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

In the Matter of	}	
	}	
Revision of Part 15 of the Commission's	}	
Rules Regarding Ultra-Wideband	}	ET Docket No. 98-153
Transmission Systems	}	

Reply Comments of Multispectral Solutions, Inc.

Multispectral Solutions, Inc. (MSSI) is pleased to submit these further reply comments in response to the Notice of Proposed Rule Making (NPRM), FCC 00-163, in the above referenced proceeding. These comments address the most recent submissions provided to the FCC under this docket, and attempt to dispel myth from fact based upon solid evidence from UWB test results. Conclusions and recommendations are also provided to suggest the manner in which this proceeding can continue toward a rule making by the Commission which is equitable and fair to both the nascent UWB industry and existing spectrum users.

Based upon solid evidence from UWB measurements data and analyses as shown below, MSSI recommends that the FCC amend Part 15 of the Commission's rules to:

- allow UWB operation only above 3.1 GHz;
- impose an emission limit of -50 dBc or better for any *spurious* (i.e., other than main lobe) UWB emissions falling below 3.1 GHz;
- impose a maximum PRF of 20 MHz on UWB pulse emissions until a complete assessment of the potential for interference from higher PRF systems is performed;
- impose a peak power constraint of 1 Watt for UWB operation;
- not consider pulse dithering as a remedy for UWB interference; and,
- not consider additional mitigating factors when determining the permissible emission levels and frequencies for UWB operation.

It is further recommended that the FCC proceed with a Further Notice of Proposed Rule Making (FNPRM) to present for comment specific rules as addressed above for UWB operation above 3.1 GHz.

Myth #1 – Ultra Wideband (UWB) is non-interfering

Facts:

- Without exception, *all* test data taken to date has documented the potential for interference from UWB devices to systems operating below 3.1 GHz, even at UWB emission levels significantly below existing FCC Part 15 limits. UWB interference to GPS, for example, was addressed by multiple organizations – including two UWB proponents – and is summarized in the Table below.

Test	**Min Range**	**Max Range**	**Average**	**Criteria**
Stanford/ Interval Research[1] (Note 1)	1 meter	100 meters	33 meters over all modes tested	Distance for loss of first satellite
NTIA[2] – (note 2) Aviation Terrestrial Surveying	 185 meters 28 meters 102 meters	 1556 meters 78 meters 103 meters	 633 meters 41 meters 102.5 meters	Distance at maximum allowable system tolerance in operational scenarios
Marshall Space Flight Center/Time Domain[3] (Note 3)	1/3 meter	4.5 meters	2/3 meter	Distance when fewer than 5 of 11 satellites tracked
Johns Hopkins University/APL[4] (Note 3)	3 meters	3 meters	3 meters	Distance for loss of lock on all satellites
University of Texas – Austin (Note 3)	3 meters	>25 meters	~20 meters	Distance for loss of first satellite (Figure I-1)

- Note 1: Interval Research tests conducted by R. Aiello, now CTO for Fantasma Networks.
- Note 2: NTIA tests did not consider initial GPS acquisition which would add another 6 dB degradation – 2 x Range for aviation, and 1.4 x Range for terrestrial/surveying applications.
- Note 3: Measurements and tests funded by Time Domain Corporation.

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[1] Aiello, G.R., G.D. Rogerson and P. Enge, "Assessing Interference of Ultra-Wideband Transmitters with the Global Positioning System – A Cooperative Study," paper presented at Stanford University, December 1999.

[2] David S. Anderson, Edward F. Drocella, Steven K. Jones and Mark A. Settle, "Assessment of Compatibility between Ultrawideband (UWB) Systems and Global Positioning Systems (GPS) Receivers", NTIA SPECIAL PUBLICATION 01-45, February 2001. J. Randy Hoffman, Michael G. Cotton, Robert J. Achatz, Richard N. Statz and Roger A. Dalke, "Measurements to Determine Potential Interference to GPS Receivers from Ultrawideband Transmission Systems", NTIA REPORT 01-384, February 2001, (hereinafter "NTIA GPS Report").

[3] "GPS-UWB Interference Issue," PowerPoint presentation by Time Domain Corporation.

[4] "Final Report, UWB-GPS Compatibility Analysis Project," The Johns Hopkins University/Applied Physics Laboratory, 8 March 2001, (hereinafter "JHU/APL Report").

- In its non-GPS/UWB assessment study[5], the NTIA determined that the following systems would be significantly degraded by UWB emissions at Part 15 levels: Distance Measuring Equipment (DME) Interrogator airborne receivers (960-1215 MHz), DME ground transponders (1025-1150 MHz), Air Traffic Control Radio Beacon System (ATCRBS) ground interrogator receivers (1090 MHz), ATCRBS airborne transponders (1030 MHz), Air Route Surveillance Radar (ARSR-4) (1240-1400 MHz), Search and Rescue Satellite Land User Terminals (SARSAT LUT) (1544-1545 MHz), Airport Surveillance Radar ASR-9 (2700-2900 MHz), Next Generation Weather Radar NEXRAD (2700-3000 MHz), and Maritime Radionavigation Radar (2900-3100 MHz). Accordingly, the NTIA concluded that operating UWB devices below 3.1 GHz will be quite challenging.

- Qualcomm, Sprint, Rockwell Collins, Sirius Satellite Radio, Cingular Wireless, The U.S. GPS Industry Council and others have recently filed NPRM comments urging the Commission not to allow UWB operation below 3.1 GHz due to their independent analyses of the potential for interference to their systems.

<u>Conclusions:</u>

- Interference from UWB emissions below 3.1 GHz, even at levels significantly below existing Part 15 limits, has been demonstrated through a number of independent measurement and analysis studies.

- In a recent filing[6], Time Domain Corporation indicated that “TDC and others have repeatedly stated that this proceeding should ensure that UWB devices will not disrupt important safety of life system, such as those operated by the FAA. If any UWB uses are found by the Commission to pose a credible risk of causing harmful interference to GPS systems by the FAA or the aviation industry, TDC fully expects that the Commission will not authorize those UWB uses.” Credible risk has been demonstrated.

<u>Recommendations:</u>

- The FCC should prohibit the use of UWB operation below 3.1 GHz to protect GPS and other affected aviation bands.

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[5] "The Temporal and Spectral Characteristics of Ultrawideband Signals," William A. Kissick, editor, NTIA Report 01-383, January 2001 (http://www.its.bldrdoc.gov/pub/ntia-rpt/01-383/). "Assessment of Compatibility Between Ultrawideband Devices and Selected Federal Systems," Brunson, L.K. et al., NTIA Special Publication 01-43, January 2001 (http://www.ntia.doc.gov/osmhome/reports/uwb/uwb.pdf), (hereinafter "NTIA non-GPS Report").

[6] “Comments of Time Domain Corporation”, ET Docket 98-153, 12 September 2000.

Myth #2 – Pulse Train Dithering Significantly Reduces UWB Interference

Facts:

- In NTIA's most recent submissions on the potential for UWB interference to GPS, the impact of pulse train dithering was measured as an improvement of at best 10 dB over non-dithered UWB systems. NTIA stated that "[t]he measurements also show that dithering of the UWB pulses in the time domain, using the techniques considered in this assessment, can be effective in spreading the spectral lines in the frequency domain, making the effective signal appear more noise-like. The GPS C/A-code receiver showed approximately 10 dB less sensitivity to these noise-like UWB signals as compared to those UWB signals deemed as CW-like." However, the NTIA added that "multiple-entry (aggregate) measurements indicate that this advantage is lost when a multiple of as few as three of these UWB signals with equivalent power levels at the GPS receiver input are considered in aggregation."[7]

- Wideband, "noise-like" waveforms have been utilized for years in Electronic Counter Measure (ECM) techniques for jamming radar and communications systems. Such waveforms are also designated as "barrage noise" jamming. "Barrage noise signifies the spreading of noiselike jamming energy over a wide frequency band such that many victim radars can be jammed over their whole agile bandwidths simultaneously. Bandwidth on the order of 100 MHz to an octave is thought of as being barrage." "[T]his form of jamming is among the best if the jammer designer can achieve the required power densities, since it is not intelligence-sensitive like many forms of smart noise and deception-jamming techniques."[8]

Conclusions:

- Pulse dithering has minimal (< 10 dB) effect on reducing potential interference from UWB systems. Even this "advantage" is lost when 3 or more UWB emitters can be seen by the victim receiver.

- Just because a waveform is "noise-like", this does not eliminate the possibility of interference to other services.

Recommendations:

- Given that Part 15 cannot specify the total number of UWB emitters which may operate in a given area, the above facts point out that the FCC should not consider pulse dithering as a remedy for UWB interference.

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[7] NTIA GPS Report.

[8] Van Brunt, L.B., **Applied ECM**, Vol. 1, EW Engineering, Inc., Dunn Loring, VA, 1978, pp. 464-467.

Myth #3 – High UWB Pulse Rates Have Little Impact on UWB Interference Potential

Facts:

- NTIA[9], Stanford University[10] and The Johns Hopkins University/Applied Physics Laboratory[11] have each demonstrated that, for UWB pulse repetition frequencies (PRFs) exceeding the bandwidth of a victim receiver, the interference level increases as the *square* of the PRF ratio.

- Given a 6 dB margin for GPS acquisition over tracking performance[12], the NTIA has demonstrated that a 20 MHz *dithered* PRF UWB transmission must be at least *33.3 dB down* from existing Part 15 levels (*41.6 dB down* for non-dithered emissions) in order to not interfere in analyzed GPS scenarios. In a recent presentation to the RTCA[13], the NTIA stated that its UWB-GPS analysis only considered a subset of potential GPS receivers and possible scenarios. Thus the potential exists for interference at UWB emission levels below those stated in the report. NTIA reports on UWB interference to non-GPS Federal systems demonstrated similar problems with high PRF emissions.

Conclusions:

- It has been clearly demonstrated that high PRF (i.e., > 100 kHz) UWB emissions are interfering to GPS and federal systems operating below 3.1 GHz and should not operate in those bands.

- All UWB emissions falling below 3.1 GHz should be attenuated by at least 50 dB relative to the peak emission level above 3.1 GHz.

Recommendations:

- The FCC should restrict unlicensed UWB operation to frequencies above 3.1 GHz, and impose an emission limit of -50 dBc or better for any *spurious* (i.e., other than main lobe) UWB emissions falling below 3.1 GHz.[14]

- Furthermore, the FCC should impose a maximum PRF of 20 MHz on UWB pulse emissions until a complete assessment of the potential for interference from higher PRF systems is performed.

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9 NTIA GPS Report.

10 "Potential Interference to GPS from UWB Transmitters, Test Results. Phase 1A: Accuracy and Loss-of-Lock testing for Aviation Receivers," M. Luo, D. Akos, S. Pullen and P.Enge, Stanford University, 26 October 2000.

11 JHU/APL Report, pp. 5-20 through 5-22.

12 NTIA GPS Report page 1-6 *"A 6 dB factor is often used in GPS interference analysis to account for the greater sensitivity of initial satellite acquisition over the satellite tracking mode of operation."*

13 "NTIA Study of UWB and GPS Compatibility," NTIA presentation to the RTCA, 12 March 2001, Wash. DC.

14 Similar out-of-band constraints are in place for high-speed U-NII operation in the 5-6 GHz frequency range.

Myth #4 – Spread Spectrum Limits (e.g., 1W peak) are Exorbitantly High for UWB Operations

Facts:

- Existing Part 15 regulations specify, for operation above 960 MHz, a maximum *average* E-field strength intensity of 500 μV/m at 3 meters as measured in a 1 MHz bandwidth. The *peak* field intensity can be up to 20 dB higher, or 5000 μV/m.

  As an example, for a UWB waveform having an apparent center frequency of 5 GHz, the instantaneous bandwidth would be at least 0.25 x 5.0 GHz = 1.25 GHz. In a 1 MHz resolution bandwidth, the peak signal can therefore have a value of up to (1250/1) x 5000 μV/m = 6.25 V/m. Since E-field and power are related by the expression

  $$E = \sqrt{\frac{30P}{R^2}}$$

  the *allowable* peak power P is calculated to be 11.7 Watts. Limiting the same emission to a 1 Watt peak level, the resultant *peak* E-field, as measured in a 1 MHz bandwidth, would have been only 1460 μV/m, or 10.7 dB *lower* than existing Part 15 limits.

- UWB is a non-constant envelope emission which, as a consequence, has a lower average power vs. peak power. This is unlike constant envelope, direct sequence and frequency-hopped spread spectrum modulations in which the peak and average powers are equal. By setting a peak power constraint equal to that of conventional spread spectrum emissions, the resultant peak and average energy densities (W/Hz) are significantly lower.

Conclusions:

- With a peak power constraint of 1 Watt, peak and average energy densities for UWB emissions are significantly lower than for existing Part 15.247 spread spectrum emissions. This is due to the wider bandwidth requirement (setting the peak emission levels) and non-constant envelope behavior (setting the average emission levels).

- 1 Watt emission levels for UWB can satisfy existing Part 15 emission limits.

Recommendations:

- The FCC should consider a peak power constraint of 1 Watt for UWB operation under Part 15, similar to those levels imposed on spread spectrum and U-NII.

Myth #5 – Mitigating Factors Should be Taken Into Account in Setting Maximum UWB Emission Levels

Facts:

- Under existing FCC Part 15 rules, additional "mitigating" factors are not considered when determining the maximum allowable field strength for a Part 15 device. UWB proponents, who have demanded that such factors be considered for UWB, have not demonstrated a distinction for UWB; rather, the claim has been made that UWB devices are in many ways equivalent to the myriad of existing Part 15 devices.

- Despite specious arguments to the contrary[15], interference from multiple UWB sources can reach a maximum at non-zero elevations (altitudes) of the victim receiver – of particular importance for aeronautical applications. This occurs for several reasons – (a) path loss changes from an R^4-behavior (due to multipath cancellation) on the ground to an R^2-behavior for line-of-sight propagation (e.g., ground-to-air)[16], where R = range between interfering source and victim receiver; (b) the masking effects of terrain are significantly reduced with elevation of the victim receiver; and (c) the number of interfering sources in view directly increases with elevation.[17] If height were not a factor in obtaining better reception and "seeing" more transmitters, the cellular industry would not have spent billions on developing its current infrastructure of cell towers.

Conclusions:

- Mitigating factors – e.g., "scattering due to vegetation, buildings, and other man-made structures, as well as typical terrain height variations and building attenuation"[18] – are non-existent in scenarios involving aeronautical safety. Furthermore, mitigating factors are already considered in existing FCC regulations involving wireless transmission systems.

Recommendations:

- Due to the planned ubiquitous proliferation of UWB devices, the FCC should not consider additional mitigating factors when determining the permissible emission levels and frequencies for UWB operation under the Commission's Part 15 rules.

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[15] McCorkle, J. and M. Rofheart, "Short Analysis on the Effects of a Large Number of UWB Systems," Technical Report TR-98-1, XtremeSpectrum, Inc., Fall 1998, page 6. "It has been shown that as the altitude of a victim receiver goes up, the energy density at the victim receiver goes down. Therefore, the worst-case receiver position is at ground level."

[16] Siwiak, K., *Radiowave Propagation and Antennas for Personal Communications*, Artech House, Boston, 1995, Chapter 3.

[17] NTIA GPS Report.

[18] "Reply Comments of Time Domain Corporation," 12 March 2001, page A6.

Myth #6 – Filtering will significantly increase the cost to manufacture UWB devices

Facts:

- Many UWB proponents have argued that filtering of a UWB waveform will increase the cost of the device and/or decrease performance, thereby severely limiting commercial applications. However, these same proponents utilize some form of filtering in their transmitter design. For example,

  The recent JHU/APL report highlighted the use of a high-pass differential-type filter by Time Domain Corporation in the Pulson Applications Developer (PAD) and Signal Emitter/Noise Generator used in the UWB-GPS compatibility tests. This filter was used for both conducted and radiated tests. The net effect of the filter was to reduce energy in the 0-2 GHz range.[19]

  Time Domain Corporation has indicated that a number of applications can be met using higher frequency UWB operation[20] (cf. Figure below from TDC submission):

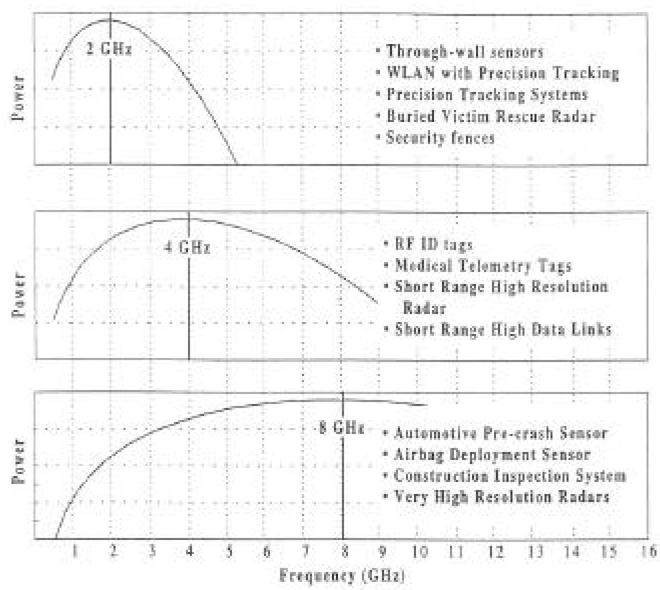

Figure 1. Applications of UWB and the Probable Bands of Operation.

  For example, a 4 GHz center frequency would permit the development of RF ID Tags, Medical Telemetry Tags, Short Range High Resolution Radars, Short Range High Data Links. An 8 GHz center frequency would permit the development of Automotive Pre-crash Sensors, Airbag Deployment Sensors, Construction Inspection Systems, and Very High Resolution Radars.

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[19] JHU/APL Report, pp. 4-11.

[20] Reply Comments of Time Domain Corporation , ET Docket No. 98-153, 12 September 2000, pages 1-20, also Figure 1 on page 11.

According to Time Domain, applications such a Through-wall sensors, WLAN with Precision Tracking, Precision Tracking Systems, Buried Victim Rescue radar, and Security fences are best accomplished with a center frequency of 2 GHz. This is due to the perceived need to penetrate typical construction material 30 feet deep or more, the ability to resolve personnel standing shoulder to shoulder at a range of 20 feet, antenna arrays capable of fitting in a standard 30 inch door frame and relatively low cost.

- In an earlier filing to the FCC, Pulson Communications (now part of Time Domain Corporation) advised the FCC to adopt rules to allow for the use of bandwidth-limited UWB systems with a 5.5 GHz center frequency and bandwidth of 2 GHz.[21]
- Fantasma Networks, Inc. has recently advocated staying above 2 GHz to protect GPS.[22] This indicates filtering is utilized in their transmitter design.
- XtremeSpectrum, Inc. also uses filtering and has advocated limiting UWB field strengths below 2.7 GHz.[23]

<u>Conclusions:</u>

- There are a broad range of applications that can be met using higher frequency UWB operation.[24]
- Nearly all lower frequency (< 2 GHz) applications listed above are currently permitted under FCC waivers to Time Domain Corporation, Zircon and U.S. Radar. Since sales of these devices have not been made a part of the record, it must be assumed that none have occurred and that the licenses have been of little value to the general public, the licensees or the FCC.

<u>Recommendations</u>

- The FCC should not delay a rule making because a few UWB proponents claim that UWB commercial use will be severely diminished by setting a lower frequency cut-off. While it may be easier to generate UWB energy at lower frequencies, recent test data has demonstrated that the impact to existing services is an unacceptably high price to pay.
- Given the high value of frequency spectrum, it is well understood that, if unlicensed spectrum is made available, it will result in the introduction of many new wireless products and services well beyond the plans and vision of current UWB proponents.

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[21] Cunningham, John E. and P. Withington, "Comments on Apple Computer's Petition for Rulemaking 'NII', 24 May 1995", RM-8653, July 10, 1995.

[22] Reply Comments of Fantasma Networks, Inc., ET Docket No. 98-153, 27 October 27 2000.

[23] Reply Comments of XtremeSpectrum, Inc., ET Docket 98-153, 27 October 2000.

[24] One of the unique characteristics of UWB technology is the ability to simply change the frequency operation. For example, MSSI has developed systems that operate from a low end of 30 MHz to an upper end of 12 GHz. All these systems employ spectral band limiting to confine the spectrum.

Summary of Recommendations

Based upon solid evidence from UWB measurements data and analyses, MSSI recommends that the FCC amend Part 15 of the Commission's rules to:

- allow UWB operation only above 3.1 GHz;
- impose an emission limit of -50 dBc or better for any *spurious* (i.e., other than main lobe) UWB emissions falling below 3.1 GHz;
- impose a maximum PRF of 20 MHz on UWB pulse emissions until a complete assessment of the potential for interference from higher PRF systems is performed;
- impose a peak power constraint of 1 Watt for UWB operation;
- not consider pulse dithering as a remedy for UWB interference; and,
- not consider additional mitigating factors when determining the permissible emission levels and frequencies for UWB operation.

It is further recommended that the FCC proceed with a Further Notice of Proposed Rule Making (FNPRM) to present for comment specific rules as addressed above for UWB operation above 3.1 GHz.

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