Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of Revision of Part 15 of the FCC's Rules Regarding Ultra-wideband Transmission Systems	ET Docket 98-153

Reply Comments of Time Domain Corporation

In Response to the Request for Comments on
Test Data Submitted by NTIA Regarding
Potential Interference to Selected Federal Systems
from Ultra-Wideband Transmission Systems

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Executive Summary

The NTIA Reports provide a foundation upon which regulations can be based. Indeed, the reports offer assurance that Ultra-Wideband ("UWB") can be implemented without undue risk of harmful interference and without unduly restricting the introduction of this new technology.

Time Domain Corporation ("TDC") and others in their opening comments analyzed the impact of numerous "real-world" mitigating and operational factors that were not reflected in NTIA's analysis. Taking these relevant real-world factors into account would provide between 40 and 60 dB of additional signal margin for UWB. In these reply comments, TDC shows that, for currently proposed UWB signal parameters, incorporating these factors would allow UWB equipment to operate safely at current Part 15 limits both above and below 3.1 GHz. In an Appendix, TDC uses NTIA's model and accompanying analysis to show that relaxation of the proposed peak-to-average ratio limit to 41dB is viable and assures flexibility for the design of UWB equipment.

The Commission's decisions on the authorization of UWB technology will not only impact the degree to which the beneficial uses of the technology can be realized. The choices could have far-reaching ramifications. Setting excessively restrictive power limits for UWB without sound justification will impede not only the development of UWB, but will set a bad precedent for a host of other spectrum-based technologies and services both for government and commercial users.

The Commission has structured this rulemaking into well-defined stages. The Commission used the NPRM to organize the dialogue around the issues that are relevant to defining rules to allow for the deployment of UWB equipment. Calls in the comments for a Further Notice of Proposed Rulemaking and further testing are nothing more than an attempt to delay this proceeding and delay introducing the benefits of UWB technology. The FCC expected that the testing stages would proceed apace and provide much-needed input. The agency's Office of Engineering and Technology staff has been closely monitoring the several testing programs, and its record of involvement illustrates that the Commission will have in its hands a full and solid record, which will be generated in response to multiple calls for public comment, upon which to base sound regulatory decisions.

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I. Introduction

TDC believes that the NTIA Reports provide useful information. However, on their face, the reports do not provide sufficient evidence that UWB devices operating at Part 15 levels will cause harmful interference or, for that matter, have any noticeable operational impact on any of the tested systems. NTIA quantified UWB interference potential by measuring the level at which UWB signal power exceeds "protection criteria." TDC explained in its opening comments that this bears little relation to the concept of *harmful interference,* as both the FCC and NTIA define that term. In order to understand fully NTIA's UWB compatibility assessment, the test results must be extended to incorporate a number of "real-world" mitigation factors – many of which are acknowledged by NTIA as relevant, but none of which are reflected in NTIA's conclusions.[1]

TDC is pleased that even the U.S. GPS Industry Council recognizes that "[t]he challenge is not to seek ways to debunk or bury UWB, but to harness its promise without unduly damaging the nation's IT economic engine."[2] With the countless benefits and innovative applications of UWB technology, there is no doubt that FCC authorization will further fuel the nation's information economy engine.

II. UWB Opponents Fail to Acknowledge the Impact of the Mitigation Factors

In its opening comments, TDC explained that in order to put the NTIA analysis into proper perspective, a minimum of 40 dB of additional margin must be incorporated into the conclusions. This significant amount of signal margin is based on the handful of mitigation factors that NTIA explicitly acknowledges as well as a collection of mitigation factors that NTIA does not mention. To comprehend fully the impact of the NTIA Report, it is critical that these mitigation factors be taken into account, for these reasons: (1) NTIA's model was based on

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[1] In fact, in Section V and in Appendix A of these Reply Comments, TDC uses the information presented by NTIA as a basis for recommending that the Commission authorize a maximum peak-to-average ratio of 41 dB.

[2] Comments of the U.S. GPS Industry Council (Feb. 23, 2001) ("GPSIC") at 9.

"ideal conditions,"[3] which do not represent reality, and (2) not one of these relevant factors is reflected in the conclusions made by NTIA.

As TDC explains in these Reply Comments, taking 40 to 60 dB of additional "real-world" loss into account is a key step towards removing the restrictions on UWB signals that are presented in the NTIA Report. Thus, NTIA's conclusion that operations above 3.1 GHz can be accomplished with fewer restrictions than operations below 3.1 GHz, as well as the sweeping conclusions drawn by several commenters[4] that UWB operations below 3.1 GHz must be prohibited, lack proper foundation.

Not surprisingly, none of the commenters who want to delay the introduction of UWB technology account for, or even mention, the critical impact of the mitigation factors. Quite surprisingly, however, these parties expect the FCC to accept claims that UWB causes harmful interference to licensed services when NTIA did not identify or quantify any "real-world"

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[3] NTIA Report at 5-25.

[4] *See, e.g.*, GPSIC at 9 (no UWB devices should be permitted to operate below 3.1 GHz and no UWB devices – licensed or unlicensed – should be allowed to operate in bands restricted for safety of life.); comments of Multispectral Solutions, Inc., ("MSSI") at 2 (arguing that NTIA demonstrated the potential for significant interference below 3.1 GHz); comments of National Association of Broadcasters (Feb. 23, 2001) at 3 (NTIA found that a UWB device operating at Part 15 levels would cause interference to almost every system tested and that multiple UWB devices operating below 3.1 GHz would cause interference to existing licensed services.); supplemental comments of Rockwell Collins at 4 ("it is likely these important aviation services would be disrupted"), and at 10 (undisputed evidence that UWB operations below 3.1 GHz will cause harmful interference to current licensees).

operational impact.[5] Experience has shown that the application of "real-world" technical and operational factors is key to efficient spectrum use, the introduction of new and innovative technologies, and the development of responsible policy decisions.

III. The NTIA Federal Systems Test Report Provides Adequate Information on Which to Base Regulatory Decisions.

A. A Further Notice of Proposed Rulemaking Is Not Necessary.

The Commission has structured this proceeding into well-defined stages. TDC believes that the Commission's approach has been extremely prescient. First, the FCC issued a Notice of Inquiry ("NOI") to gather basic information about UWB. Then, 21 months later in May 2000, the agency released its Notice of Proposed Rulemaking ("NPRM"). The Commission has used the NPRM to set the dialogue around the issues that are relevant to defining rules that would allow UWB equipment to be deployed in the most timely and least restrictive manner.

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[5] NTIA's results were based on a computer model that calculated UWB signal levels at particular distances and determined whether they exceeded particular protection criteria. AT&T Wireless Services, Inc. has the mistaken belief that NTIA's tests concentrated on harmful interference from UWB devices to government systems. *See* Comments of AT&T Wireless Services, Inc. (Feb. 23, 2001) at 2. Lockheed Martin also believes that NTIA has provided evidence of potentially harmful interference. *See* Comments of Lockheed Martin Corp. at 3. Lockheed Martin comments (at 2) that the NTIA tests seriously undermine the FCC's earlier conclusion of the feasibility of UWB operations above 2 GHz. Each of these parties is wrong, as demonstrated herein.

The Commission expected that the testing stages would proceed apace and provide the necessary input.[6]

In the NPRM, the agency explained that "various parties are planning experimental programs to study the interference potential of UWB devices."[7] The Commission also noted that its staff will be monitoring the progress of the tests and will request comments on the test results and analyses.[8] The FCC has been true to its word, as the Commission's Office of Engineering and Technology staff has been closely monitoring the testing programs. Moreover, in the Public Notice issued by the Commission requesting comment on the instant report, the FCC stated that it would issue subsequently a Public Notice seeking comment on the test data and analyses of UWB to GPS receivers.[9] This record of involvement by the Commission signals that the agency will continue in this oversight role as the testing progresses. Moreover, this illustrates that the Commission will have in its hands a solid and complete record – generated in response to multiple calls for public comment – upon which to base sound regulatory decisions. Accordingly, a Further Notice of Proposed Rulemaking is not necessary,

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[6] NTIA conducted extensive tests to quantify and measure the most pertinent characteristics of UWB signals. These include effects of UWB signal pulse repetition frequencies ("PRFs"), average power levels, peak power levels, similarity to white gaussian noise, the relationship between PRF and victim receiver bandwidth, as well as the characteristics of dithered and non dithered UWB signals.

[7] NPRM at ¶ 31.

[8] *See id.*

[9] *See* Comments Requested on Test Data Submitted by the National Telecommunications and Information Administration Regarding Potential Interference from Ultra-Wideband Transmission Systems (ET Docket No. 98-153), *Public Notice*, DA 01-171 (Jan. 24, 2001).

and calls in the comments for an FNPRM[10] and additional tests are nothing more than an attempt to delay this proceeding and delay introducing the benefits of UWB technology.[11]

In the NPRM, the FCC announced that it would seek comment on the results of the UWB compatibility tests. We are currently in the first stage of this test results comment period, as the FCC has requested comments on NTIA Federal Systems Test Report. On Friday, March 9, 2001, NTIA released its compatibility assessment of GPS and UWB operations. On March 9, 2001, Johns Hopkins University Applied Physics Laboratory submitted a report analyzing GPS and UWB operations based on testing conducted at the University of Texas Applied Research Laboratory. TDC expects the Commission to set comment and reply comments periods to solicit input on the interpretation of these reports as they pertain to the NPRM as it has done with the instant report. This sound process will provide the Commission with a substantial record on which to base regulatory decisions.

B. Part 15 Is the Proper Place for UWB Technology.

The commenters seeking licensing or other extraordinary regulatory burdens for UWB[12] challenge the core of the pragmatic Part 15 approach.[13] As TDC has explained throughout this

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[10] *See* Comments of Lockheed Martin at 5 (FNPRM should be issued following the conclusion of all interference tests to ensure fair opportunity for public comment). GPSIC at 8 (FNPRM should be released before adopting any rules); comments of ARINC and ATA (Feb. 21, 2001) at 3 (NTIA's conclusions are preliminary; NTIA emphasized that further measurements and analysis are needed before authorizing UWB)

[11] Moreover, any party wishing to supplement an earlier filing or provide new information is free to do so under the Commission's well-defined *ex parte* rules.

proceeding, the successful history of Part 15 and the similarities of earlier decisions (and related arguments made in opposition) to the present situation provide the basis for authorizing UWB operations using levels heretofore unusable for heretofore unheard of live-saving and critical communications applications. TDC highlights these points below.

Over its 50-year evolution, Part 15 has led to the development and market entry of countless new and innovative products. It has spurred competition, and it has lowered consumer costs while opening new options for security, convenience, leisure, learning and business. Billions of useful Part 15 devices and millions of communications products (such as wireless handsets) that emit low-level radio "noise" are part of our every day lives. There are over 100 devices capable of emitting RF energy in the average home and countless more in the typical business complex. As the Commission has reported, "at any time of day most people are within a few meters of consumer products that use low-power, non-licensed transmitters"[14]

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[12] *See* Cingular Wireless LLC (Feb. 23, 2001) at 2, 3; comments of Lockheed Martin (Feb. 23, 2001) at 4; comments of Sirius Satellite Radio, Inc. (Feb. 23, 2001) at 2, 4.

[13] The U.S. GPS Industry Council ("GPSIC") has stated that authorization of UWB on an unlicensed basis gives the FCC no control or recourse if harmful interference occurs. *See* Comments of U.S. GPS Industry Council (Feb. 23, 2001) at 6. GPSIC is wrong. This statement presumes that the Commission will make a mistake in this rulemaking proceeding. The Commission and GPSIC can find solace in the fact that emissions from devices operating in compliance with Part 15 have never been found to constitute harmful interference. Moreover, as TDC has already explained, devices that comply with Part 15 rules are not permitted to cause harmful interference, and the operator is obligated to stop transmissions if interference is caused.

[14] *See* Understanding the FCC Regulations for Low-Power, Non-Licensed Transmitters at 1, OET Bulletin No. 63, edited and reprinted Feb. 1996.

and digital devices,[15] all of which emit radio "noise" into the environment.[16] TDC and others are simply asking that UWB technology be permitted to use the same Part 15 levels to provide critical life saving and communications capabilities.

IV. Aggregation of UWB Devices Poses No Greater Risk Than Currently Authorized Part 15 Emitters.

When mitigating factors are properly incorporated into NTIA's analysis, UWB equipment is shown to operate safely with the Federal Systems analyzed by NTIA. As TDC has explained throughout this proceeding, compatibility assessment analyses must include attenuation from buildings, foliage and terrain masking. Moreover, these analyses must also include system specific considerations.

NTIA's aggregate analysis should have considered the UWB propagation channel. As discussed at length in TDC's Opening Comments and in Appendix A to these Reply Comments, a proper propagation model would have added 40 to 60 dB of attenuation to the UWB signal. Figure 1 is a map showing the location of the SARSAT Local User Terminal in Suitland, Maryland. The circle on the map has a radius of 2.9 km, the range at which the NTIA model predicts that a single UWB emitter at a height of 2 meters would affect the SARSAT

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15 *See* Understanding the FCC Regulations for Computers and Other Digital Devices at 2, OET Bulletin No. 62, edited and reprinted Feb. 1996.

16 In addition, tens of millions of non-communications devices such as microwave ovens emit energy as RF noise on an unlicensed basis pursuant to Part 18 of the Commission's Rules.

earth station.[17] As can be seen from this map a rather substantial suburban population falls within this required exclusion zone. It is also an area with substantial foliage. In this environment, UWB devices would have heavily obstructed propagation path. It is also very likely that there is already a collection of Part 15 devices emitting signals well within this radius.

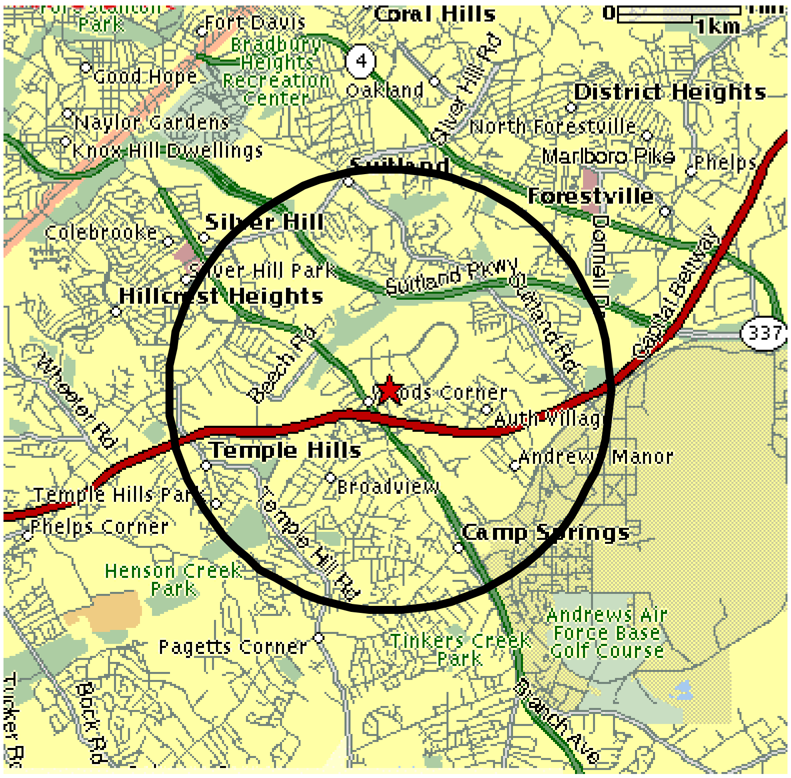

Figure 1. Map showing location of the NOAA SARSAT Local User Terminals in Suitland, MD.

After taking into account propagation losses and using NTIA's questionable criteria, the range at which UWB emitters might interact with the SARSAT system would be a few tens of meters. Since the LEOLUT system uses high gain receive antennas mounted 12 meters above

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17 *See* NTIA Report, Table 1 at viii.

the ground, at such short ranges, UWB emitters would be well out of the beam of the receive antenna.

It is also important to note that the NTIA analysis was based on a 0º elevation. The COSPAS-SARSAT organization specifies that the LUT shall be able to track the LEO SARSATS when they reach 5º above the horizon (5º elevation).[18] Links below this elevation are unreliable, especially with small antennas. The FCC has similar rules.[19]

NTIA stated that the signal levels from UWB devices add linearly.[20] Relying on this statement, several parties expressed concern with the potential proliferation of UWB devices.[21] These commenters believe that somehow large numbers of UWB devices will significantly add to the noise floor. As TDC stated in its opening comments, had NTIA adequately considered the attenuation from buildings, foliage, and terrain irregularities, for example, aggregate UWB

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[18] "COSPAS-SARSAT LEOLUT Performance Specifications and Design Guidelines," COSPAS-SARSAT, Document C/S T.002, Issue 3, Rev. 1 (Oct. 1999) Section 3.5 at 3-1.

[19] *See* 47 C.F.R. §25.205, Minimum angle of antenna elevation. "Earth station antennas shall not normally be authorized for transmission at angles less than 5° measured from the horizontal plane to the direction of maximum radiation. However, upon a showing that the transmission path will be seaward and away from land masses or upon special showing of need for lower angles by the applicant, the Commission will consider authorizing transmissions at angles between 3° and 5° in the pertinent directions. In certain instances, it may be necessary to specify minimum angles greater than 5° because of interference considerations."

[20] In making this determination NTIA measured the emissions from a total of two UWB devices having identical signal characteristics.

[21] *See* NTIA Report at Section 6.4. *See, e.g.,* Comments of NAB at 3 (noting same). Supplemental Comments of Sprint at 6 (UWB industry used "unrealistic" assumptions and drew "misleading" conclusions)

emissions would be substantially reduced from the levels that NTIA calculated. While white noise sources add linearly, the propagation effects have to be taken into account. In the real world, a victim receiver will not "see" the arithmetic sum of the output power of a large number of UWB emitters. Rather, it will be the sum of the attenuated powers because of attenuation due to the propagation channel.

Power is not manufactured out of the ether. It is well understood that white noise power will aggregate on a linear basis. Two independent white noise sources, equally distant and in the main beam of a victim receiver would input twice as much power into the receiver as a single source. TDC agrees with NTIA that noise-like UWB sources will add linearly, and that the aggregation of multiple sources must account for the additional losses, not limited to, but including foliage, buildings and terrain. In Section 5.6.2 of the report, NTIA concludes that aggregate interference from uniformly distributed emitters at distances of less than 1 km would decrease by at least 15 dB in suburban areas and 20 dB in urban areas relative to the free space loss model that NTIA used.

The Johns Hopkins University Applied Physics Laboratory Report, which was released on March 9, 2001, analyzed data taken by the University of Texas Advanced Research Laboratory to determine whether the effect of multiple UWB devices on a GPS receiver was different from what would be expected from multiple sources of white noise as regulated under Part 15 of the FCC Rules. UT:ARL tested collections of 16, 8, 4, 2 and 1 UWB device(s) at various distances away from GPS receivers to determine whether the effect of multiple devices was a linear sum of the white noise from each device. Johns Hopkins found that "[t]he UWB devices tested by ARL:UT produce signals that are white noise-like. The aggregate signal produced by more than one of these devices is also white noise-like." Thus, single and multiple UWB emissions are white noise sources, which means that standard and well-known RF system models can be applied to evaluate the impact of UWB devices on systems. UWB does not require the development of new theories or models.

Aeronautical Radio (ARINC) and the Air Transport Association of America (ATA), in their joint comment, repeat the claim made by the NTIA that a single UWB device emitted at the proposed power level would interfere with the operation of the Search and Rescue Satellite System (SARSAT).[22] These parties unfortunately fail to recognize that NTIA's model did not include the operational characteristics of the system or a reasonable propagation model for the UWB signals. Had these factors been considered, NTIA would have concluded that UWB would not create a problem for the SARSAT system.[23]

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22 *See* Joint Comments ARINC and ATA (Feb. 23, 2001) at 2.

23 Appendix A to these Reply Comments shows that by incorporating a conservative 40 dB correction factor to NTIA's propagation model shows that NTIA's protection criteria are not exceeded for this system.

V. Peak-to-Average Ratio and Other Technical Issues Raised By the NTIA Report

A. Peak-to-Average Issue

There are two inseparable issues: the peak-to-average limits that should be applied to devices emitting UWB signals and the measurement methodology used to determine compliance with those limits. These issues are closely related because different measurement procedures lead to potentially different results.

NTIA's discussion of peak-to-average issue,[24] like that of MSSI[25] and Sprint,[26] misuses the peak-to-average limit proposed in the NPRM. All of these parties failed to understand the impact of the FCC's proposed peak-to-average requirement, which is intended to limit the peak power emitted by any UWB device.

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[24] NTIA Report at v. "Moreover, operation of many proposed UWB devices under current Part 15 rules is made difficult because they seek to operate with much higher peak powers than the rules permit (47 CFR §15.35(b)."

[25] *See* Reply Comment of Multispectral Solutions, Inc. (Mar. 6, 2001).

[26] *See* Sprint Supplemental Comments (Feb 23, 2001) at 3.

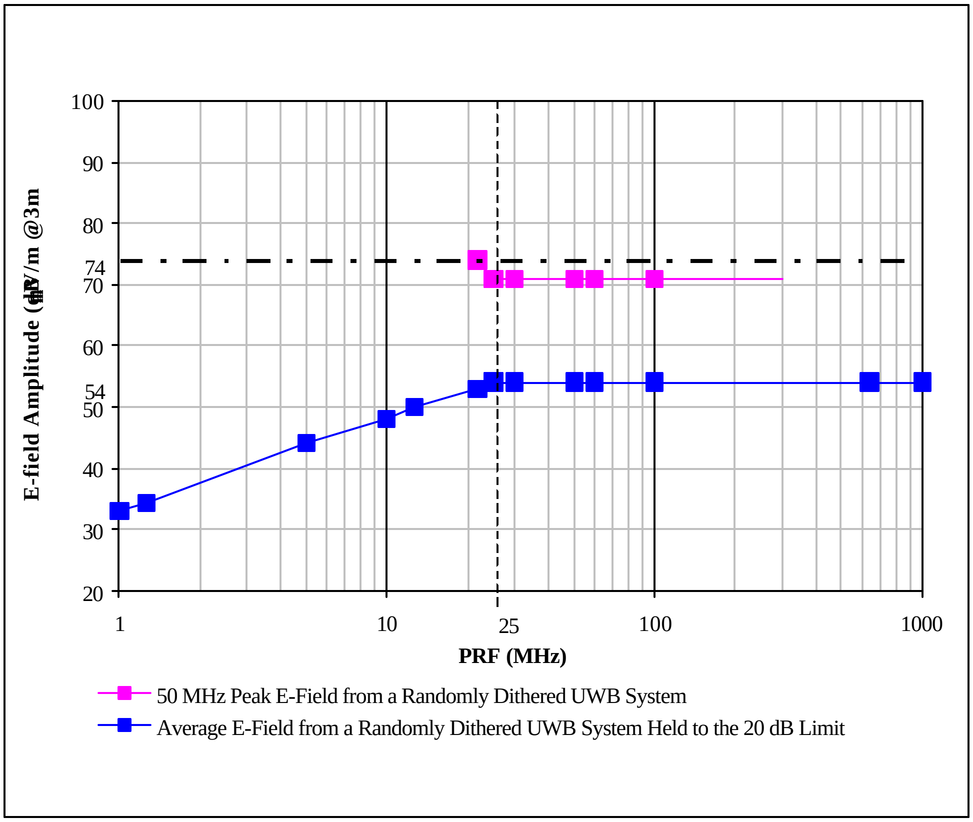

Figure 2. Graph Depicting How the FCC Proposed 50 MHz Band-limited Peak Constrains the Peak Power of All UWB Systems.

Figure 2 shows how the proposed 20 dB peak-to-average limit would become the limiting constraint on a UWB emitter when the pulse repetition frequency (PRF) is less than 25 MHz (based on the 50 MHz measurement protocol). In this figure, the top-most line (*i.e.*, the dot-dashed line) at 74 dBµV/m, is 20 dB above the 54 dBµV/m average limit as proposed by the FCC. When the PRF is greater than 25 MHz, a randomly dithered (*i.e.*, noise coded) UWB signal meeting the average limit would have a peak-to-average ratio that falls on the top pink line (for the 50 MHz peak E-field) and so the peak-to-average ratio would be less than 20 dB. The line depicting the average level (*i.e.*, the positively sloped blue/square line) shows the effect the proposed 20 dB peak-to-average limit has on the actual radiated power a UWB device with a lower PRF can radiate.

When the PRF is less than 25 MHz, the peak-to-average limit is the effective constraint and the average power must be reduced to comply with the 74 dBμV/m peak limit. The average power would then fall on the positively sloped blue/square line and so be less than the average limit. In short, for PRFs above 25 MHz, the UWB signal is limited by the average level, and for PRFs below 25 MHz, the UWB signal is limited by the peak-to-average limit.

The FCC also proposed an absolute peak level that represents the absolute time domain peak voltage level measured with an oscilloscope with infinite bandwidth. In order for any receiver to "see" a UWB pulse, the receiver's bandwidth must be as wide as the UWB signal's bandwidth. It is a tautology to say that only UWB systems will see the absolute peak of a UWB waveform, not narrowband receivers – there are no "narrowband" receivers that have a 500 MHz receive bandwidth centered at 2 GHz.[27]

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[27] Or for that matter, there are no narrowband receivers with a one gigahertz receive bandwidth centered at 4 GHz, or 2 GHz or greater receive bandwidth centered at 8 GHz. These are the unique characteristics of UWB systems.

As TDC's submissions on UWB signal measurements have documented, an absolute peak limit does not imply anything about the potential of a signal to interfere with a narrowband system.[28] Moreover, an absolute peak is not measurable, and therefore, superfluous.

B. Band-Limited Peak-to-Average Measurement Protocol

On the other hand, a band-limited peak is very relevant to estimating the interference potential of a UWB waveform and, as a secondary impact, would place a physical limit on the absolute band-unlimited peak. TDC's filings on UWB measurement issues have documented the FCC's concept of a 50 MHz band-limited peak measurement protocol ("50 MHz measurement protocol").[29] The advantages of this protocol over the bandwidth correction factor modeling approach used by NTIA are that the former approach is both measurable and immune to differences in UWB signal characteristics.

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[28] *See* TDC Comments (Sept. 12, 2001) at 34, 43; TDC Reply Comments (Oct. 27, 2000) at 52.

[29] *See See* TDC Reply Comments (Oct. 27, 2000) Appendix C (as updated in an erratum filed Feb. 20, 2001); TDC Ex Parte Filing (Feb. 16, 2001). NTIA used in its analysis a Bandwidth Correction Factor ("BWCF"). While this BWCF can be within a few decibels of the results that would be obtained by using the TDC 50 MHz measurement protocol, the BWCF cannot be measured and may not work for all UWB signals. However, the 50 MHz measurement protocol uses a filter to obtain an actual measurement. Engineers, armed with this peak-to-average measurement protocol and the average measurement protocol, have hard information upon which to measure interactions with UWB signals.

C. TDC's Proposed Peak-to-Average Limit

Figure 3 depicts TDC's proposal for a peak-to-average limit using the 50 MHz bandwidth limited measurement protocol. As can be seen in the figure, when the peak-to-average limit is 41 dB even systems with PRFs of as low as approximately 1 MHz will comply with the peak-to-average limit without a reduction in average power level.

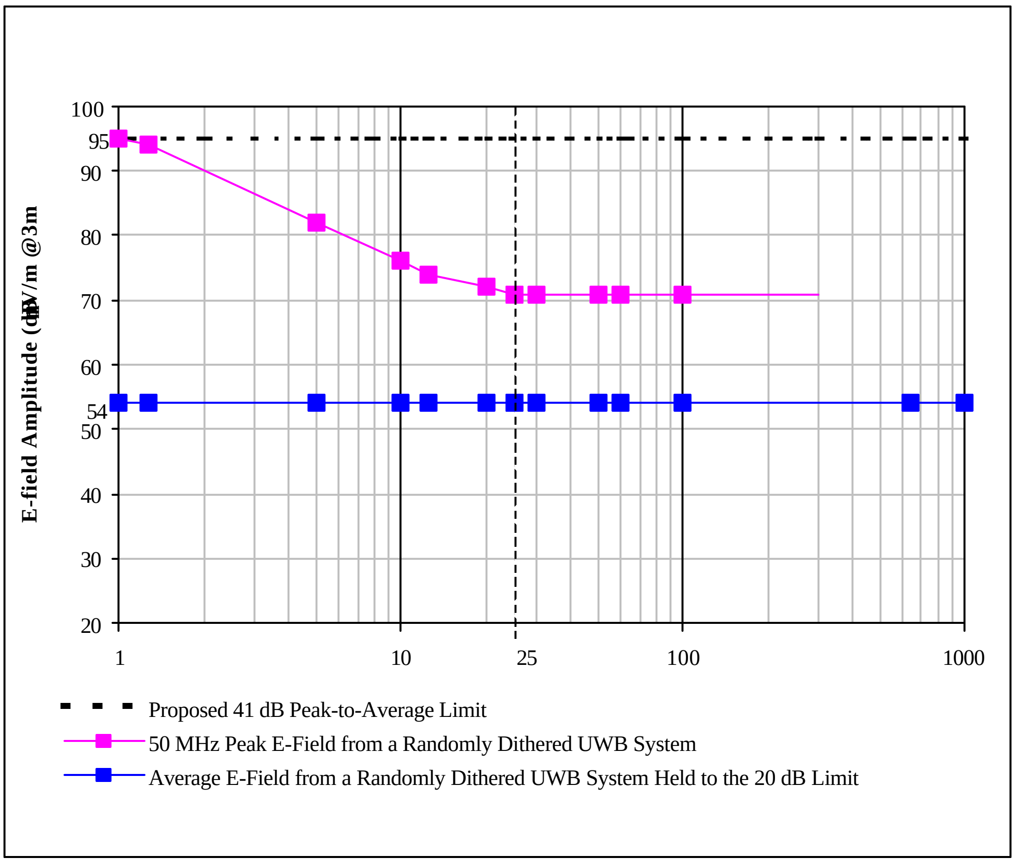

Figure 3. Depiction of TDC's Proposed Peak-to-Average Limit

D. The 20 dB Peak-to-Average Limit

The 20 dB limit proposed by the FCC is an artifact of old narrowband regulatory concepts and should not apply to UWB signals. Documents submitted jointly by Sprint and TDC analyzing the interaction of UWB and PCS showed that a 5 MHz PRF noise-coded

UWB signal (with a peak-to-average of 26 dB) can be modeled on the basis of average power. Moreover, no other testing has shown a correlation between interference potential and the 20 dB peak-to-average limit proposed by the FCC. However, the 20 dB peak-to-average limit proposed by the FCC would inhibit the fielding of valuable UWB systems that would not cause harmful interference.

TDC has identified several issues with the model used by NTIA that call into question NTIA's data and related conclusions. These issues include the failure to use appropriate path loss figures, the failure to recognize factors that add to the system noise floor, and, most importantly, a critical oversight regarding the application of the FCC proposed 20 dB peak-to-average level. Many of these issues were discussed in TDC's opening comments. TDC follows up this discussion with a detailed examination of NTIA's modeling approach in Appendix A to these Reply Comments.

NTIA's analysis fails to recognize that a UWB device must simultaneously comply with the average and peak signal level specifications proposed by the FCC. NTIA used Bandwidth Correction Factors ("BWCFs") to relate the UWB power level measured in a 1 MHz bandwidth, as specified in the NPRM, to the UWB power level a victim receiver would see in its bandwidth from the same signal. However, NTIA's analysis failed to account adequately for the interaction of the FCC proposed specifications and the impact this would have on the actual power a given victim receiver would see in its bandwidth. In so doing, the NTIA analysis has effectively shown that a higher peak-to-average ratio should be authorized by the Commission.

In Appendix A, TDC shows that the Commission can raise the peak limit from 20 dB to 41 dB while continuing to meet NTIA's own protection criteria. In fact, application of a 41dB peak limit will offer more protection than the levels represented in the NTIA Report because NTIA did not account for any reduction in average power that is required in order to simultaneously meet the peak-to-average limit for lower PRFs. A peak-to-average limit of 41 dB will not severely constrain UWB technology, as would the Commission's current 20 dB proposal. The 20 dB proposal would impact average power levels for PRFs of 1 MHz or less for non-dithered systems and for dithered signals with PRFs in the range of 25 MHz or less based on NTIA's analysis.[30]

This 41 dB peak-to-average proposal is much more aligned with the Commission's historic policy of not imposing technical constraints on any technology where such constraints are not warranted. In Appendix A, TDC demonstrates that this limit is an excellent compromise between higher limits that could be potentially problematic and the lower limit proposed by the FCC, which would unduly limit UWB technology.

VI. Conclusion

Based on the FCC's prior decisions and its statements in the UWB NPRM, TDC urges the Commission not to forego the current capabilities and future promise of UWB technology based on the explicit conclusions of the NTIA Report. As TDC and others explained in the

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30 *See* NTIA Report at D-2.

opening round of comments, NTIA's measurement procedures and methodology were based on theoretical protection criteria. They were not designed to measure the presence of harmful interference. Harmful interference is the result of interfering signals in the passband of a victim receiver that "seriously degrades, obstructs, or repeatedly interrupts [the] radiocommunications service." It makes no difference whether the signals emanate from a UWB device, another Part 15 regulated device, or from an unregulated source. The Commission's long-term experience shows that the general Part 15 limits, which were based on the digital device limits, have worked particularly well in preventing harmful interference. The NTIA Report proves this point as well. When it is read with an understanding of the relevant mitigation factors, the Federal Systems Test Report offers the basis for authorization of UWB operations on a Part 15 basis.

Respectfully,

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Appendix A – A Detailed Analysis of NTIA's Model

In this appendix, TDC examines NTIA's modeling approach. TDC has identified several issues with the model used that call into question NTIA's data and conclusions. These issues include the failure to use appropriate path loss figures, the lack of recognition of factors that add to the system noise floor, and, most importantly, a critical oversight regarding the application of the FCC proposed 20 dB peak-to-average level. As shown herein, the following key findings emerge from TDC's investigation:

- A well-crafted peak-to-average limit will effectively control the interaction of UWB with Federal Systems and not stifle the deployment of UWB equipment. TDC and others have shown that mitigation factors will reduce emissions levels by 40 to 60 dB. When the conservative 40 dB factor is applied, the average UWB signal levels modeled by NTIA show that compliance with NTIA's protection criteria is feasible for UWB devices operating at the –41.3 dBm power level posited by NTIA.

- NTIA's model shows that the peak-to-average limit proposed in the NPRM over a 50 MHz bandwidth can be set at 41 dB without exceeding the protection criteria used by NTIA – except in the case of an FSS earth station receiver with a 5° elevation angle. However, the modeling of the FSS earth station at a 5° elevation angle fails to take into account a number of additional mitigation factors. The model does not include (1) any consideration of digital signal processing capabilities, (2) the appropriate interference criteria for communications systems (*i.e.*, carrier-to-noise rather than interference-to-noise), or (3) any measure of the likelihood of needing to use a 5° elevation angle for regular reliable C band service because in an urban or suburban area a 5° elevation angle would likely have a C band satellite antenna looking toward buildings and other obstructions.

To assist with its presentation, TDC uses the tables from the Executive Summary of the NTIA Report that summarize the assessments for average power (Table 1) and peak power (Table 2) interactions.[31]

[31] In the following presentation, TDC uses NTIA's own modeling and protection criteria to illustrate that the Commission must increase the peak-to-average ratio for UWB in order to enable all the benefits of UWB while controlling the potential for any adverse interaction. This does not mean that TDC agrees with NTIA's approach. As TDC has stated, it does not agree that the protection criteria used by NTIA can be equated with harmful interference. TDC believes firmly that many additional factors have to be included in the calculus to determine the presence of harmful interference. Nor does TDC believe that the Bandwidth Correction Factor ("BWCF") approach posited by NTIA is the most appropriate means to model emissions from a UWB device. TDC has developed in comments responsive to the NPRM a measurement procedure based on a 50 MHz bandwidth. *See* TDC Reply Comments (Oct. 27, 2000) Appendix C (as updated in an erratum filed Feb. 20, 2001); TDC Ex Parte Filing (Feb. 16, 2001).

Table 1. Table 1 From NTIA Report

TABLE 1 Summary of Assessment of Effects of UWB Devices on Federal Systems For Average Power Interactions

SYSTEM	Freq. (MHz)	UWB PRF (MHz)	UWB Height 2 Meters				UWB Height 30 Meters			
			Non-Dithered		Dithered		Non-Dithered		Dithered	
			Max. EIRP to Meet Protect Criteria (dBm/MHz (RMS))	MinSep (km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect Criteria.	Max. EIRP to Meet Protect Criteria (dBm/MHz (RMS))	MinSep (km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect Criteria (dBm/MHz (RMS))	MinSep (km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect Criteria (dBm/MHz (RMS))	MinSep (km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria
Distance Measuring Equipment (DME) Interrogator Airborne Rcvr	960-1215	≤0.1 ≥1	-46 -47	0.08 0.09	-46 -46	0.08 0.08				
DME Ground Transponder Rcvr	1025-1150	≤0.1 ≥1	-63 -64	0.26 0.29	-63 -63	0.26 0.26	-56 -57	0.26 0.29	-56 -56	0.26 0.26
Air Traffic Control Radio Beacon Sys (ATCRBS) Air Transponder Rcvr	1030	≤1 ≥10	-44 -37	0.02 NA	-44 -44	0.02 0.02				
ATCRBS Gnd Interrogator Rcvr	1090	≤1 ≥10	-31 -21	NA NA	-31 -31	NA NA	-45 -36	0.27 NA	-45 -45	0.27 0.27
Air Route Surveil. Radar (ARSR-4)	1240-1370	≤0.1 ≥0.1	-60 -61	5.5 6.1	-60 -60	5.5 5.5	-80 -82	>15 >15	-80 -80	>15 >15
Search & Rescue Sat. (SARSAT) Ground Station Land User Terminal (LUT)	1544-1545	≤0.1 ≥1	-68 -69	2.9 3.1	-68 -68	2.9 2.9	-65 -66	5.5 6.1	-65 -65	5.5 5.5
Airport Surveillance Radar (ASR-9)	2700-2900	≤0.1 ≥1	-44 -46	0.8 1.1	-44 -44	0.8 0.8	-64 -66	1.3 1.5	-65 -65	1.3 1.3
Next Gen Weather Radar (NEXRAD)	2700-2900	≤0.1 ≥1	-39 -42	NA 1.4	-39 -39	NA NA	-73 -76	5.8 7.9	-73 -73	5.8 5.8
Maritime Radars	2900-3100	≤1 ≥10	-56 -50	1.2 0.6	-56 -56	1.2 1.2	-57 -51	1.2 0.6	-57 -57	1.2 1.2
FSS Earth Station (20^{o} Elevation)	3700-4200	≤1 10 ≥100	-36 -26 -20	NA NA NA	-36 -36 -36	NA NA NA	-42 -32 -26	.20 NA NA	-42 -42 -42	.20 .20 .20
FSS Earth Station (5^{o} Elevation)	3700-4200	≤1 10 ≥100	-51 -41 -35	0.60 NA NA	-51 -51 -51	0.60 0.63 0.63	-77 -67 -61	1.0 0.6 0.4	-77 -77 -77	1.0 1.0 1.0
CW Radar Altimeters at minimum altitude	4200-4400	≤0.1 ≥1	25 14	NA NA	25 14	NA NA				
Pulsed Radar Altimeters at Minimum Altitude	4200-4400	≤1 10 ≥10	14 14 14	NA NA NA	14 14 14	NA NA NA				
Microwave Landing System	5030-5091	≤ 0.1 ≥1	-45 -54	0.07 0.16	-45 -45	0.07 0.07				
Terminal Doppler Wx Radar (TDWR)	5600-5650	≤1 ≥10	-35 -35	NA NA	-35 -35	NA NA	-63 -63	6.0 6.0	-63 -63	6.0 6.0

A. Interpreting The Information Presented In Table 1 of the NTIA Report

Column 1 lists the systems investigated by NTIA. These systems represent a cross section of Federal system receivers that operate for the most part in restricted bands in the frequency range from just below 1 GHz to 5.56 GHz. The intermediate frequency ("IF") bandwidths of these systems range from 150 kHz to 40 MHz and the system sensitivities range from about –110 to –130 dBm. These specifications are likely to cover most, if not all, public and commercial receiver systems operating in the above frequency range.

Column 2 lists the operating band of the system and column 3 represents the range of UWB PRFs that were investigated. Although the range of PRFs investigated ranged from 0.001MHz to 500 MHz, NTIA grouped the results according to PRFs that produced similar modeled effects.

The next 8 columns present the calculated values that determine the sharing requirements for UWB sources relative to the victim receiver systems listed in column 1. UWB operational parameters that were incorporated into the analysis include the above range of PRFs, non-dithered and dithered modes of UWB operation and UWB source heights of 2 meters and 30 meters. Columns 4, 6, 8 and 10 list the maximum EIRP (in terms of dBm/MHz) that a UWB source can have to satisfy the protection criteria specified by NTIA. The protection criteria are based on the average UWB signal power level at the victim receiver input that would raise the victim receiver IF noise floor by either 0.5 dB or 1.0 dB depending on the specific receiver. In this column, EIRP levels higher than –41.3 dBm/MHz mean that a UWB device operating at an EIRP power level of –41.3 dBm/MHz will pose no threat to the victim receiver system, and EIRP levels lower than –41.3 represent the level that a UWB device must have its signal attenuated to in order to pose no threat to the victim receiver system in the context of the NTIA protection criteria at the specified height of the UWB emitter.

Column 4 shows EIRP values that meet NTIA's specified protection criteria range from a low of –69 dBm to +25 dBm. By comparing the level shown in column 4 to a level of –41.3 dBm/MHz, one can determine if the protection criteria would be met by a UWB device meeting the average field strength limit specified in the NPRM. NTIA calculated the maximum EIRP value for a compliant UWB device operating under the proposed technical specification in the NPRM to be –41.3 dBm/MHz. The significance of the above comparison is that, based on NTIA's own model, if –41.3 is lower than the value listed in column 4, there will be no average power interaction from UWB devices to that receiver system at the specified 2 meter height for the UWB device.

Consider, for example, the analysis for CW and Pulsed Radar Altimeters. NTIA concluded that UWB sources pose no threat of average power interactions with these systems because the calculated values of maximum EIRP average power interaction in columns 4 and 6 are higher than –41.3 dBm/MHz. The same holds true for other systems where the maximum EIRP average power interaction levels in columns 4, 6, 8 and 10 are higher than –41.3 dBm/MHz.

NTIA used the following formula to compute the values in columns 4 through 11:

$$EIRP_{MAX} = I_{MAX} + BWCF_{A/P} - G_R(\theta) + L_P$$

I_{MAX} represents the interfering signal level at the receiver input (*i.e.*, the signal level that just meets NTIA's protection criteria); $BWCF_{A/P}$ is a correction factor to relate the average power as measured in a 1 MHz resolution bandwidth to the average or peak power in the victim receiver IF bandwidth; $G_R(\theta)$ is a factor that accounts for the victim receiver antenna elevation and gain in the direction of the UWB device, and L_P is the propagation loss between the UWB source and the victim receiver antenna. This equation was also used to calculate the data presented by NTIA in Table 2.

B. Incorporating the Real World Mitigation Factors into Table 1

In its opening comments, TDC discussed the vast discrepancy between the results calculated with this formula using a minimal path loss figure and the actual real-world impact on path loss. NTIA acknowledged that the path loss figures used in their terrain model did not account for a number of real-world mitigation factors, such as scattering due to vegetation, buildings, and other man-made structures, as well as typical terrain height variations and building attenuation. TDC further demonstrated additional influences related to in-situ operational characteristics of the receivers raised their noise floors considerably. TDC determined that the combined effect of these omissions would easily add between 40 and 60 dB of additional loss. TDC now shows how incorporating this additional loss would affect NTIA's presentation.

Applying to Table 1 the more conservative 40 dB correction factor (rather than the also justified higher 60 dB factor)[32] and using the technique of graying areas that present no threat to the various receiver systems, yields the values presented in Table 1A. Even with this conservative 40 dB correction factor, only one "white" block remains – the block related to the ARSR-4 Air Route Surveillance Radar in the presence of an undithered UWB device that is 30 m high where NTIA calculated a separation distance in excess of 15 km. Note however, that even for this system, UWB devices are within a mere 0.7 dB of meeting NTIA's protection criteria.[33] Moreover, it is difficult to imagine when a UWB device would be at a 30 m height and not be within a building, in which case an additional 9 dB of building attenuation would have to be considered.

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32 Note also that the use of the more conservative 40-dB correction factor provides an additional safety margin of at least 20 dB to the analysis that follows.

33 The antenna for a typical ARSR-4 system is mounted on a 25-75 foot tower and enclosed by a hemispherical radar dome to shield the equipment from the environment. The tower is further enclosed in a 50-100 foot fenced-in area, often with warnings that limit access. Photographs of a typical installation are available at <http://www.rannoch.com/projs.html>.

Table 1A. Table 1 from NTIA Report As Modified to Include The 40 dB Correction Factor[34]

TABLE 1 Summary of Assessment of Effects of UWB Devices on Federal Systems For Average Power Interactions

SYSTEM	Freq. (MHz)	UWB PRF (MHz)	UWB Height 2 Meters				UWB Height 30 Meters			
			Non-Dithered		Dithered		Non-Dithered		Dithered	
			Max. EIRP to Meet Protect Criteria dBm/MHz (RMS))	MinSep (km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect Criteria.	Max. EIRP to Meet Protect. Criteria dBm/MHz (RMS))	MinSep (km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect Criteria dBm/MHz (RMS))	MinSep (km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect Criteria (dBm/MHz (RMS))	MinSep (km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria
Distance Measuring Equipment (DME) Interrogator Airborne Rcvr	960-1215	≤0.1 ≥1	-6 -7	0.08 0.09	-6 -6	0.08 0.08				
DME Ground Transponder Rcvr	1025-1150	≤0.1 ≥1	-23 -24	0.26 0.29	-23 -23	0.26 0.26	-16 -17	0.26 0.29	-16 -16	0.26 0.26
Air Traffic Control Radio Beacon Sys (ATCRBS) Air Transponder Rcvr	1030	≤1 ≥10	-4 3	0.02 NA	-4 -4	0.02 0.02				
ATCRBS Gnd Interrogator Rcvr	1090	≤1 ≥10	9 19	NA NA	9 9	NA NA	-5 -4	0.27 NA	-5 -5	0.27 0.27
Air Route Surveil. Radar (ARSR-4)	1240-1370	≤0.1 ≥0.1	-20 -21	5.5 6.1	-20 -20	5.5 5.5	-40 -42	>15 >15	-40 -40	>15 >15
Search & Rescue Sat. (SARSAT) Ground Station Land User Terminal (LUT)	1544-1545	≤0.1 ≥1	-28 -29	2.9 3.1	-28 -28	2.9 2.9	-25 -26	5.5 6.1	-25 -25	5.5 5.5
Airport Surveillance Radar (ASR-9)	2700-2900	≤0.1 ≥1	-4 -6	0.8 1.1	-4 -4	0.8 0.8	-24 -26	1.3 1.5	-25 -25	1.3 1.3
Next Gen Weather Radar (NEXRAD)	2700-2900	≤0.1 ≥1	1 -2	NA 1.4	1 1	NA NA	-33 -36	5.8 7.9	-33 -33	5.8 5.8
Maritime Radars	2900-3100	≤1 ≥10	-16 -10	1.2 0.6	-16 -16	1.2 1.2	-17 -11	1.2 0.6	-17 -17	1.2 1.2
FSS Earth Station (20^o Elevation)	3700-4200	≤1 10 ≥100	4 14 20	NA NA NA	4 4 4	NA NA NA	-2 8 14	.20 NA NA	-2 -2 -2	.20 .20 .20

34 In each of the modified tables in this Appendix A TDC has only altered the Maximum EIRP values. The Minimum Separation Distance entries have not been recalculated and are left as is.

FSS Earth Station (5° Elevation)	3700- 4200	≤1 10 ≥100	-11 -1 5	0.60 NA NA	-11 -11 -11	0.60 0.63 0.63	-37 -27 -21	1.0 0.6 0.4	-37 -37 -37	1.0 1.0 1.0
CW Radar Altimeters at minimum altitude	4200- 4400	≤0.1 ≥1	65 54	NA NA	65 54	NA NA				
Pulsed Radar Altimeters at Minimum Altitude	4200- 4400	≤1 10 ≥10	54 54 54	NA NA NA	54 54 54	NA NA NA				
Microwave Landing System	5030- 5091	≤ 0.1 ≥1	-5 -14	0.07 0.16	-5 -5	0.07 0.07				
Terminal Doppler Wx Radar (TDWR)	5600- 5650	≤1 ≥10	5 5	NA NA	5 5	NA NA	-23 -23	6.0 6.0	-33 -33	6.0 6.0

C. Impact of 20 dB Peak-to-Average Level Proposal in the NPRM

TDC next shows additional shortcomings with NTIA's model. NTIA's model did not account for the Commission's proposed requirement to limit peak power in a 50 MHz resolution bandwidth[35] (or even the proposed requirement for true peak power across the total emission bandwidth).[36] NTIA only considered the average limits proposed by the Commission, and, because of this, NTIA's conclusions are severely skewed.

The FCC's peak-to-average limit effectively controls the average power a UWB device may radiate for PRFs below approximately 10 to 20 MHz. For UWB equipment, the FCC proposed to limit average emission levels to 500 μV/m measured at a distance of 3 meters (using instrumentation employing an average detector with a 1 MHz resolution bandwidth filter). The FCC also proposed to limit peak level emissions measured in a 50 MHz bandwidth to

[35] The Note to Table 2 of NTIA's Report plainly states that peak-to-average power levels greater than 30 dB were modeled by NTIA.

[36] NTIA's use of BWCFs greater than 60 dB attests to this. See Tables 4-44b and 4-45b.

20 dB above the maximum permitted average level, equivalent to 5000 µV/m measured at 3 meters.[37] These two requirements are tightly interrelated.

To understand this interrelation as it concerns UWB systems, consider a UWB signal with a PRF of 0.1 MHz that has an average level measured in a 1 MHz bandwidth that is just compliant with the NPRM proposal. This is the UWB signal shown in Table 1A for the ARSR-4 radar system as still not meeting the specified protection criteria. To quantify the effect of the 20-dB peak level specification on average power, TDC uses the NTIA formulas for peak level Bandwidth Correction Factors ("BWCFs"). These BWCFs are used to determine the response of victim receivers having different IF bandwidths relative to the measurement reference bandwidth of 1 MHz.

Equation 3-12 in the NTIA report can be used to calculate the peak response of a 50 MHz system to a non-dithered PRF of 0.1 MHz. It is important to note that NTIA uses average and peak BWCFs that are normalized to the average power level measured in a 1

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[37] The average power and 20 dB peak-to-average limit are consistent with the limits currently contained in Sections 15.209 for average field strength and 15.35(b) for peak field strength. *See* NPRM at ¶ 43. The FCC also proposed a total peak limit of 60 dB above the average limit measured in a 1 MHz resolution bandwidth (using a formula that would further reduce the peak limit based on the 10 dB bandwidth of the entire emission). The total peak power has been previously addressed by TDC. *See* TDC Comments (Sept. 12, 2000) at 43-44; TDC Reply Comments (Oct. 27, 2000) at 60.

MHz bandwidth.[38] Substituting into Equation 3-12 0.1 MHz for PRF and 50 MHz for receiver bandwidth provides a peak $BWCF_p$ of 51 dB.

Thus, for the same 0.1 MHz PRF signal, the calculated peak level response of a system with a 50 MHz wide bandwidth relative to the average level response in a 1 MHz bandwidth is 51 dB. However, the maximum permitted peak level in a 50 MHz bandwidth relative to the maximum average level in a 1 MHz bandwidth proposed in the NPRM is 20 dB. Accordingly, to comply with the FCC proposed 20 dB peak-to-average level, the 0.1 MHz PRF signal must be attenuated by the difference between 51 dB and 20 dB, or 31 dB. This attenuation would necessitate lowering the average power by 31 dB. Although the proposed average power limit permits a –41.3 dBm/MHz level, a UWB signal with a 0.1 MHz PRF is limited to an average power that is 31 dB below this level. Thus, the signal that supposedly exceeded the NTIA protection criteria (*i.e.*, for the ARSR-4 system) will actually meet NTIA's criteria with over 30 dB of additional margin when the UWB signal level is attenuated to comply with the peak limit specification proposed by the Commission in the NPRM.

For dithered signals, the calculated BWCF for a 50 MHz bandwidth is 51 dB (through application of NTIA Equation 3-14). Thus, the above analysis on the effect of the 20 dB peak limits holds true for both dithered and non-dithered UWB signals.

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[38] *See* NTIA Report at 3-2.

Further, NTIA's analysis shows that the average power of any non-dithered signal with a PRF of less than 11 MHz would be restricted by the peak level limit to a level lower than the proposed average power limit and a dithered signal with a PRF less than or equal to 25 MHz would be restricted as a consequence of the 20 dB peak limit. Lower PRFs in both cases would result in correspondingly lower average power levels in order to comply with the 20 dB peak-to-average limit.

D. NTIA's Model Clearly Shows That the Proposed Peak Limit Can Be – and, Indeed, Must Be – Adjusted by 21 dB.

The proposed 20 dB peak limit specification imposes severe restrictions upon UWB technology. Because UWB signals with PRFs below approximately 20 MHz would be required to lower their average power to comply with this restrictive limit, nearly every UWB application using low PRFs would be precluded. TDC does not believe that the Commission intentionally intended to create this obstacle for UWB technology. To do so would be contrary to one of the Commission's guiding principles, that is, regulatory requirements should not impose artificial barriers to development of new technologies. The Commission has long held that technical regulations should only be imposed to the extent needed to prevent a significant probability of causing harmful interference thereby providing industry with the widest latitude possible in developing products and competing in the market place with those products.

Armed with the understanding that NTIA's analysis is based on average power signal levels well in excess of the average levels that would be permitted due to the restrictive nature of the peak limit proposal, TDC will now explain how NTIA's model shows that relaxation of the 20 dB peak limit can be accomplished without exceeding NTIA's posited protection criteria.

As noted above, NTIA's average power analysis was based on a UWB average power level equivalent to 500 uV/m at 3 meters (which NTIA calculated to be -41.3 dBm/MHz) irrespective of PRF.[39] NTIA's own Table 1 shows that average power interaction effects are typically minimally related to PRF, as there is only a 10 dB variation for UWB signals with PRFs between 10 kHz and 10 MHz. In other words, NTIA has shown that for a specific receiver, the interaction effects from a 10 MHz PRF are within 10 dB of the interaction effects of a 0.1, 0.01, or 0.001 MHz PRF provided the average EIRP of each signal is -41.3 dBm/MHz.

Based on this small 10 dB variation with such a wide range of PRF values, and the reductions in average power that result when the 20 dB peak limit specification in the NPRM that was unaccounted for in the NTIA analysis, TDC illustrates that the Commission can raise this peak limit specification. Indeed, raising the peak-to-average limit to 41 dB will allow UWB technology to thrive while continuing to meet the protection criteria used by NTIA in that agency's analysis.

NTIA's analysis shows that the impact of UWB signal interaction based on average power is only minimally related to PRF. From this it is reasonable that the peak limit should not

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39 *See* NTIA Report at vi.

be so low that lower PRFs would be required to reduce the average power by more than 10 dB as a function of PRF in order to comply with the peak limit. TDC has retained this 10 dB factor to account for the average power interaction variation as shown by NTIA to be justified as it relates to variations in PRF.

TDC uses this 10 dB PRF dependence factor to account for the average power variation, and to show why the peak to average limit can be raised to 41 dB (as measured in a 50 MHz bandwidth) in the following manner: For a 0.1 MHz PRF,[40] the response of a 50 MHz receiver bandwidth would be 51 dB above the average power of that signal measured in a 1 MHz bandwidth. TDC reduces the 51 dB calculated peak level response of 50 MHz bandwidth system by the 10 dB PRF dependence factor to reach a limit of 41 dB. This is done so that the FCC will adequately account for the PRF interaction relationships for average power that NTIA developed in its analysis.

If the 20 dB peak limit is replaced by 41 dB, and the actual average UWB EIRP power is recalculated, the level for the 0.1 MHz PRF signal will still be 10 dB lower than NTIA's allowed –41.3 dBm/MHz level, which NTIA calculated as the EIRP level permitted by the levels proposed by the FCC. This required reduction in UWB EIRP level would be reflected in Table 1A for the ARSR – 4 system, for example, by raising the –42 dBm/MHz limit by 10 dB

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[40] This is the same PRF (for the ARSR-4 system) where average power interactions were within 0.7 dB of meeting the NTIA protection criteria after adjustment with the 40 dB correction factor. *See* Table 1A, *supra*.

to –32 dBm/MHz. Thus, the ARSR – 4 radar would be afforded 9.3 dB of margin for meeting NTIA's protection criteria.

When considering the impact of the real-world mitigation factors (that provide 40 dB to 60 dB of additional margin) and the peak limit effects, it is clear that, as far as average power considerations are concerned, there will be no adverse interactions between UWB systems and Federal systems of the kind modeled. Moreover, the imposition of a peak limit measured in a 50 MHz bandwidth that has been relaxed to 41 dB maintains protection for average power interactions and provides an additional 10 dB of margin to the average levels presented in NTIA's Table 1. The 41 dB peak-to-average limit for UWB equipment would continue to meet NTIA's protection criteria and would also eliminate the severe restriction on UWB technology that the 20 dB limit imposes.

E. Peak Level Interactions Between UWB And Federal Systems

Having addressed average power interactions and having shown that the 20 dB peak limit can be relaxed by 21 dB with no deleterious effects, the analysis TDC applied to Table 1 can now be applied to the peak level interaction analysis NTIA presented in Table 2. Table 2 of NTIA's Report, which is reprinted below, delineates the peak power interactions. (In Table 2, NTIA notes that the shaded areas are for PRF values that would result in peak-to-average power levels greater than 30 dB. TDC will use shading in subsequent updates to this table to indicate data that no longer are found to exceed NTIA's criteria.)

Table 2. Table 2 From NTIA Report

TABLE 2 Summary of Assessment of Effects of UWB Devices on Federal Systems For Peak Power Interactions with Digitally Modulated Systems

SYSTEM	Freq. (MHz)	UWB PRF (MHz)	UWB Height 2 Meters				UWB Height 30 Meters			
			Non-Dithered		Dithered		Non-Dithered		Dithered	
			Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) For -41.3 DBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria
Search & Rescue Sat. (SARSAT) Ground Station Land User Terminal (LUT)	1544-1545	0.001	-104	>15	-104	>15	-101	>15	-101	>15
		0.01	-94	12.0	-94	12.0	-91	>15	-91	>15
		0.1	-84	7.3	-84	7.3	-81	>15	-81	>15
		1	-74	4.2	-74	4.2	-71	11.3	-71	11.4
		≥10	-69	3.1	-68	2.9	-66	6.1	-65	5.4
FSS Earth Station (20^{o} Elevation)	3700-4200	0.001	-89	6.6	-89	6.6	-95	>15	-95	>15
		0.01	-79	3.9	-79	3.9	-85	>15	-85	>15
		0.1	-69	2.2	-69	2.2	-75	5.3	-75	5.3
		1	-59	1.2	-59	1.2	-65	1.7	-65	1.7
		10	-39	NA	-50	0.5	-45	0.25	-55	0.6
		100	-20	NA	-40	NA	-26	NA	-45	0.25
		500	-20	NA	-36	NA	-26	NA	-42	.20
FSS Earth Station (5^{o} Elevation)	3700-4200	0.001	-104	12.3	-104	13.2	-130	>15	-130	>15
		0.01	-94	8.4	-94	8.4	-120	>15	-120	>15
		0.1	-84	5.1	-84	5.1	110	>15	-110	>15
		1	-74	3.0	-74	3.0	-100	10.1	-100	10.2
		10	-54	1.0	-64	1.7	-80	1.3	-90	3.3
		100	-35	NA	-54	1.0	-61	0.44	-80	1.3
		500	-35	NA	-51	0.6	-61	0.44	-77	1.0
Note:	(1) The calculations were made at UWB PRF Values of, 0.001, 0.01, 0.1, 1, 10, 100, and 500 MHz. When the distance values and Maximum EIRP values were the same for a range, they were grouped together to save space in the table. Thus, for the LUT the calculations for 10, 100, and 500 MHz were the same and are shown in the row labeled ≥10 MHz. (2) The shaded areas are for PRF values that would result in peak-to-average power levels greater than 30 dB.									

In Table 2 NTIA provides an analysis related to peak level interactions to three digital communications systems presumably sensitive to peak related interactions. Because NTIA did not incorporate any real-world interference mitigation factors related to digital signal processing techniques, it follows that the NTIA analysis is an absolute worst-case scenario. To generate the numbers in this table NTIA also used Equation 3-1 as was used in the average power analysis presented in Table 1. Table 2 shows that the maximum allowable EIRP to meet the protection criteria may be defined as a function of PRF. Although this table presents the results of peak level interaction effects, columns 4, 6, 8, and 10 are specified in terms of the average EIRP power level permitted from a UWB device to meet the protection criteria.

Table 2 shows a maximum sensitivity to peak related interactions is associated with FSS Earth Stations from UWB sources using very low PRFs, i.e., 0.001 MHz equivalent to 1 kHz, requiring the UWB EIRP signal level to be no higher than -130 dBm.

The first step in addressing the issues presented by Table 2 of the NTIA analysis will be to incorporate the conservative 40 dB correction factor for unaccounted losses as was done for Table 1. Again, the grayed out data entries in Table 2A are those values that now meet NTIA's specified protection criteria. Well over half of the data now meet the protection criteria.

Table 2A. Table 2 From NTIA Report As Modified to Include The 40 dB Correction Factor

TABLE 2 Summary of Assessment of Effects of UWB Devices on Federal Systems For Peak Power Interactions with Digitally Modulated Systems

SYSTEM	Freq. (MHz)	UWB PRF (MHz)	UWB Height 2 Meters				UWB Height 30 Meters			
			Non-Dithered		Dithered		Non-Dithered		Dithered	
			Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria
Search & Rescue Sat. (SARSAT) Ground Station Land User Terminal (LUT)	1544-1545	0.001	-64	>15	-64	>15	-61	>15	-61	>15
		0.01	-54	12.0	-54	12.0	-51	>15	-51	>15
		0.1	-44	7.3	-44	7.3	-41	>15	-41	>15
		1	-34	4.2	-34	4.2	-31	11.3	-31	11.4
		≥10	-29	3.1	-28	2.9	-26	6.1	-25	5.4
FSS Earth Station (20° Elevation)	3700-4200	0.001	-49	6.6	-49	6.6	-55	>15	-55	>15
		0.01	-39	3.9	-39	3.9	-45	>15	-45	>15
		0.1	-29	2.2	-29	2.2	-35	5.3	-35	5.3
		1	-19	1.2	-19	1.2	-25	1.7	-25	1.7
		10	1	NA	-10	0.5	-5	0.25	-15	0.6
		100	20	NA	0	NA	14	NA	-5	0.25
		500	20	NA	4	NA	14	NA	-2	.20
FSS Earth Station (5° Elevation)	3700-4200	0.001	-64	12.3	-64	13.2	-90	>15	-90	>15
		0.01	-54	8.4	-54	8.4	-80	>15	-80	>15
		0.1	-44	5.1	-44	5.1	-70	>15	-70	>15
		1	-34	3.0	-34	3.0	-60	10.1	-60	10.2
		10	-24	1.0	-24	1.7	-40	1.3	-50	3.3
		100	-15	NA	-14	1.0	-21	0.44	-40	1.3
		500	-15	NA	-11	0.6	-21	0.44	-37	1.0

TDC will now work towards incorporating NTIA's failure to recognize that the proposed peak limit effectively limits both peak and average levels. However, in lieu of the NPRM proposal of a 20 dB maximum peak-to-average limit, TDC will use its proposed 41 dB peak limit.

The first step in this process is shown in Table 3. Table 3 shows the calculated peak level response of a 50 MHz IF bandwidth to UWB signals of varying PRFs. NTIA Equation 3-14 was used to calculate the levels for dithered signals and the equations in Section 3.5.1.2 of the NTIA report were used for non-dithered signals.

Table 3. Calculated Peak Response Based on NTIA's Model

PRF (MHz)	Calculated Peak Response In a 50 MHz Bandwidth (dB)	
	Non-dithered	dithered
0.001	71	71
0.01	61	61
0.1	51	51
1	41	41
10	21	31
100	0	21*
500	0	*

* Applicability of Equation 3-14 to this PRF is questionable. See conditions for Equation D-6 that is also applicable to dithered signals in this range.

It was previously shown that, for lower PRFs, the need to meet both peak and average limits effectively forces both the peak and average levels to be attenuated by the amount the peak limit specification measured in a 50 MHz wide bandwidth is exceeded. Table 3 shows that, with the proposed 41 dB peak-to-average ratio, signals with PRFs of 0.1 MHz or less are required to attenuate their peak levels by at least 10 to 30 dB. Table 3 also shows the severity of the 20 dB peak limit. The proposed 20 dB peak-to-average limit would require attenuation of both the peak and average signal levels by 30 to 50 dB. Power reductions of this magnitude would effectively prevent any useful deployment of UWB technology using lower PRF technology.

Adjusting NTIA's table for peak power interactions to account for the 41 dB peak limit is provided in Table 2B. Again, the grayed areas show where NTIA's protection criterion is being met.

Table 2B. Table 2 From NTIA Report Further Modified With
The Proposed 41 dB Peak-to-Average Level

TABLE 2 Summary of Assessment of Effects of UWB Devices on Federal Systems For Peak Power Interactions with Digitally Modulated Systems

SYSTEM	Freq. (MHz)	UWB PRF (MHz)	UWB Height 2 Meters				UWB Height 30 Meters			
			Non-Dithered		Dithered		Non-Dithered		Dithered	
			Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria	Max. EIRP to Meet Protect. Criteria (dBm/MHz (RMS))	MinSep.(km) for -41.3 dBm/MHz (RMS) EIRP to Meet Protect. Criteria
Search & Rescue Sat. (SARSAT) Ground Station Land User Terminal (LUT)	1544-1545	0.001	-34	>15	-34	>15	-31	>15	-31	>15
		0.01	-34	12.0	-34	12.0	-31	>15	-31	>15
		0.1	-34	7.3	-34	7.3	-31	>15	-31	>15
		1	-34	4.2	-34	4.2	-31	11.3	-31	11.4
		≥10	-29	3.1	-28	2.9	-26	6.1	-25	5.4
FSS Earth Station (20° Elevation)	3700-4200	0.001	-19	6.6	-19	6.6	-25	>15	-25	>15
		0.01	-19	3.9	-19	3.9	-25	>15	-25	>15
		0.1	-19	2.2	-19	2.2	-25	5.3	-25	5.3
		1	-19	1.2	-19	1.2	-25	1.7	-25	1.7
		10	1	NA	-10	0.5	-5	0.25	-15	0.6
		100	20	NA	0	NA	14	NA	-5	0.25
		500	20	NA	4	NA	14	NA	-2	.20
FSS Earth Station (5° Elevation)	3700-4200	0.001	-34	12.3	-34	13.2	-60	>15	-60	>15
		0.01	-34	8.4	-34	8.4	-60	>15	-60	>15
		0.1	-34	5.1	-34	5.1	-60	>15	-60	>15
		1	-34	3.0	-34	3.0	-60	10.1	-60	10.2
		10	-24	1.0	-24	1.7	-40	1.3	-50	3.3
		100	-15	NA	-14	1.0	-21	0.44	-40	1.3
		500	-15	NA	-11	0.6	-21	0.44	-37	1.0

Table 2B shows that there is only one remaining system that does not meet the NTIA specified protection criteria. These data are for UWB devices that are 30 m high in proximity to the 5° elevation angle FSS earth station.

TDC noted above that the peak related interaction effects are directly related to PRF. Consequently, it is both interesting and compelling to note that, based on NTIA's analysis, a

UWB source using a 266 Hz PRF should be more of a problem to the 5º elevation FSS earth station than a UWB signal with a 1 kHz PRF. According to the NTIA model, then, a UWB signal with a PRF of 266 Hz would be expected to behave similarly to the ignition system pulse rate from an 8 cylinder, 4 cycle gasoline engine turning at 4000 revolutions per minute. At 4000 rpm, a 6 cylinder engine fires at a rate of 200 Hz and a 4 cylinder engine fires at a rate of 133 times per sec. For a UWB device with a PRF of 133 Hz, NTIA's model shows the average EIRP level could be no higher than –139 dBm/MHz in order to meet the protection criteria with no possibility of peak level interaction.

Based on NTIA's analysis model for peak related interference, it is clear that typical gasoline engines would be much more likely to cause interference to FSS Earth Stations than a UWB source would – specifically a UWB source compliant with the proposed average field strength limit with a proposed peak limit of 41 dB, measured in a 50 MHz bandwidth. Random ignition interference would radiate at its own peak level as would other unregulated incidental sources of high peak level emissions. While the average power in these incidental sources is very low (relative to the proposed limit), they have very high peak energy levels well above those that would be permitted by TDC's proposed peak limit specification.

The gasoline engine scenario clearly calls into question NTIA's peak level interaction model for the 5º FSS Earth Station. An analysis based on an unrealistic absolute worst case scenario cannot come close to accurately reflecting real world conditions relative to the performance of these systems. If it did, the interactions from the previously mentioned sources of incidental radiated energy would require the site to be isolated from traffic and other apparatus at distances greater than tens of kilometers to preclude peak level interactions and render it useless in stormy weather conditions. These isolated places are not places where UWB devices are likely to find consumer applications.

FSS C band earth stations are typically used to receive signals from geo-stationary orbit ("GSO") satellites. When the antennas of these stations are aligned at a 5º elevation angle, the main beam and the first side lobe of the antenna would cast a large footprint on the surrounding area where there would obviously be numerous incidental radiation sources. One then has to wonder how Earth Station systems can operate at these low angles and receive no interference from the surrounding normal environmental interference.

One possible answer lies in the unaccounted for digital signal processing capabilities these systems have that was not included in the NTIA analysis. The 40 to 60 dB correction factor incorporated by TDC was based solely on corrections to the path loss model used by NTIA. Digital signal processing capabilities do not affect the path loss and it is therefore appropriate to consider these capabilities separately. NTIA, in discussing marine radar interference to FSS Earth Stations operating at low antenna elevation angles, has even acknowledged that "[a]dvanced digital signal processing techniques, such as forward error correction coding and bit interleaving, can be <u>very effective</u> in reducing the susceptibility of an

FSS earth station receiver to EMI from adjacent-band radar and from other interference sources."[41]

Another possibility is that the NTIA peak level analysis produces results that are much more severe than exists in the real world as we know it today. Interference analysis for digital communications as a common industry practice uses bit error rate changes and/or carrier to noise (C/N) ratios of approximately 12 dB for interference analysis.[42] They do not use noise power I/N ratios that are measured as incremental changes in the IF noise output of the victim receiver. NTIA has historically applied an I/N ratio in radar system interference analysis, not for communications systems interference analysis.[43] UWB equipment would easily meet such C/N criteria.[44]

The conclusions from the foregoing analysis may be summarized as follows:

- NTIA showed that, for a wide range of PRFs, average power interactions with the systems analyzed varied by a maximum of 10 dB for PRFs below 100 MHz. Using NTIA's

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[41] NTIA Report TR-99-361, "Technical Characteristics of Radiolocation Systems Operating in the 3.1 – 3.7 GHz Band and Procedures for Assessing EMC with Fixed Earth Station Receivers" at ¶ 7.2.4.

[42] In paragraph 33 of the NPRM, the FCC urged commenters to discuss protection ratios in terms of signal to interference. NTIA Report TR-99-361 (see n. 41, *supra*) on FSS interference caused by radar systems uses a C/N ratio of 12 dB. The level of UWB signal required to affect the 12 dB C/N ratio would be much higher than the I/N ratio used by NTIA in its communication systems analysis involving UWB.

[43] *See* NTIA Report TR-99-361.

formulas, TDC's proposed 41 dB peak specification would effectively allow UWB devices to meet the protection criteria specified by NTIA without average or peak power interactions with their systems.

- A 41 dB peak limit places a sufficient peak level cap for the full range of PRFs. The EIRP levels and distances calculated in NTIA's analysis are not valid because they include UWB systems with peak power levels greater than either 20 dB or 41 dB (measured in a 50 MHz bandwidth).

- The adjusted permissible UWB EIRP level of –60 dBm for the 5º elevation angle FSS earth stations is 18.7 dB below the level that a UWB device compliant with the proposed 41 dB peak limit would produce. TDC posits some possibilities exist to account for this scenario, thereby maintaining compliance with NTIA's protection criteria for this system:

    1. The FSS Earth Station scenario still predicted by the revised NTIA numbers to be problematic involves UWB devices at a height of 30m. TDC cannot envision a scenario in which the UWB device at 30 m would not be located inside a building.

    2. That the digital signal processing interference mitigation techniques employed by the FSS Earth Stations that NTIA did not incorporate in their analysis will more than compensate for the level referenced above, and

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44 Note that had the 60 dB correction factor been incorporated the FSS earth station would not be an issue.

3. That NTIA used in its calculations an incorrect protection criteria, *i.e*., an I/N ratio developed for radar system analysis. Use of C/N ratios of the order of 12 dB for performance considerations relative to ambient background signals would be more appropriate as evidenced by industry practice, and would likely show that UWB equipment would meet the latter criteria.

- The automobile engine scenario plainly demonstrates that the peak level interaction model for FSS Earth Station cannot come close to accurately reflecting real world conditions relative to the performance of these systems.

TDC has shown that the Commission can raise the peak limit from 20 dB to 41 dB while continuing to meet the protection criteria used in NTIA's model. In fact, application of a 41dB peak limit will offer more protection than the levels represented in the NTIA Report because NTIA did not account for any reduction in average power that is required in order to simultaneously meet the peak level limit for lower PRFs.[45] Further, a peak limit of 41 dB will not severely constrain UWB technology, as would the Commission's current proposal. The

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45 In Appendix D of its report, NTIA concludes that the lowest achievable ratio for peak power measured in a 50 MHz bandwidth to rms average power measured in a 1 MHz bandwidth for a dithered signal is 27 dB for a PRF of 25 MHz. *See* NTIA Report at D-2. Suffice it to say that such a restriction on dithered UWB technology is totally unwarranted. TDC's proposal for a 41 dB peak limit in a 50 MHz bandwidth would shift the point where the average/peak power level interaction begins to affect the average power level down to approximately a 1 MHz PRF for dithered and non-dithered signals.

Commission's proposal would impact average power levels for PRFs of 11 MHz or less for non-dithered systems and for dithered signals with PRFs in the range of 20 to MHz or less based on NTIA's analysis.

NTIA's analysis fails to recognize that a UWB device must simultaneously comply with the average and peak signal level specifications proposed by the FCC. NTIA's BWCFs were intended to relate the power level measured in a 1 MHz bandwidth, as specified in the NPRM, to the power level a victim receiver would see in its bandwidth from the same signal. However, NTIA's analysis failed to adequately account for the interaction of the FCC proposed specifications and the impact this would have on the actual power a given victim receiver would see in its bandwidth. In so doing, the NTIA analysis can be effectively used to illustrate that a higher peak-to-average ratio should be authorized by the Commission.

This 41 dB peak-to-average proposal is much more aligned with the Commission's historic policy of not imposing technical constraints on any technology where such constraints are not warranted. TDC has shown that a 41 dB limit is an excellent compromise between higher limits that could be potentially problematic and the lower limit proposed by the FCC, which would unduly limit UWB technology.