Where E_{air} and E_{total} are the electric fields with and without foliage present. The losses for even short distances quickly become large at the higher frequencies. Although there is a large variation in the losses specified by these various models and measurements, there is no doubt that foliage attenuation has a serious affect on the propagation of UWB signals. These losses increase with distance traveled (and thus by implication, the incident angle of the wave), with frequency, and with the density of the foliage. Even more recent were measurement made by Durgin, Rappaport and Xu[11] of losses due to foliage in at 5.85 GHz. They report on hundreds of measurements made in and around typical suburban houses. Their results show that propagation losses through individual trees can be as much as 11-13.5 db, depending on the size and type of tree.

In addition to foliage, there has been significant work done to understand the effects of RF propagation through buildings and structures. The authors of the report gave estimates for losses expected for devices operated indoors. In addition to the numbers given in the report for

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[5] T. Tamir, "Radio Wave Propagation long Mixed Paths in Forest Environments", IEEE Trans. Ant. Prop,. AP-25-4, July 1977, pp. 471-477

[6] F Ulaby, M. Whitt, and M. Dobson, "Measuring the Propagation Properties of a Forest Canopy Using a Polarimetric Scatterometer", IEEE Trans. Ant. Prop., 38-2, February 1990, pp. 251-258

[7] A. Tavakoli, K. Sarabandi, and F. Ulaby, "Horizontal Propagation Through Periodic Vegetation Canopies", IEEE Trans. Ant. Prop,. 38-7, July 1991, pp. 1014-1023

[8] K. Sarabandi, A. Tavakoli, and F. Ulaby, "Propagation in a Two-Dimensional Periodic Random Medium with Inhomogeneous Particle Distribution", IEEE Trans. Ant. Prop,. 40-10, October 1992, pp. 1175-1186

[9] I. Kovács, P. Eggers, K. Olsen, "Radio channel characterization for forest environments in the VHF and UHF frequency bands", IEEE Vehicular Tech. Conf.,Fall 1999, pp. 1397—1391.

[10] L-W Li, J-H Koh, T-S Yeo, M-S Leong, and P-S Kooi, "Analysis of Radiowave Propagation in a Four-Layered Anisotropic Forest Environment", *IEEE Trans. Geo. Remote Sens.*, **37-4**, July 1999, pp. 1967-1979

[11] Greg Durgin, *et al.*, "5.85-GHz Radio Path Loss and Penetration Loss Measurements In and Around Homes and Trees" IEEE Communications Letters, Vol. 2, No. 3, March 1998, pp 70-72

propagation from the inside of a building to the outside, the article by Durbin, *et al.* reported that the effect of having the transmitter and receiver on opposite sides of a typical house was an additional 24 dB of path loss.[12]

It is clear that there is substantial evidence documenting the attenuating effects of foliage and buildings, and there is no question that allowance for these effects should be included in any analysis that hopes to accurately predict performance in the real world, especially when considering aggregate scenarios, which we will discuss below.

4. Augmented Analysis

The conclusions of the report are based on analysis and simulations that were made for each of the systems addressed by the report. In the previous section we saw that many of the general assumptions about propagation may have led to incorrect conclusions. In this section we describe specific problems in the analysis of specific systems.

4.1 The Microwave Landing System (MLS)

In the MLS, the receiver is on an aircraft and it is used as the aircraft makes an approach for landing. The report indicates that main lobe of the antenna for the receiver looks down at a 20-30 degree angle below horizontal toward the ground in front of the aircraft.[13] The MLS is designed to enable precision landing and to provide guidance to an aircraft during landing out to a maximum range of 43 nautical miles.[14] At maximum range of 43 nautical miles, the airborne receiver would clearly not experience any UWB interference that could possibly exceed the protection threshold of −134 dBm. The analysis performed by NTIA shows a potential violation of the selected protection criterion at a range of 160 meters.[15] In order for a UWB device to be this close, however, the airplane would have to be flying at a maximum 80 meters altitude. The only time that an aircraft would fly this low is during a landing. But when the airplane is this low during a landing, the range between the airplane and the MLS beacon is less than 1 km. At this range, the MLS receiver is operating at a high signal to noise ratio, not at its noise floor. Assuming the receiver operates with an SNR of 13 dB at 43 nautical miles, then even at 1 km, which could be outside the airport, the receiver would operate at 38 dB higher signal to noise ratio.

<u>Conclusion:</u> Clearly it is impossible for a UWB device to cause harmful interference to an MLS system.

4.2 The Next Generation Weather Radar (NEXRAD)

Several factors were not included in the NTIA analysis of the NEXRAD weather radar. First, the protection criterion sets the limit on added interference at −120 dBm, which is 6 dB below the calculated NEXRAD receiver noise power of −114 dBm. This protection criterion simply sets the interference to prevent the signal-to-noise ratio from degrading by more than 1 dB based on the noise floor of the receiver, rather than considering harmful degradation relative to the practical operational limitations of a real radar installation with geometries governed by careful site planning. Also, the analysis did not account for 12 dB of building penetration loss and 3 dB of

[12] *Ibid.*
[13] NTIA Report 01-43, page A-18
[14] NTIA report 01-43, page A-16
[15] NTIA report, Table 1.

coupling loss between the UWB system's linear polarization and the NEXRAD's circular polarization. After incorporating these factors, the analysis shows that UWB devices can easily coexist with the NEXRAD weather radar.

For the cases where the UWB device was at 2 meters height, the report concludes that the UWB output must be below the specified –41.3 dBm/MHz by 0.4 dB. It is clear that simply including the polarization coupling loss of 3 dB, the 2 meter height case is resolved. By also adding indoor-to-outdoor building penetration loss of 12 dB (15 dB total loss), the 2 meter UWB case allows –26.7 dBm/MHz emissions, or 14.6 dB margin above Section 15.209 limits.

Next we consider the case where the UWB device is at a height of 30 meters above the ground, for example, on the 10th floor of a high-rise building. Using the NTIA analysis results shown in Figure 4-4, page 4-6, and moving the threshold 15 dB to account for the building loss and polarization loss, we find that the UWB device must be at least 1 km away from the receiver. Figure 1 illustrates this case and shows that the beam is only 16 meters in diameter at this range. The site planning for this weather radar to get it away from obstructions, as well as insure the safety of people by limiting their exposure to high RF fields essentially guarantees that UWB devices would not be operating at this distance in the main beam of the radar. In any case, the radar itself is blocked in this scenario and the harm to the system will be due to the blockage, not from UWB devices.

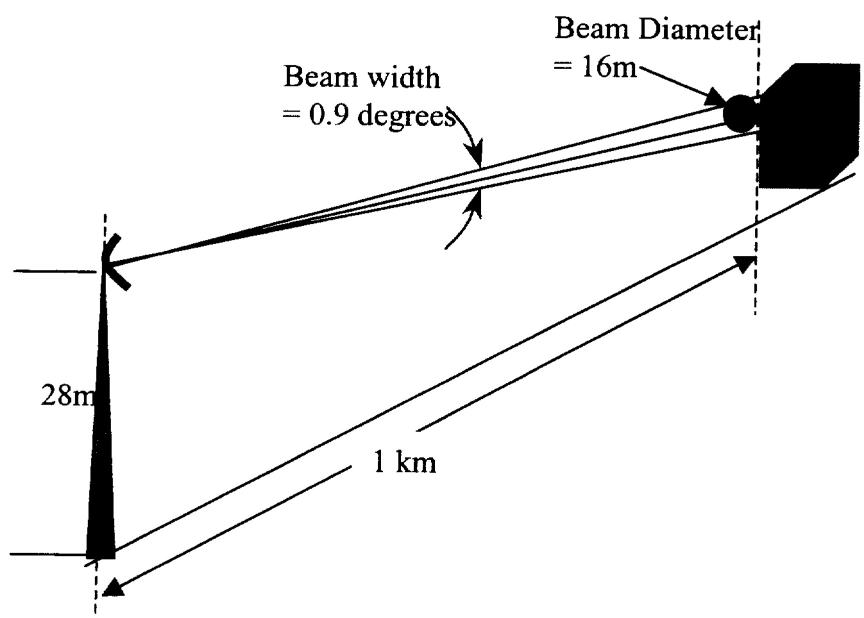

Figure 1: Illustration of NEXRAD radar beam impinging on a building 1 km away.

Conclusion: The analysis shows UWB devices will not cause harmful interference to the NEXRAD radar.

4.3 The 4 GHz FSS Earth Station

The same usage/geometry and building-loss factors that were not included in the NEXRAD radar were similarly omitted from the NTIA's analysis for the FSS system. So the analysis is also similar. The geometry shown in Figure 1 is also applicable here, where the beamwidth is 2 degrees, and the spot size is 17 meters in diameter at 500 m range. The highest level of interference indicated by the analysis in the report occurs when the UWB device is 30 m high and directly in the main beam of the satellite antenna at a horizontal range of approximately 300 meters. To see this, consider Figure 2, which shows a plot of EIRP versus range for 30 m UWB height (3 m FSS height) generated using the NTIA computer modeling software for the 4 GHz earth station (ES) receiver. After adding 12 dB of building penetration loss, the NTIA analysis shows that the range must be greater than 500 meters to be below the protection criteria. However, site planning is done to preclude the antenna being blocked by a building that close. This is particularly true when the receive antenna is set up for an unusually low elevation of only 5° above the horizon (typical elevation is more likely to be 15° or higher for most of the continental United States). Furthermore, the blockage would be significant in order to have a UWB device in the main beam of the 2° beamwidth antenna at 500m range, so the system would not work. At as little as 6.5° off the beam axis, the antenna gain is reduced by over 30 dB relative to the beam axis.[16]

At a UWB emitter height of 2 meters, the NTIA analysis showed that an EIRP of −51 dBm/MHz would match the protection criteria. However, inclusion of the 12 dB building penetration loss (not to mention any foliage or irregular terrain features) between the UWB device and the earth station receiver, would allow the UWB device to radiate −39 dBm/MHz. This is 2.3 dB greater than −41.3 dBm/MHz.

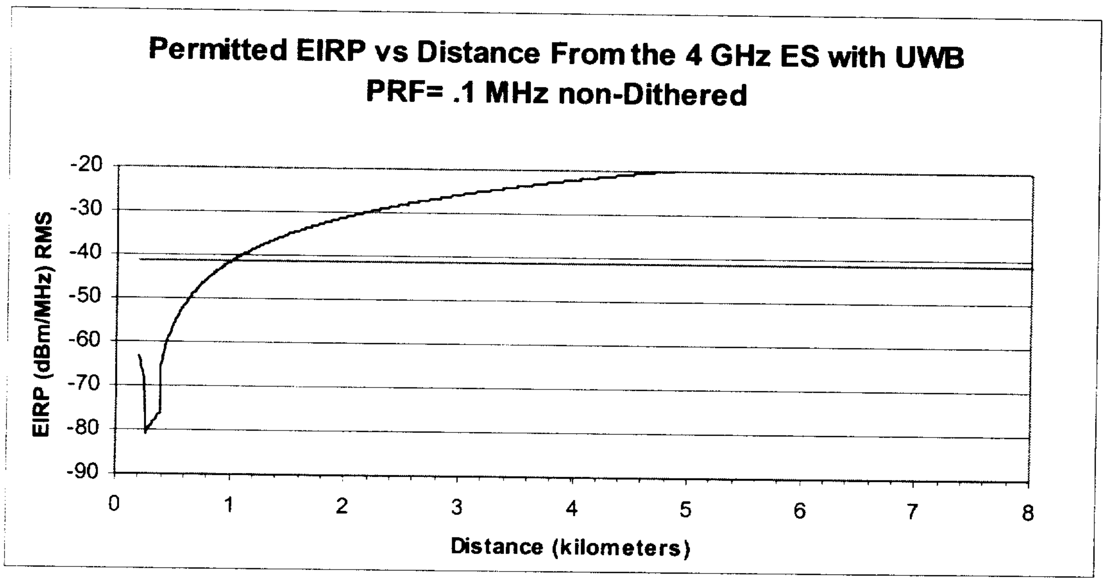

Figure 2: Plot of permitted EIRP versus separation distance generated by the NTIA-supplied ITM computer model for the 4 GHz FSS Earth Station with 5° elevation and 30 meter UWB emitter height.

Conclusion: The analysis shows UWB devices will not cause harmful interference to a 4 GHz FSS earth station.

4.4 SARSAT Local User Terminal (LUT)

The COSPAS-SARSAT specification[17] calls for being able to receive and process all satellite data for a satellite pass above 5° elevation angle, except where prevented by local obstructions.

[16] NTIA report, page A-22.
[17] COSPAS-SARSAT specification, T.002, Issue 3 - Revision 1 , October 1999

COSPAS-SARSAT[18] satellites in low earth orbit (LEO) have a 100-minute orbital period and typically transit the sky in about 15 minutes. When the antenna is elevated above 2°, the gain of the antenna will be lower in the direction of the UWB source. If we consider simulation results for a LUT with antenna elevation of 5° (shown in Table 1 and Figure 3), we see that the maximum UWB EIRP is significantly higher than reported in the original NTIA results.[19]

non-Dithered

PRF (MHz)	Av BWCF (dB)	Max UWB EIRP (dBm/MHz)	delta ref lvl (dB)
0.001	-1.0	-58.3	-17.0
0.01	-1.0	-58.3	-17.0
0.1	-1.0	-58.3	-17.0
1	0.0	-59.3	-18.0
10	0.0	-59.3	-18.0
100	0.0	-59.3	-18.0
500	0.0	-59.3	-18.0

Dithered

PRF (MHz)	Av BWCF (dB)	Max UWB EIRP (dBm/MHz)	delta ref lvl (dB)
0.001	-1.0	-58.3	-17.0
0.01	-1.0	-58.3	-17.0
0.1	-1.0	-58.3	-17.0
1	-1.0	-58.3	-17.0
10	-1.0	-58.3	-17.0
100	-1.0	-58.3	-17.0
500	-1.0	-58.3	-17.0

Table 1: Results of simulation for SARSAT LUT with elevation angle of 5°.

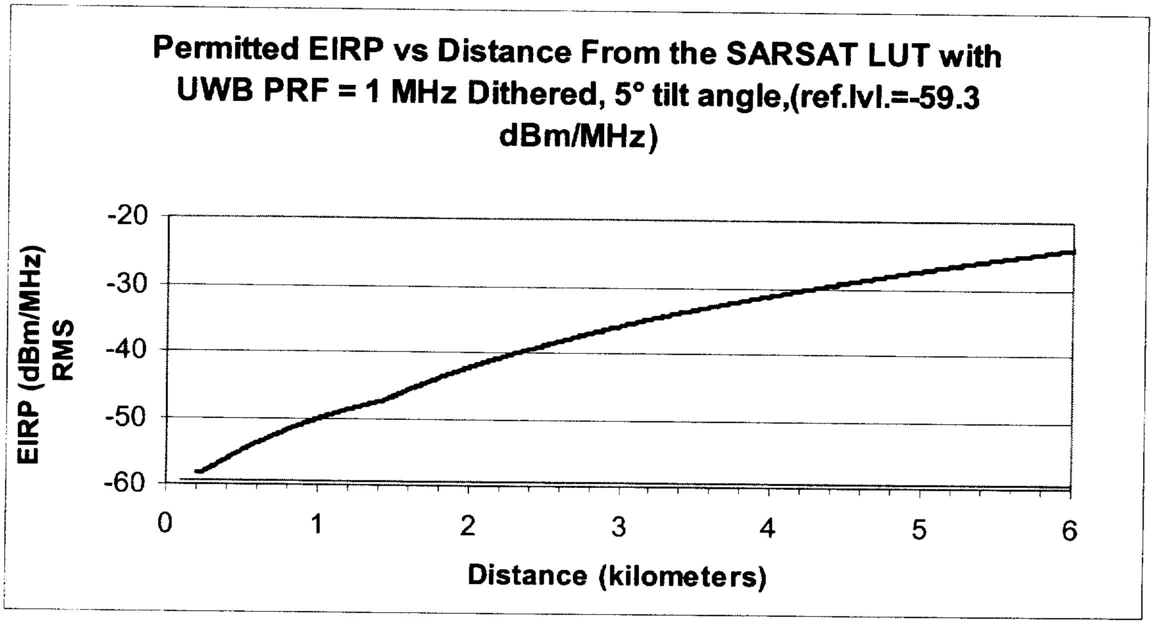

Figure 3: Results of simulation for SARSAT LUT with elevation angle of 5° (Note, the reference level indicated in this plot, -59.3 dBm/MHz, is based on the proposed spectral mask detailed below).

At greater elevation angles than 5°, there will be even more margin. Even in the cases where the satellite is tracked all the way to 2°, the addition of 9 dB building loss will provide protection to the LUT.

[18] COSPAS-SARSAT system introduction, G.003, Issue 5 - Revision 1, October 1999
[19] NTIA report 01-43, Table 1.

Conclusion: With the suggested spectral masking plus building losses, the LUT is protected to elevations as low as 2° above the horizon. At the horizon there is a 0.7 dB excess above the protection threshold, but at this point of 0° elevation the LUT would be blocked by the location in which the interference source resides or by intervening foliage/terrain features.

4.5 *Maritime Radio-Navigation Radar*

The basic problem with the analysis of this system is that operational realities make the simple noise-floor analysis meaningless. The information in appendix A.12 does not list the expected range performance. We have found that the Furuno FAR-2865SW S-Band Radar seems to meet the general characteristics listed in the appendix, and was chosen for this evaluation. Data from the manufacturer indicates that it is a 30 kW peak power, S-band radar with a 12 foot antenna that is 1.9° in azimuth and 25° in elevation. The noise figure is 4 dB, the pulse width ranges from 0.08–1.2μS, and the PRF ranges from 500–2200 PPS. Maximum range is listed as 160 km. Antenna sidelobes are 25 dB down within ±10° of boresite, and 30 dB beyond 10°.

There are two cases to consider, pointed at land, or not pointed at land. If the radar is pointing more than 2° off a landmass on which UWB emitters are situated, then the UWB impact is lowered by 25 dB. Therefore, the UWB device operates 10-16 dB below the protection criterion. This lower antenna gain is more than sufficient to compensate for the 9-15 dB levels by which the protection criterion threshold was exceeded in the original NTIA analysis.[20]

The radar range equation shows that radars work in the $1/R^4$ regime. That means that a target that is minimally detectable at 160 km is 12 dB stronger at 80 km, 24 dB stronger at 40 km, 36 dB stronger at 20 km, 48 dB stronger at 10 km, 60 dB stronger at 5 km, 72 dB stronger at 2.5 km, and 84 dB stronger at 1.25 km. Well before the ship reaches the indicated 1.2 km separation distance from the UWB source, the target amplitudes will be such as to overcome any noise floor issue.

Conclusion: When the radar is directed away from any landmass (and therefore UWB interferers), the lower antenna gain prevents any interference from UWB devices. When directed at the land, the amplitude of the return signal makes the UWB emitter impact on the noise floor irrelevant. UWB devices will not have any harmful effect on these radio-navigation radars.

4.6 *ARSR-4 and ASR-9*

The ARSR-4 is a long-range search radar and is subject to many of the same considerations as the NEXRAD system. As in the case of the NEXRAD, a UWB device is unlikely to be located in the main beam of this antenna. For a UWB emitter at 2 meters height, the NTIA analysis indicates that protection criterion thresholds would be exceed by approximately 20 dB. Adding 9 dB of path loss caused by indoor-to-outdoor propagation and applying the proposed spectral mask at -18dB is sufficient to ensure that the UWB emission levels would not exceed the protection criterion for this system.

For the ASR-9 airport surveillance radar, the NTIA report indicates that protection criterion thresholds would be exceed by 2.8-4.6 dB. Adding 9 dB of path loss caused by indoor-to-outdoor propagation for a device at 2 meters height is sufficient to ensure that the UWB emission levels

[20] NTIA report 01-43, Tables 4-52 and 4-53, page 4-63.

below the Section 15.209 limits will not cause interference that exceeds the protection criterion for this system.

4.7 DME Transponder (Ground Station)

There is some confusion in reading and interpreting the DME Transponder table (NTIA 01-43, page A-19) and the associated interference criteria (page A-20). The sensitivity to meet the 70% reply efficiency would seem to be the level that needs protection, rather than the noise floor. Nonetheless, the UWB limit is set 10 dB below the noise floor to provide protection to 0.5 dB noise floor increase, and an additional 6 dB of protection is added beyond that. This appears to be an overly restrictive criterion.

Using our proposed spectral mask, the UWB average power will be reduced to at least -59.3 dBm/MHz. Using the numbers in the NTIA spreadsheets the device still exceeds the protection criterion by 3.9 dB for the case when the UWB source is at 2 meters, and the required protection distance is 35 meters. (See charts and plots below). The addition of building loss (9 dB at these frequencies) will bring the UWB emitter to 5.1 dB below the interference threshold.

non-Dithered

PRF (MHz)	Av BWCF (dB)	Max UWB EIRP (dBm/MHz)	delta ref lvl (dB)
0.001	-1.0	-63.2	-3.9
0.01	-1.0	-63.2	-3.9
0.1	-1.0	-63.2	-3.9
1	0.0	-64.2	-4.9
10	0.0	-64.2	-4.9
100	0.0	-64.2	-4.9
500	0.0	-64.2	-4.9

Dithered

PRF (MHz)	Av BWCF (dB)	Max UWB EIRP (dBm/MHz)	delta ref lvl (dB)
0.001	-1.0	-63.2	-3.9
0.01	-1.0	-63.2	-3.9
0.1	-1.0	-63.2	-3.9
1	-1.0	-63.2	-3.9
10	-1.0	-63.2	-3.9
100	-1.0	-63.2	-3.9
500	-1.0	-63.2	-3.9

Table 2: Simulation results for 2 meter UWB source height.

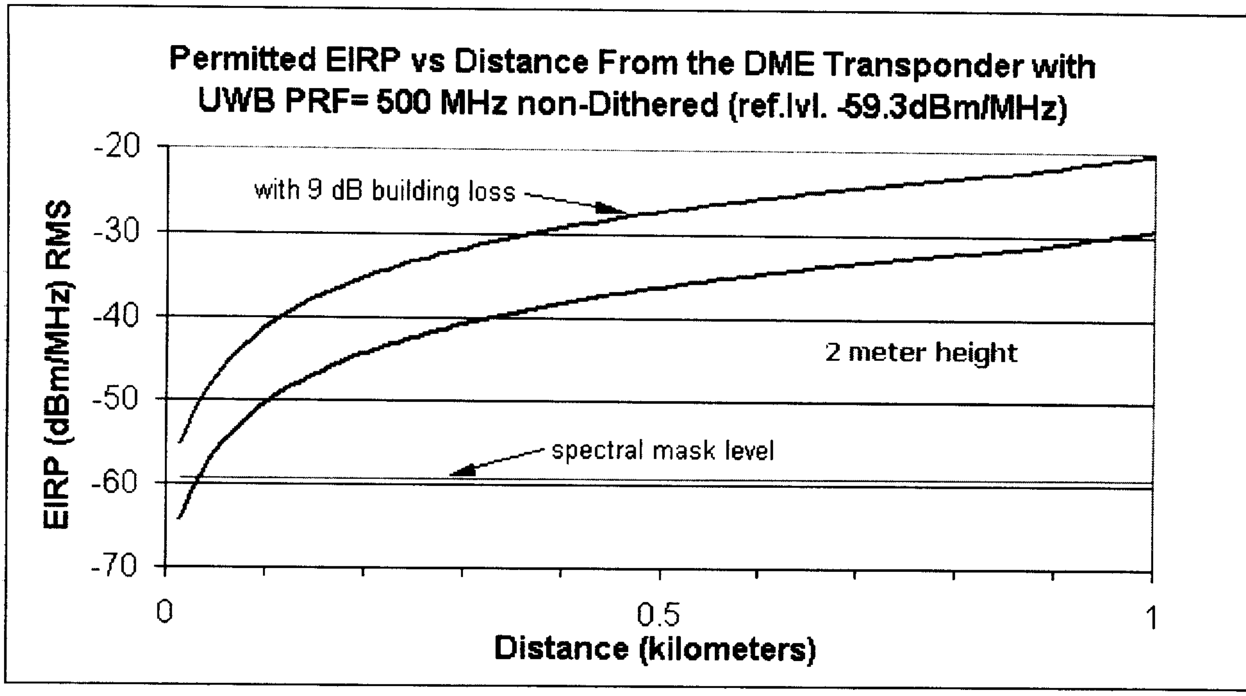

Figure 4: Simulation results for 2 meter UWB source height (Note, the reference level indicated in this plot, -59.3 dBm/MHz, is based on the proposed spectral mask detailed below).

In the case where the UWB emitter is at 30 meters, and the proposed spectral mask is again applied, there is no problem, and in fact there is 3 dB of margin as can be seen in the charts and plot below.

non-Dithered

PRF (MHz)	Av BWCF (dB)	Max UWB EIRP (dBm/MHz)	delta ref lvl (dB)
0.001	-1.0	-56.3	3.0
0.01	-1.0	-56.3	3.0
0.1	-1.0	-56.3	3.0
1	0.0	-57.3	2.0
10	0.0	-57.3	2.0
100	0.0	-57.3	2.0
500	0.0	-57.3	2.0

Dithered

PRF (MHz)	Av BWCF (dB)	Max UWB EIRP (dBm/MHz)	delta ref lvl (dB)
0.001	-1.0	-56.3	3.0
0.01	-1.0	-56.3	3.0
0.1	-1.0	-56.3	3.0
1	-1.0	-56.3	3.0
10	-1.0	-56.3	3.0
100	-1.0	-56.3	3.0
500	-1.0	-56.3	3.0

Table 3: Simulation results for 30 meter UWB source height.

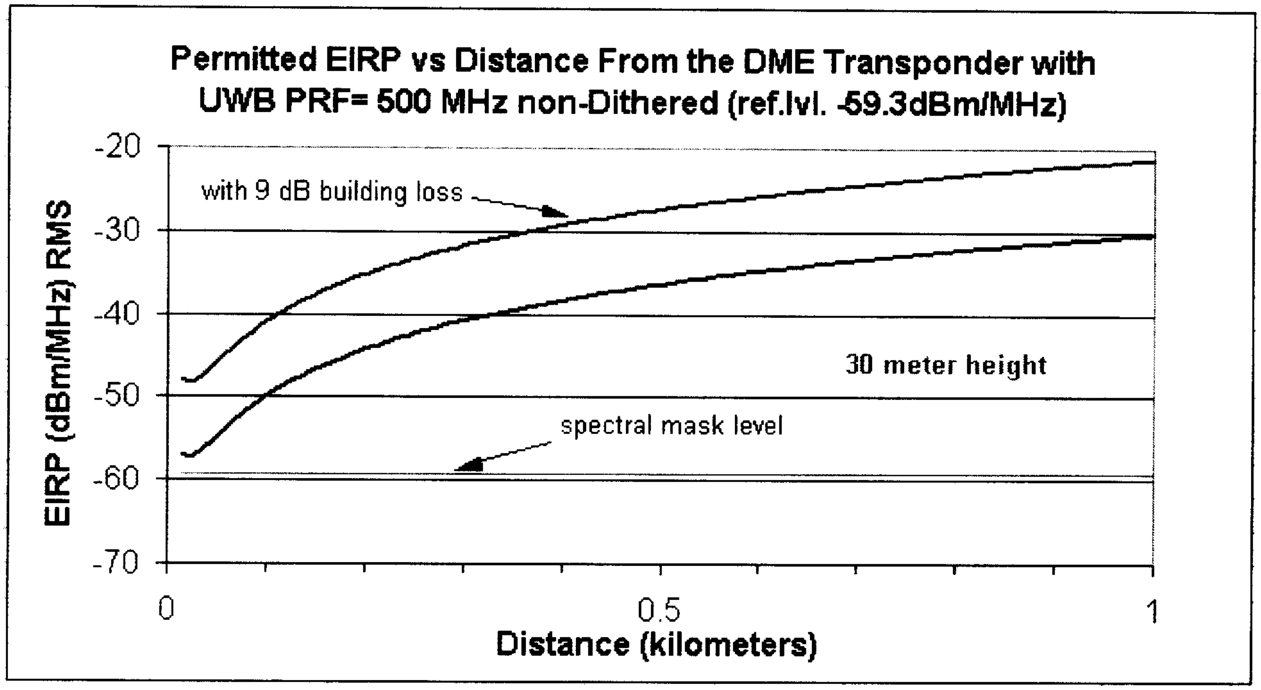

Figure 5: Simulation results for 30 meter UWB source height including 9 dB correction for in-building source (Note, the reference level indicated in this plot, -59.3 dBm/MHz, is based on the proposed spectral mask detailed below).

5. Aggregation of UWB Emitters

Sections 5.1 and 5.2 of the NTIA report extend its single-emitter analysis in order to ascertain the interference levels that would be expected from multiple UWB devices. This analysis is essentially a theoretical study, but does include extremely limited measurements made in an attempt to validate some of the assumptions of the theoretical study. In this section we describe several problems with the analysis for aggregate UWB emissions. In particular, the inadequacy of the propagation models used and the assumptions about UWB emitter density have led to unjustified conclusions. When more accurate models and assumptions are used, the same analyses show that UWB devices are unlikely to cause harmful interference in federal telecommunications systems, even when the effects of large numbers of active devices are considered.

5.1 Realistic UWB Emitter Densities

One of the fundamental differences between UWB devices and narrowband RF devices is that all UWB devices share a single RF channel. This fact leads to inherent limits on the density of active device in any small physical location. Because UWB devices can interfere with *each other* as well as non-UWB RF systems, closely situated devices must coordinate transmissions or suffer interference levels that would prevent effective operation.

Wireless networks based on UWB technology can be developed, but their design will certainly include provisions to allow closely situated devices to share the common RF channel. Multiple access protocols will be used, for example, to allow time multiplexing of transmissions for multiple access. This situation implies that there will be lower activity factors in regions of high device density, leading to an inherent limit on the density of actual UWB device emissions.

Simulation results are presented for densities as high as 10,000 active devices per square kilometer. At a density of 10,000 emitters per km^2, there would be over *50 billion* total emitters in the hypothetical 1300 km radius circle used to generate the curve for the SARSAT uplink system. A few hundreds of emitters per km^2, as noted by other comments on the report,[21] is a much more reasonable expected density.

5.2 Propagation

It has been demonstrated that free-space propagation models yield poor results in the prediction of propagation losses in mobile communications systems in terrestrial environments.[22] The report itself acknowledges this fact and even demonstrates that there is a significant discrepancy between the prediction of the smooth earth ITM model and the Okamura-Hata model. In Table 5-9 the two models are compared for a number of different cases and in every case the smooth earth ITM model predicted values for propagation loss that were too low by 25-40 dB. This is particularly significant since the Okamura-Hata model was specifically developed from measurements to provide an accurate model of real-world situations, addressing environmental factors such as uneven terrain and obstructions in cluttered urban or suburban areas. Although the Okamura-Hata model was developed for use at frequencies below 2 GHz, it is also commonly extrapolated to cover frequencies up to 3GHz and therefore would have been a more realistic choice for an analysis of interference potential from single and aggregated UWB devices.[22] The NTIA did an admirable job in section 5.6 of documenting factors that clearly affect propagation (e.g. uneven terrain, building penetration, foliage and other obstructions, etc.), yet none of these factors was applied to the aggregation analysis or taken into account in the conclusions and recommendations.

In fact, these other factors have such a large effect that it is unclear whether the results presented have any meaning in real-world situations where aggregations of UWB devices might exist. For example, if we consider the case of one expected application listed in Table 5-11, a radio LAN, we would find that the additional RF propagation factors listed by the NTIA could produce an adjustment to the path loss of 40 dB or more additional attenuation (20+ dB for propagation loss

[21] Comments by Fantasma Networks, Inc., dated Feb. 23, 2001.
[22] Theodore Rappaport, Wireless Communications: Principles and Practice, Prentice Hall, 1996.

in urban/suburban environment, 12-14 dB for building penetration, as well as potentially 10 dB or more for foliage, irregular terrain, or antenna directionality). In order to see the full picture of the effects of these additional propagation factors, Table 4 below lists the UWB applications identified in the NTIA report as well as any relevant aggregate interference mitigating factors. For each application, a correction factor is computed based on the values given in the NTIA report. These figures can then be used to understand the magnitude of the combined effects of the mitigating factors.

Application	Density/ Activity	Location	Mitigating Factors	Correction Factor
Automotive Applications	High	Any	Directional Antenna Foliage, Irregular Terrain	20-35 dB
RLANS	High	Urban/ Suburban	Urban/suburban Propagation Building Penetration Losses Foliage, Irregular Terrain	35-50 dB
Ground Penetrating Radars	Low	Any	Low Emitter Density/Activity Directional Antenna Foliage, Irregular Terrain	25-35 dB
Wall Imaging Devices	Low	Urban/ Suburban	Directional Antenna Urban/suburban Propagation Building Penetration Losses Low Emitter Density/Activity Foliage, Irregular Terrain	42-57 dB
Security Systems	High	Urban/ Suburban	Urban/suburban Propagation Building Penetration Losses Foliage, Irregular Terrain	35-50 dB
Manually-operated Radars	Low	Any	Directional Antenna Low Emitter Density/Activity Foliage, Irregular Terrain	25-35 dB
Consumer Applications	High	Urban/ Suburban	Urban/suburban Propagation Building Penetration Losses Foliage, Irregular Terrain	35-50 dB

Table 4: Path loss correction factors based on mitigating factors for anticipated UWB applications.

Such large corrections to the path loss values used to derive the results in Figures 5.5.1 through 5.5.16 would completely change the conclusions of the analysis. For example, if the aggregate interference seen by victim receivers drops by 40 dB, *none* of the 14 systems at 1 GHz or higher would exceed their respective protection criteria at emitter densities of less than 1000 emitters per km^2, and only a few (SARSAT LUT downlink, ARSR-4 and the DME Ground Transponder) at less than 10,000 emitters per km^2. These densities are clearly much higher than can be reasonably expected given the natural limitations of hundreds of devices per km^2 described above.

6. Recommended Spectral Mask for Near-Term Rules

The suggested spectral mask shown in Table 5 is based on providing additional protection to current federal and commercial spectrum users such as GPS, PCS, and MMDS, in the near term while further measurements of harmful interference are made to support possible relaxed spectral limits. At the same time, the suggested mask provides a gentle slope that is consistent with finite-time waveforms. A second-order Butterworth filter, for example, provides the steepest cutoff without ringing. A third-order Butterworth rings slightly and was used to obtain the "wedding cake" spectral mask for UWB devices. It is worth noting that a pulse with a shape matching the third derivative of a Gaussian, has a spectral content peaking at 5 GHz and falling roughly on the same spectral mask.

Frequency GHz	dB from 15.209	Example Systems
<2.7 GHz	–6 dB	MMDS
<2.0 GHz	–12 dB	PCS
<1.6 GHz	–18 dB	GPS

Table 5: Suggested spectral mask.

Freq	Butterworth	Gaussian
1.0000	-29.4866	-29.4305
1.6000	-17.3158	-17.9963
1.9000	-12.9808	-14.0655
2.7000	-5.1730	-6.8267

Table 6: Comparison of spectral response of 3rd Order Butterworth filter to 3rd Derivative of a Gaussian.

Figure 6 shows a plot of this spectral mask along with the emission levels shown in the NTIA's summary tables, corresponding to the EIRP that would match the prescribed "protection criterion." The left axis is calibrated to dBm/MHz, while the right axis is calibrated in dB relative to Section 15.209 emissions. Clearly, a much lower and more restrictive limit would be required to meet the levels shown. However, after factoring into the analysis the terms described above, (e.g. indoor propagation losses, indoor-to-outdoor losses, urban propagation losses, UWB antenna pattern and polarization effects, and victim antenna beamwidth and operational constraints) the radiation limits may be significantly relaxed, as is shown in Figure 7. This figure is identical to Figure 6, except the emission levels required to meet the NTIA's "protection criterion" were computed by incorporating the additional factors described.

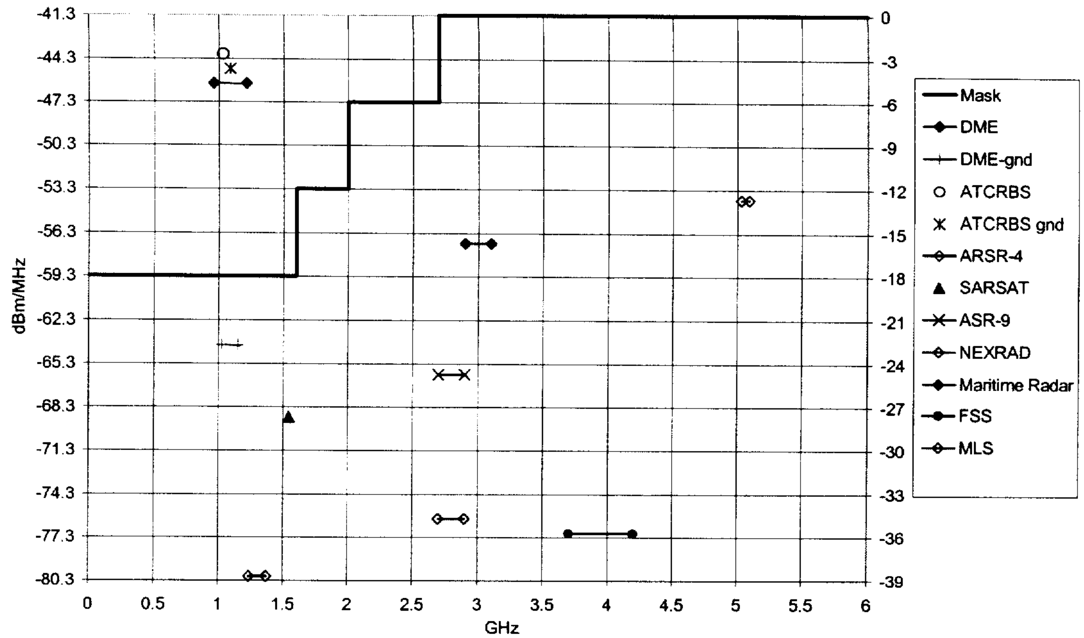

Figure 6: Suggested spectral mask and the emissions required to match NTIA's "protection criterion" results using the original calculation results from the NTIA report.

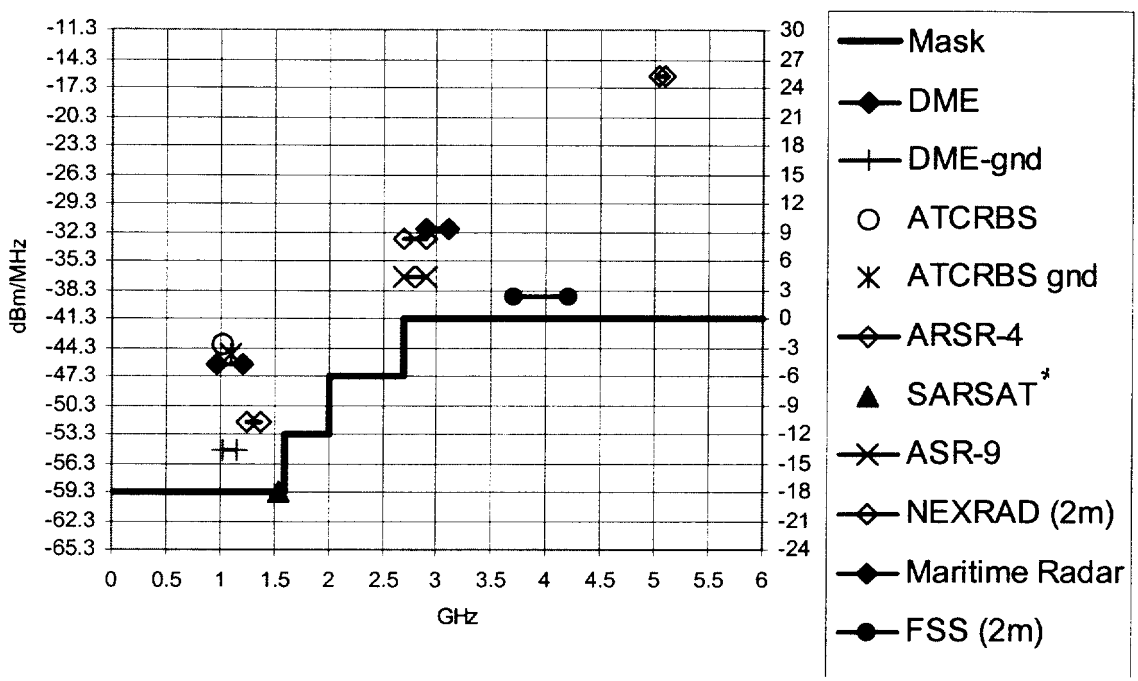

Figure 7: Suggested spectral mask and the emissions required to match NTIA's "protection criterion" using calculation that includes the additional factors described. *At or below 2° elevation- higher angles provide more protection.

7. Reply to Comment by MSSI

Comments filed on behalf of Multispectral Solutions, Inc. claim that low PRF systems actually cause *less* interference than high PRF systems. The Comment, contrary to the NTIA's analysis, our analysis, and the analysis of others,[23] suggests that high peak-to-average signals be allowed, and that low peak-to-average signals should be restricted.[24] The author includes simulation results and a short analysis in an attempt to demonstrate that a high PRF system is more likely to cause interference. There are, however, flaws in both the simulation and the analysis that were submitted in this Comment.

The author claims that, in terms of total interference power injected into a victim receiver, a 100 million pulse-per-second (Mpps) system is 10,000 times worse than a 1 Mpps system. A problem with both the simulation and the accompanying analysis is that they compare systems that have significantly different PRFs and yet equal power *per pulse* (i.e. equal peak power given equal pulse widths). Under such a comparison the signal from the 100 Mpps system would have 100 times higher average power than the 1 Mpps system. The NTIA analysis correctly compares systems by using the same power spectral density in a 1 MHz bandwidth, regardless of the PRF.

Additionally, in the appendix of the Reply, the author states that the effect of the pulse train on the receiver can be understood as the sum of the impulse responses of the receiver input filter to each of the pulses in the train. While this statement is true, the conclusion presented is not, because it was based on the assumption that there was no modulation (i.e. a UWB signal that is truly periodic and has a discrete line spectrum). If we instead consider a pulse train is modulated with data (modeled as random), as it would be in any communications system, the output voltage of the filter would not be N times as large (where N is the ratio PRF/B_{RF}), but would instead be a random-valued voltage signal with an expected value of zero. The NTIA report correctly analyses high peak-to-average waveform interaction with conventional radio systems, and the (amplitude probability distribution) APD of a receiver with various PRF's and pulse widths. The higher the PRF, the more signals appear like Gaussian distributed wideband noise in a victim receiver.

8. Summary

Our results agree with the general conclusion that UWB operation is feasible at levels equivalent to Part 15.209 limits at frequencies above 2.7 GHz.

We have shown that the recommendations in the NTIA report are far too restrictive due to simplifying assumptions used in the analysis such as:

- Simple theoretical models of propagation instead of current measurements-based models,
- Specific details concerning how victim systems operate and are used and sited,
- Effects of indoor usage restrictions on the UWB signal interference.

[23] See, for example, comments by Fantasma Networks, Inc., dated Feb. 23, 2001, pages 5-7.
[24] See Reply Comments of Multispectral Solutions, Inc.

The spectral mask suggested in our previous filing is fully supported by the analysis after it is augmented with the factors listed above. Therefore, the FCC can act with confidence to allow the operation of UWB devices with a spectral mask that provides adequate protection for all of the federal telecommunications studied in the NTIA Report 01-43, as well as comparable commercial systems. The spectral mask proposed in these comments would allow for UWB operations with spectral power density up to the equivalent of Section 15.209 emissions of –41.3 dbm/MHz at frequencies above 2.7 GHz, and tapering to lower limits as detailed in Table 5.

Respectfully submitted,

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