Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

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

To: The Commission

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

COMMENTS OF METRICOM, INC.

Metricom, Inc. ("Metricom"), by its attorneys, pursuant to Section 1.415 of the Commission's rules, hereby submits these Comments in response to the Commission's Notice of Proposed Rule Making in the above-captioned proceeding.

Metricom commends the Commission for its efforts to develop new rules for ultra-wideband ("UWB") devices. As an innovator in the use of unlicensed spread-spectrum technology for communications, Metricom recognizes the benefits of multiple access schemes operating with noise-like signals, which characterize both UWB and traditional spread-spectrum technologies. Metricom looks forward to the development of new industries and new communications devices that UWB inevitably will enable.

As a WCS licensee, however, Metricom has some concerns that the authorization and widespread deployment of UWB devices as currently proposed might adversely impact existing licensed services and decrease the value of licensed and licensable narrowband spectrum. Based upon a preliminary analysis, as described more fully below and in the "Engineering Statement"

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attached hereto as Exhibit A, Metricom believes, under currently proposed rules, it is likely that a UWB device operating in close proximity to a licensed receiver will interfere with that receiver. Metricom believes, however, that this likelihood can be minimized with appropriate technical rules governing the authorization and operation of UWB devices.

I. Background

Metricom is a young, rapidly growing, wireless telecommunications company based in Silicon Valley. With the Commission's encouragement, Metricom has pioneered the development of state-of-the-art, spread spectrum, wireless data communications systems. Metricom has used these technologies to implement its commercially available Ricochet[1] Internet access service. This service operates using several different frequency bands, and is considered the fastest, most easily deployable, and least expensive campus and metropolitan area wireless data network available today. Ricochet currently serves approximately 30,000 subscribers. Metricom's "next generation" Ricochet network, being rolled out today, operates at a gross over-the-air transmission rate of up to 1 Mbps, and provides user data rates of up to 128 kbps. To achieve these improvements, Metricom has integrated equipment operating in the 2.3 GHz band into its Microcellular Data Networks ("MCDN"),[2] pursuant to licenses Metricom purchased in the Wireless Communications Service ("WCS").

The Commission proposes to authorize UWB devices on an unlicensed basis through a number of technical changes to Part 15 of its rules. Two areas are of particular importance to

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1. Ricochet is a registered trademark of Metricom.

2. Microcellular Data Networks and MCDN are registered trademarks of Metricom.

Metricom: the rules relating to emission limits[3], and those relating to the permissible bands of operation.[4] Metricom's comments relating to those two areas are set forth below. Metricom agrees with the Commission's assessment that the adoption of any rule changes in these areas cannot be made without a complete understanding of the characteristics of UWB signals and their effect on narrowband receivers.[5] Metricom intends to conduct laboratory testing of simulated and actual UWB devices and urges the Commission to provide parties with adequate time to both complete testing and review and comment on test results[6] before it proceeds to adopt final rules.

II. Emission Limits

The Commission proposes to authorize a UWB device to operate with a peak power that exceeds its average power by a factor that ranges between 20 dB and 60 dB, depending upon the total bandwidth occupied by the device.[7] For a UWB device with a -10 dB bandwidth[8] of 50 MHz, the peak power would be limited to 20 dB above the average power. For a UWB device with a -10 dB bandwidth of 5 GHz or greater, the peak power could be as much as 60 dB above the average power.

Under the Commission's proposal, the authorized peak power for a UWB device would create a much higher probability of interference to a licensed narrowband service than would a currently authorized Part 15 device. In order for a low power device to be likely to cause interference to a victim receiver, there are essentially two items which must be present: (1) close

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3. *See, generally,* NPRM, ¶¶ 34 - 47.

4. *See, generally,* ¶¶ 22 - 30.

5. NPRM, ¶ 32.

6. NPRM ¶ 31.

7. *See* NPRM, ¶¶ 34 - 44.

8. The Commission proposes to define the bandwidth of a UWB device to be the area of the spectrum in which the device emits a power greater than -10 dB. *See* NPRM at ¶ 21.

proximity; and, (2) operation within the same bandwidth. For example, a currently authorized Part 15 device operating at the maximum permitted power could begin to interfere with a WCS licensed receiver when the Part 15 transmitter is located at a distance of approximately 100 feet from the receiver **and** it is transmitting within the bandwidth of the victim receiver. *See* Exhibit A. At this distance, the radiated power from the Part 15 device begins to raise the noise floor of the victim receive. (For this calculation, the bandwidth of the receiver is assumed to be 1 MHz.) At closer distances, the Part 15 transmitter can greatly increase the noise floor of the receiver, provided it is operating in the same frequency band. Despite this, the Part 15 rules work well to control interference, in part, because traditional Part 15 devices are essentially narrowband transmitters. Accordingly, in order to interfere with a licensed receiver, a Part 15 device must be closer than about 100 feet away, **and** it must be transmitting within the bandwidth of the licensed victim receiver. Because the probability of a nearby narrowband Part 15 device transmitting in any given 1 MHz of spectrum is quite low, the probability of interference is low.

The same is not true of UWB operations under the rules proposed. A UWB device would be allowed to spread its energy across an extremely wide bandwidth, subject to the same Part 15 limitation on average power in any 1 MHz bandwidth frequency range above 2 GHz.[9] In effect, a UWB transmitter could therefore emit a radiation pattern similar to a large number of simultaneously operating narrowband Part 15 devices, each spaced 1 MHz apart. Whereas a narrowband Part 15 transmitter must be operating in close proximity **and** within the receiver bandwidth of a victim receiver in order to interfere with that receiver, a UWB device needs **only** to be operating in close proximity in order to interfere. This is because a UWB device is likely to be emitting radiation within a victim receiver's bandwidth (because it is emitting radiation in nearly all bandwidth), and

9. *See* NPRM, ¶ 39. Below 2 GHz, the UWB emissions would have to be attenuated by at least 12 dB from the Part 15 emission limits.

depending on the characteristics of the UWB transmitter and receiver, could be virtually guaranteed to do so.

Metricom believes that UWB technology will follow through on its initial promise to deliver a wide range of innovative new services, and that UWB devices will become ubiquitous. Metricom is therefore quite concerned that the proximity problem as described above will become quite real. Therefore, the only other factor which could decrease the probability of interference, placing energy into the bands of victim receivers, must be carefully examined.

In order to significantly decrease the probability of interference to licensed services, Metricom makes the following recommendations which should decrease the radiated energy into any given frequency band:

- Each UWB device should be required to cease transmission automatically when the device is not actually transmitting information.[10]
- Both the peak and average power measurements for a UWB device should be made using the same resolution bandwidth (*e.g.*, 50 MHz) for each measurement, in keeping with current Part 15 measurement standards.[11] A wide-band video filter would be used to make the peak measurement, and a narrow-band video filter to make the average measurement. This will minimize the probability of interference to licensed services by ensuring that there is a time-averaging component to the peak-to-average measurement. In the case of a UWB device that has a -10 dB bandwidth greater than 50 MHz, a correction factor could be employed to account for the fact

10. *See* 47 C.F.R. § 15.407(c).

11. *See* 47 C.F.R. § 15.35; Public Notice, DA 00-705 (rel. March 30, 2000) (frequency hopping measurement guidelines). *Cf.* NPRM, ¶¶ 50-52 (proposing 1 MHz resolution bandwidth for average, 50 MHz resolution for peak).

that a 50 MHz resolution bandwidth may not permit an accurate measurement of the peak power.

- If the time averaging component cannot be achieved by the measurement technique described above, then UWB devices should be required to conform to a specific duty cycle in order to ensure that they do not act as a continuous source of interference. A duty cycle requirement may not be a problem for many UWB communications applications because it is believed that UWB devices designed for communications are expected to operate in a half-duplex mode, and as such must stop transmitting whenever they listen for or receive a communication.

III. Frequency Bands

The FCC has solicited comment on the band restrictions, if any, that should apply to UWB devices.[12] In particular, the Commission has advanced several variants on proposals to limit operation of certain UWB devices in the bands below 2 GHz.[13] Metricom has a strong interest in ensuring that appropriate rules governing the permitted bands of operation of UWB devices are developed, and desires to comment on these proposals. However, at the present time there is insufficient test data upon which to base a recommendation. Metricom has already begun to test UWB devices. As Metricom's and others' test results become available, Metricom expects to be able to illuminate these issues with recommendations firmly grounded in reality.

IV. Testing

The Commission has encouraged testing of UWB devices to better understand their interference potential and Metricom strongly agrees that this testing is necessary in order to simulate real world conditions. Indeed, given the present lack of laboratory evidence regarding the

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12. *See* NPRM, ¶¶ 22 - 30.

13. *See* NPRM, ¶¶ 25-30.

characteristics of UWB signals, it is difficult to make specific recommendations regarding the operation of UWB devices. Metricom recently began testing with UWB simulators in its own laboratories, and will continue testing with actual UWB devices when they become available. Metricom intends to submit its test results to the Commission when available; however, because this is very new technology and it is obviously difficult to obtain the requisite devices for testing, Metricom requests that the Commission delay, for at least a month, its proposed deadline for submission of test results into the record of this proceeding.[14] Adequate rules cannot be developed in the absence of real-world test results. At this time, Metricom projects that it can complete its testing by November 30, 2000.

V. Conclusion

Based on the foregoing discussion, Metricom urges the Commission to take further action in this proceeding in accordance with the views expressed herein.

Respectfully submitted,

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14. *See* NPRM, ¶ 31 (encouraging submission of test results by October 30, 2000).

EXHIBIT A

Engineering Statement

UWB NPRM Technical Appendix

Metricom, Inc.

Technical Overview

As a developer of Part 15 spread spectrum devices Metricom recognizes the benefits of multiple access techniques based on wideband modulations schemes that have noise like characteristics. As a WCS licensee Metricom recognizes that the changes in the peak power of the Part 15 rules as proposed in the NPRM for Ultra Wide band devices will increase the probability of interference relative to existing Part 15 devices to its licensed receivers when operated in close proximity to UWB devices. Metricom is currently performing tests in the lab to quantify this increase in probability of interference and determine if it is significant. Preliminary results in our lab tests demonstrate that typical Part 15 devices do not interfere with our 2.3 GHz receiver whereas a typical UWB device operating across the 2.3 GHz band and in near proximity has a high probability of raising the noise floor of a 2.3 GHz receiver. Currently the probability of a nearby Part 15 device raising the noise floor in the 2.3 GHz WCS band is small because the typical Part 15 device does not emit intentional or spurious energy in the 2.3 GHz WCS band due to its narrowband nature. The probability that a UWB device emitting energy into a licensed band over which it is operating is relatively high due to its wideband nature. Allowing the maximum peak power to be 60dB as proposed in the NPRM would effectively allow a single UWB device to look like a 1000 or more –41 dBm radiators spread across the band thus increasing the probability of interference to licensed receivers in close proximity to a operating UWB device. Metricom recognizes the benefits of multiple access schemes using signals with noise like characteristics such as spread spectrum, but notes that overlaying ultra wideband technology over an existing narrowband licensed spectrum runs the risk of encumbering these licensed services with increased noise floors when operated in close proximity and, thus, lowering the value of these licensed bands and forcing the users of these licensed bands to install more infrastructure to compensate for decreased link budgets.

Proposed Rule Change in Peak Power

Paragraph 43 of the NPRM proposes to change the Part 15 rules to allow the peak power measured over the entire bandwidth of the UWB signal to exceed the Part 15 average emission limit by: 20 + 20 log (-10dB bandwidth of the UWB signal measured in MHz/ 50MHz) up to a maximum of 60dB. Paragraph 50 of the NPRM indicates that the average field strength emission measurement of a UWB device is to be made in a 1 MHz bandwidth. Given this definition, a UWB device with a 30dB peak to average ratio, for example, would produce a peak power level in the receiver bandwidth equivalent to the sum of 1000 similarly designed emitters producing an EIRP of –41 dBm (54 dBuV/m at 3 m separation).

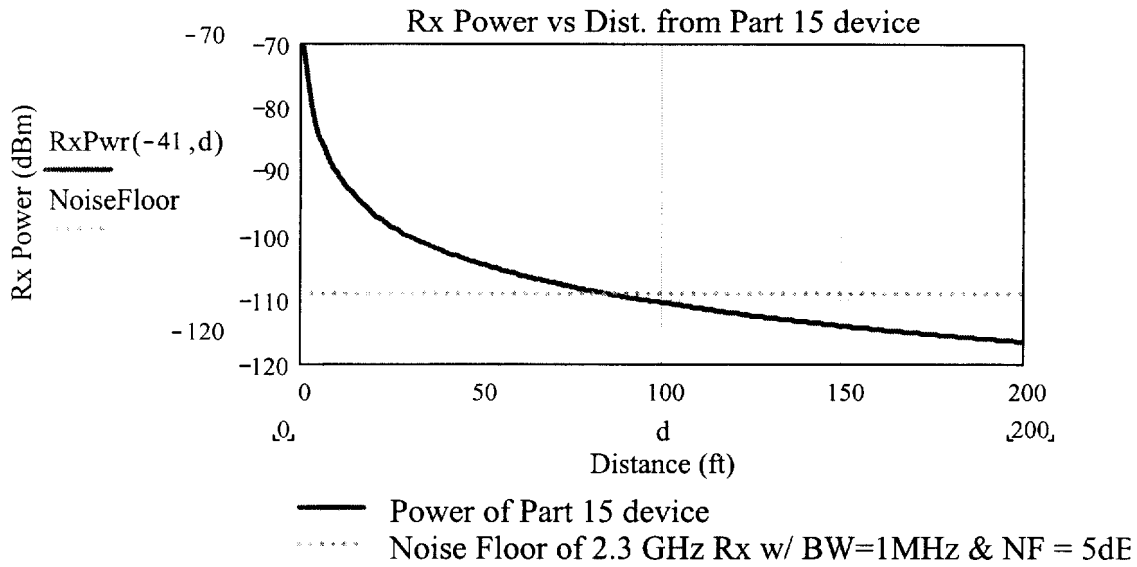
To clarify the definition of the peak to average in the case of a UWB signal, Metricom recommends that the definition be written assuming ideal test equipment. For example, from the NPRM proposed rules, it appears that the peak emission level measurement would be made with a resolution bandwidth equal to the –10dB bandwidth of the UWB signal, a video bandwidth-setting equal to the resolution bandwidth, no pulse desensitization correction factor (PDCF) and the peak hold function enabled. The average emission level measurement would be made with a resolution bandwidth of 1MHz, a video bandwidth between 10 Hz to 10 kHz and no peak hold. Then you would verify that the peak measurement with respect to the average measurement met the limit given by: 20 + 20 log (-10dB bandwidth of the UWB signal measured in MHz/ 50MHz) up to a maximum of 60dB.

The proposed rule change could also be interpreted as to allowing a UWB signal not have an average emission level greater than 500 uV/m @ 3m in any 1 MHz bandwidth above 960 MHz and to have peak emissions level less than 5000 uV/m @ 3m in any 50 MHz bandwidth.

To minimize interference to nearby license services, Metricom recommends that the peak and average measurements be made with the same resolution bandwidth equal to the –10dB bandwidth of the UWB signal. And that the peak emission measurement be made with a relatively wide video bandwidth and the average measurement be made with a narrow bandwidth. Varying the bandwidth of the video filter to measure peak to average ratios will ensure that the power of the signal in the resolution varies with time. This will ensure that when UWB devices are operated in close proximity to a license service that there is some period of time the victim receiver will see the thermal noise floor.

Interference Level of a Part 15 device vs. Distance

Paragraph 15.205 of the Part 15 rules allow unlicensed devices to transmit at levels of 500 uV/m @ 3m above 960 MHz measured in 1 MHz bandwidth. This field strength is equivalent to a –41.25d dBm isotropic radiator. The proposed rules would allow a UWB device to effectively look like a –41.25dBm radiator in every 1MHz bandwidth. The graph below shows the signal level of such a source as seen by a 2.3 GHz receiver with a 1 MHz wide receiver. The noise floor line shows the noise floor of a 2.3 GHz receiver assuming a 5 dB noise figure. This graph shows that a –41.25 dBm isotropic source needs to be approximately 100 feet away to be below the noise floor of a 2.3 GHz receiver having a 1 MHz noise bandwidth. This is roughly the radius of interference noted in paragraph 25 of the NPRM by Arthur Little: "As Arthur D. Little, Inc. points out, for example, an UWB signal operating at the general emission limits in 47 C.F.R. § 15.209 would fall below a victim receiver's thermal noise at a distance of 40 meters at 500 MHz, and at a distance of 10 meters at 5 GHz". This effectively means that a licensed receiver within approximately 100 feet of an operating UWB device will suffer some amount of reduction in receiver sensitivity.



The RxPwr curve is derived from the following equation:

$$\mathrm{RxPwr}(T,d) := T + 10\cdot e\cdot \log\left(\frac{c}{f\cdot 4\cdot \pi\cdot d\cdot 5280^{-1}}\right)$$

T: The transmit power of the source (dBm)
e: The pathloss exponent
c: speed of light
f: frequency
d: distance (miles)

The noise floor curve is derived from the following equation:

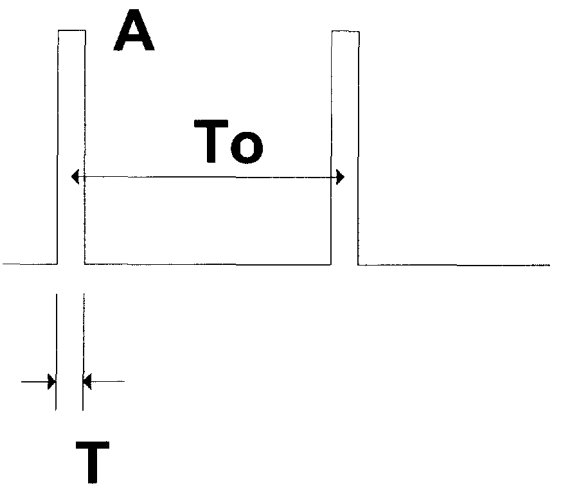
$$\mathrm{NoiseFloor} := -174 + 10\cdot \log(\mathrm{RxBw}) + \mathrm{NF}$$

-174: The noise power in 1 Hz bandwidth (dBm)
RxBw: The noise bandwidth of the receiver (Hz)
NF: The noise figure of the receiver

The characteristics of a pulse train

A typical implementation of a UWB device used for communication applications could consist of a step recovery diode generating a pulse at some Pulse Repetition Frequency (PRF) followed by a low pass filter to limit the energy below some frequency. While the

pulse shown below is not the exact pulse that would be used in UWB devices it can be used to show the characteristics of a pulse system.

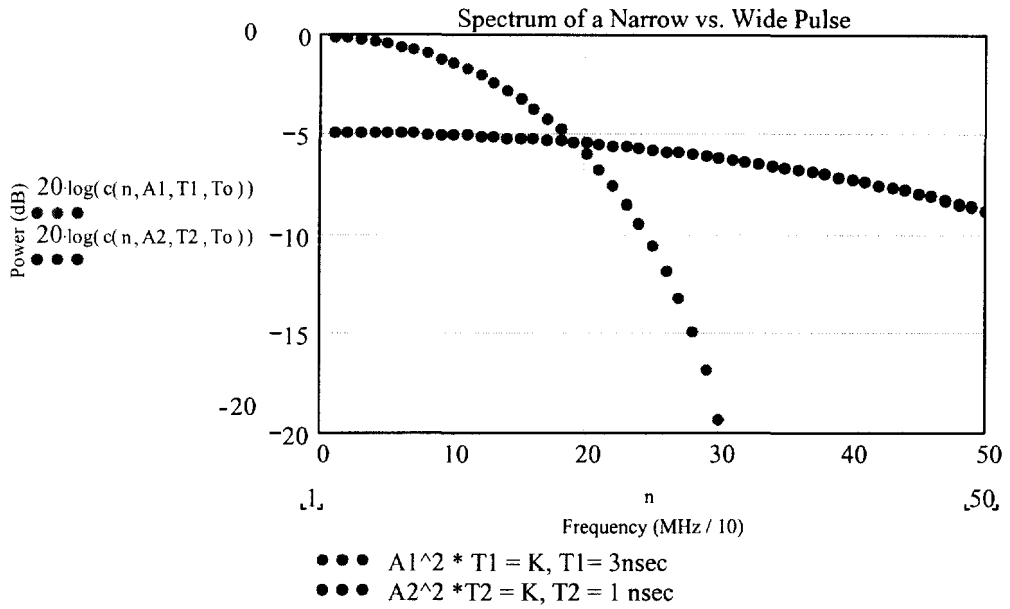


The frequency domain representation of the pulse train shown above is given by:

$$c(n, T, To) := \frac{T \cdot A}{To} \cdot \mathrm{sinc}\left(\frac{n \cdot T}{To}\right)$$

This equation gives the amplitude of the frequency components of the pulse train. From this equation some of the characteristics of a pulse train in the frequency domain are observed:

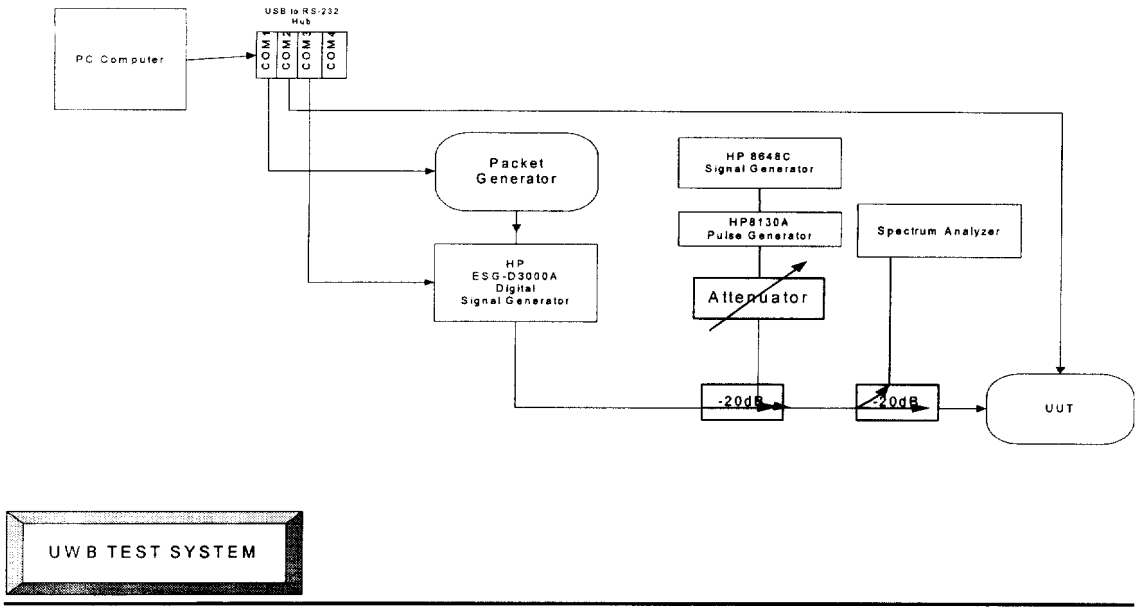
- The spacing between the spectral lines is equal to the pulse rate
- The magnitude and power of the spectral line is a function of the pulse width and rate
- The narrower the pulse the wider the signal is spread over frequency
- Modulating the amplitude or position of the pulse smears the spectral lines
- While in the in the time domain the signal has a pulse characteristic, in the frequency domain the signal appears as an average continuous power spread across the line spectra.



The graph above shows the difference in frequency spectrum of a 3nsec pulse vs a 1 nsec pulse with the same energy. The graph illustrates how the power is spread over a larger bandwidth as the pulse width is made smaller.

Lab Results

Metricom is performing tests in the lab based on conducted and radiated interference measurements to quantify the interference impact of a UWB signal vs. that of a typical Part 15 device. The conducted test setup consists of a HP8130 pulse generator coupled through an attenuator and then combined with a HP Signal generator used to generate Metricom packets. To quantify the increase in probability of interference from UWB devices relative to typical Part 15 devices the HP8130 pulse generator will be replaced with various Part 15 devices and UWB devices. Metricom notes that the availability of actual UWB devices at this time appears limited, the process to acquire them on the order of weeks and asks that an extension of the Oct. 30 deadline for testing results be considered. Additionally Metricom desires to work closely with the UWB vendors during the testing process to ensure test results are correctly reviewed and interpreted. Metricom has no test results to report at this time but can show the frequency plots of a simulated UWB signal modulated and unmodulated vs. a Part 15 Metricom modem.



The test procedure consisted of:

1) Adjusting the level of the HP signal generator (i.e. the Metricom packet generator) until the packet success is 90%
2) Increase the HP signal generator level by 1 dB and verify that the packet success is 99.9%
3) Adjust the attenuator of the interfering signal until the packet success is 90%
4) Repeat steps 1 through 3 for the following interference sources
5) Metricom Part 15 Modem

These plots show the time domain and frequency domain characteristics of a interfering UWB signal with a Pulse Repetition Frequency (PRF) of 10 MHz. In the 2.3 GHz WCS band the average power of the simulated UWB signal in a 1 MHz bandwidth was –65 dBm. This is 24 dB less than would be allowed under the proposed rules.

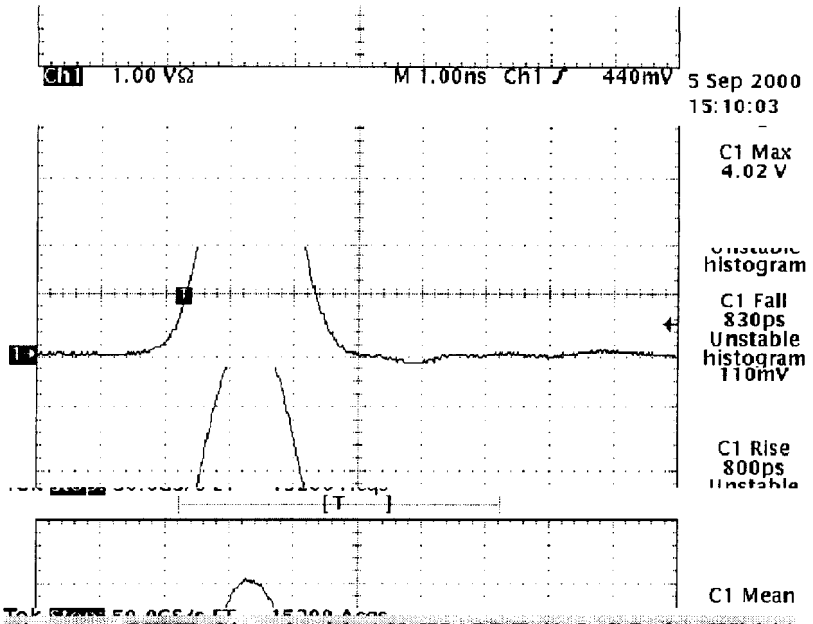


Figure 1: UWB Signal with 10MHz PRF (1.5nS Pulse Width)

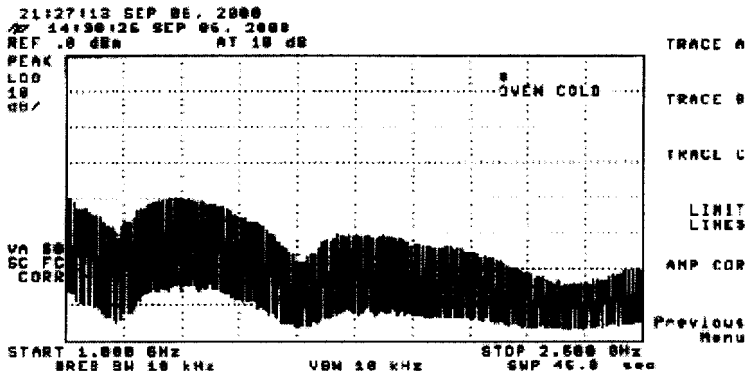


Figure 2: UWB Signal with 10MHz PRF (1.5nS Pulse Width)

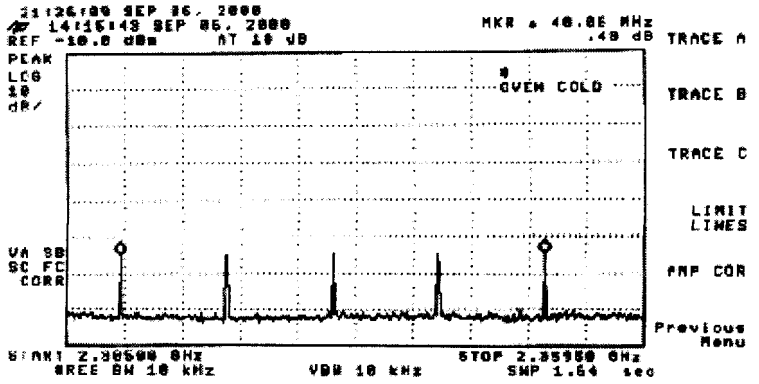
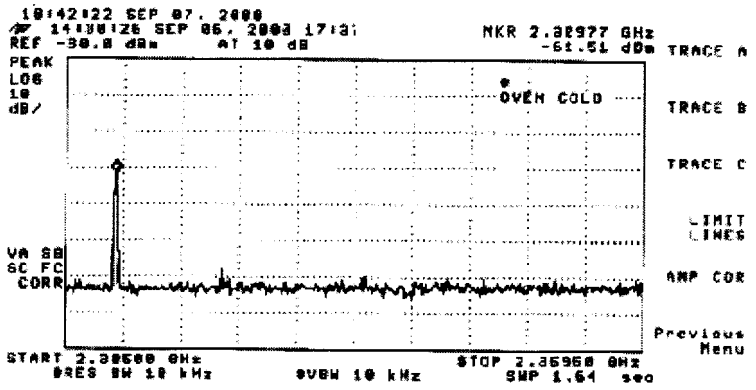


Figure 3: UWB Signal with 10MHz PRF (1.5nS Pulse Width)

Figure 3 above shows the spectra lines of the UWB signal in the WCS band.

The figure below shows the spurious energy of a Part 15 Metricom modem in the WCS band. The signal shown in the graph is the test signal from the HP signal generator used to generate Metricom packets, it is not a spur from the Metricom modem. This graph illustrates that the probability interference from a nearby typical Part 15 device to a 2.3 GHz receiver is very low because its intentional and spurious energy is confined to a very small portion of the spectrum.