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	}	

RESPONSE TO
OPPOSITION TO PETITION FOR RECONSIDERATION

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In its 31 July 2002 Opposition to Petitions for Reconsideration[1,2], XtremeSpectrum, Inc. ("Xtreme") states that:

> *"[t]he record clearly shows that systems with a high pulse repetition frequency (PRF) are less interfering than those with a low PRF, not more."*[3]

Xtreme goes on to cite two recent papers from the *2002 IEEE Conference on Ultra Wideband Systems and Technologies*, chaired by MSSI President Dr. Robert Fontana, which purport to support this claim.[4]

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[1] *Opposition to Petitions for Reconsideration*, ET Docket 98-153, XtremeSpectrum, Inc., 31 July 2002.

[2] *Petition for Reconsideration*, ET Docket 98-153, Multispectral Solutions, Inc., 14 June 2002, revised 18 June 2002.

[3] Xtreme at page x.

[4] Xtreme at page xi.

In the first cited paper by Durisi and Romano[5], the authors do not claim that low PRF systems are much more harmful. Rather, the authors simply makes the observation that a Gaussian assumption (as has often been made throughout the course of this proceeding), cannot adequately predict the impact on BER performance at lower PRFs. Another proof of this fact can be found in the paper by Fontana.[6]

In the second cited paper by Foerster[7], the author, contrary to Xtreme's claim, points out that "the performance is worse for the DS [direct sequence UWB] systems compared to a system with no DS spreading. This is due to the inter-chip interference caused by the multipath and the non-zero autocorrelation of the spreading sequences." However, the author states that "[o]ne of the main reasons for using direct sequence spreading is to enable multiple [UWB] users to share the same spectrum simultaneously." Thus, to combat multipath, the higher PRF UWB system must use increasing amounts of power (in order to further lower BER); although, as the author contends, it may be possible for multiple (interfering) UWB systems to now operate in tandem. Furthermore, Foerster's paper makes no mention of an average power constraint, as claimed by Xtreme.

It is apparent from these specious "counter arguments" and misinterpretations of their own cited references, that Xtreme has fully misunderstood the basic principles of UWB pulse communications. While it is indeed true that, *given the same average power*, high

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[5] Durisi, G. and G. Romano, "On the Validity of Gaussian Approximation to Characterize the Multiuser Capacity of UWB TH-PPM," Proceedings UWBST 2002, May 2002.

[6] Fontana, R.J., "An Insight into UWB Interference from a Shot Noise Perspective," Proceedings UWBST 2002, May 2002.

[7] Foerster, J.R., "The Performance of a Direct-Sequence Spread Ultra-Wideband System in the Presence of Multipath, Narrowband Interference, and Multiuser Interference," Proceedings UWBST 2002, May 2002.

PRF and low PRF systems can have essentially the same interference potential; constant average power is NOT a desirable design goal for UWB communications systems. For example, consider two idealized waveforms, one having twice the PRF of the other (cf. Figure 1), but each having the same, identical, peak power.

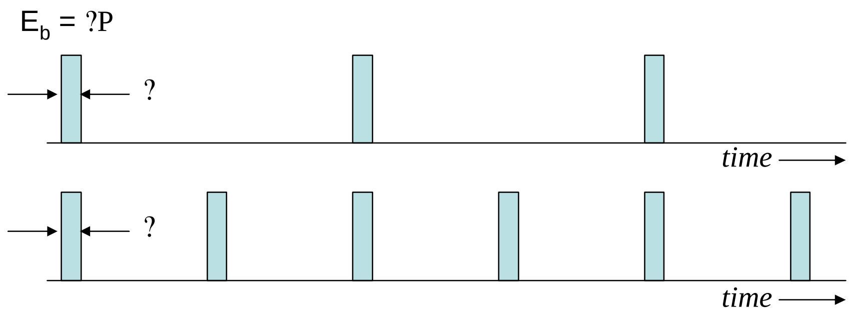

Figure 1. Idealized UWB Pulse Trains

Note that the bit error rate performance of these two systems is identical when communicating over the same range R. Specifically, with the same peak power, the energy per bit (or energy per symbol) is equal, resulting in the same energy-to-noise ratio E_b/N_0 and, thus the same bit error rate (BER) performance at a fixed range R. However, note that to achieve the same BER performance at the higher data rate, more average power was required (exactly twice as much in the above example). Hence, fixing the average power as stated by Xtreme, would simply result in poorer range performance for an increasing data rate.

Thus, for UWB pulse systems, a *peak power* constraint, subject of course to FCC limits on both peak and average power densities, is appropriate. Given this peak power constraint, it is straightforward to demonstrate that increasing PRFs cause increasing amounts of interference into a victim receiver.

In Figure 2 below, the results of a Matlab simulation[8] in which a biphase-modulated UWB pulse train is applied to the input of a 10 MHz bandwidth victim receiver are shown. Specifically, note that for low PRFs (i.e., below the victim receiver acquisition bandwidth), the output of the filter consists of a separable sequence of pulses (filter impulse response). At high PRFs, energy starts to build up in the filter creating both high peak and average values. (Note the transition where PRF is equal to receiver bandwidth.)

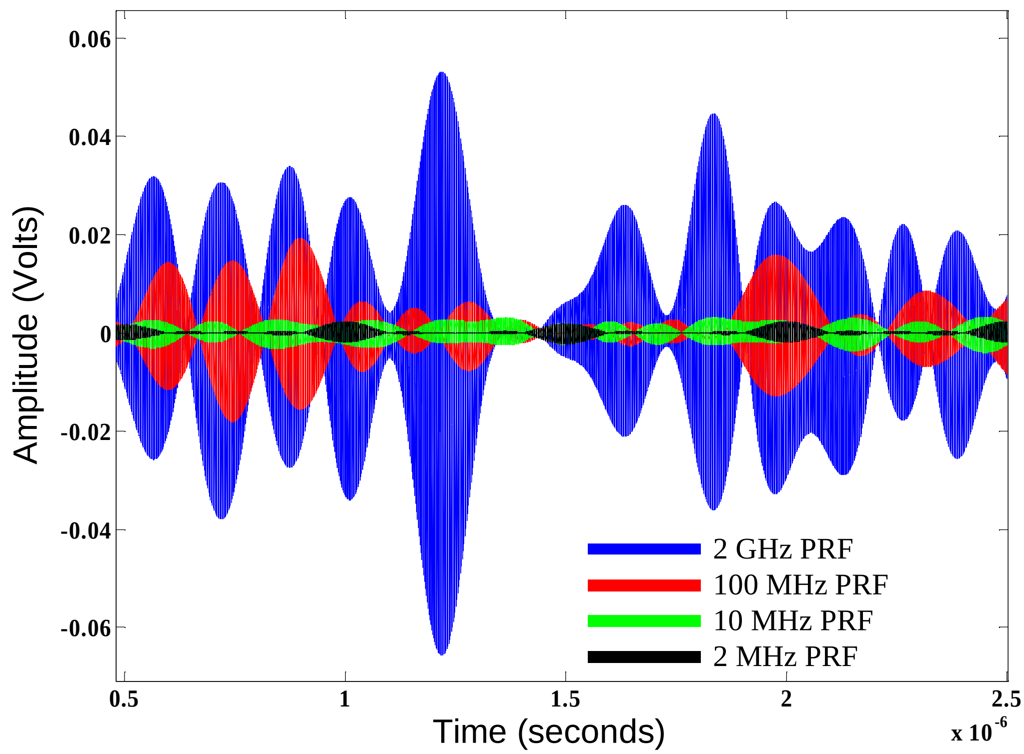

Figure 2. Response of 10 MHz Bandpass Filter (Victim Receiver) to Biphase Modulated UWB Pulse Trains at different PRFs.

Furthermore, note that the peak-to-average ratio for the less interfering, low PRF waveform, is significantly higher than that for the high PRF waveform (in the above example, a full 60 dB higher). Thus, it is also true that high peak-to-average ratio does

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[8] The Matlab code for this simulation is provided in Appendix A.

not imply high interference. To the contrary, high peak-to-average ratios (subject, of course, to peak power constraints as outlined, for example, in 47 CFR §15.35) are what *make* low PRF, UWB systems non-interfering and the reason such systems have been used for low probability of detection (LPD) applications by the military for years. This is yet another proof that pulse desensitization correction is not required in determining the interference potential of pulsed systems. Rather, pulse desensitization – i.e., the resultant insensitivity of a lower bandwidth receiver to a wide bandwidth waveform – is precisely what makes UWB waveforms both difficult to intercept and non-interfering. As illustrated above, high PRF or high duty cycle waveforms do not share these desirable properties.

Finally, note that these results are consistent with both Stanford/DOT[9] and NTIA test measurement results:

> *"The results from the measurement component of this study indicate that both the C/A-code tracking GPS receiver and the semi-codeless GPS receiver demonstrate a tolerance to all of the UWB signal permutations examined with a PRF of 100 kHz. For the scenarios considered in this assessment, aggregate effects were deemed not to be a concern with respect to those UWB waveforms with a PRF of 100 kHz. When the PRF was increased to 1 MHz, the C/A-code receiver began to show continuous wave (CW)-like interference susceptibility to the unmodulated UWB signal permutations at low power levels. When the PRF was increased to 5 MHz and then to 20 MHz, CW-like interference effects to the C/A-code receiver*

[9] Telephone conversation between Dr. Per Enge, Stanford University Aeronautics and Astronautics Dept. and Dr. Robert Fontana, MSSI President, 1 August 2002.

were observed to be more prevalent."[10]

Conclusion

For a given communications range/performance (i.e.. BER) goal, the fact of the matter is that high PRF systems are more interfering than low PRF ones. Thus, Xtreme's concept of a "Moore's Law radio", in which further advances in semiconductor technologies give rise to UWB systems having higher and higher data rates, can only be viable if the range of such systems goes to zero as the data rate is increased. This is a natural consequence of the peak and average power constraints imposed by the FCC, and a natural consequence of the interference impact of high PRF systems.

Furthermore, as outlined in MSSI's original Petition for Reconsideration[11], the requirement for pulse desensitization correction (PDC) is inconsistent with the proper design of low interference systems, is inconsistent with the previous record (specifically, the record relating to §15.35 and §15.209) and results in a UWB rule making which encourages the commercial development of potentially highly interfering systems in previously restricted bands.

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[10] "Assessment of Compatibility between Ultrawideband (UWB) Systems and Global Positioning System (GPS) Receivers," NTIA Special Publication 01-45, February 2001, page viii.

[11] MSSI Petition for Reconsideration, at III.

Appendix A
Matlab Code for BPSK Simulation

```
%
% Note:  Requires Matlab Signal Processing library
%
[t,y]=Pulser(5000,2e9,20e9,4e9,1,2); % 2Gb/s biphase UWB pulses
Fs=20e9; dt=1/Fs;
h=fir1(20000,[4e9-5e6,4e9+5e6]/(Fs/2)); % Linear phase 10MHz BW filter
s=filter(h,1,y);
plot(t,s); hold on
[t,y]=Pulser(250,100e6,20e9,4e9,1,2); % 100Mb/s biphase UWB pulses
s=filter(h,1,y); plot(t,s,'red');
[t,y]=Pulser(25,10e6,20e9,4e9,1,2); % 10 Mb/s biphase UWB pulses
s=filter(h,1,y); plot(t,s,'green');
[t,y]=Pulser(5,2e6,20e9,4e9,1,2); % 2Mb/s biphase UWB pulses
s=filter(h,1,y); plot(t,s,'black');

function [t,y]=Pulser(Np,Fp,Fs,Fo,Bf,type);
%
% Program to simulate a random pulse train
% Usage: [t,y]=Pulser(Np,Fp,Fs,Fo,Bf,type);
%
%  Np = Number of pulses desired
%  Fp = PRF (Hz)
%  Fs = Sample Rate (Hz)
%  Fo = Center Frequency of pulse (Hz)
%  Bf = Fractional Bandwidth of pulse (numerical)
%  type = 0 (all ones)
%         1 (random monopolar)
%         2 (bipolar)
%
%  t = Time axis (dt=1/Fs)
%  y = Pulse train output
%
dt=1/Fs; dp=1/Fp; N=round(Np*dp/dt);
T=N*dt; t=0:dt:T; d=0:dp:T; amp=[];
switch type
case 0 % all ones
    for i=1:length(d)
        amp(i) = 1;
    end
case 1 % monopolar
    for i=1:length(d)
        amp(i)=round(rand);
    end;
case 2 % bipolar
    for i=1:length(d)
        amp(i)=2*round(rand)-1;
    end;
end
d=[d;amp]';
y=pulstran(t,d,'gauspuls',Fo,Bf);
```