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 Transmission Systems	Docket No. 98-153

Comments of The Ultra-Wideband Working Group

December 22, 1998

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Executive Summary

Ultra-wideband ("UWB") technologies can save lives, protect property, and provide for more effective uses of radio in a variety of applications that largely involve short range low power operations. Many of these are not feasible without UWB; others can be enhanced greatly by the use of UWB.

Comprised of developers, potential customers, and test engineers, the Ultra-Wideband Working Group ("UWBWG") urges the Commission to move forward with a notice of proposed rule making to amend the regulations in order to establish regulations through which UWB technologies can serve the American public without causing harmful interference to existing services.

UWB technologies can be implemented in low cost, low power integrated circuits; provide for the efficient use of large amounts of RF bandwidth at relatively low frequencies; achieve extremely fine time and range resolution in radar and positioning applications; offer large amounts of processing gain; provide immunity from multipath distortion; work well with sparse antenna arrays; transmit signals that exhibit a low probability of detection and interception; and support systems that are extremely unlikely to interfere with existing services. As such, UWB technologies can bring about dramatic improvements in communications systems, radar operation, and positioning/ranging systems.

Because of their unique characteristics, UWB technologies can support a wide variety of socially beneficial applications. Many of these involve public safety, industry, transportation and construction. Other applications of UWB technology can enhance the lives of the physically disabled and consumers. Nearly all of these benefits, however, depend on the Commission's implementing a regulatory framework that allows UWB techniques to be employed.

The UWBWG proposes a technical definition of ultra-wideband for the Commission's Rules. These comments also recommend a regulatory structure largely built upon amendments to Part 15 of the Commission's Rules to facilitate unlicensed operation on the conditions that harmful interference not be caused and that interference received be accepted. For most applications, the UWBWG recommends emissions limits based on the Class A and Class B digital device limits. The UWBWG also encourages the Commission to adopt measurement procedures much like those now employed for the measurement of noise from digital devices.

In short, the UWBWG urges the Commission to recognize the opportunity now before the agency to advance the technological state of the art associated with wireless applications by moving forward to propose regulations that will bring to the public the benefits of ultra-wideband technologies.

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The Ultra-Wideband Working Group ("UWBWG") submits these comments in response to the Commission's *Notice of Inquiry* ("*NOI")* released September 1, 1998.[1] As a committee of developers, potential customers, and test engineers of ultra-wideband ("UWB") technologies, the UWBWG commends the Commission for initiating this examination and offers these general comments on matters of common interest among its members.[2] UWB technologies can provide significant benefits through new products and enhancements to current applications that cannot be offered by other approaches. Accordingly, the UWBWG urges the Commission to move forward to issue a notice of proposed rule making looking toward the amendment of the agency's

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[1] ____FCC Rcd _____ (Sept. 1, 1998). Notice was given in the *Federal Register* on September 21, 1998. 63 FR 50184 (1998).

rules to facilitate the regular use of UWB technologies in a variety of beneficial applications of a largely short range, low power nature. In the meantime, the Commission should continue to learn more about the real world uses of UWB technologies through the grant of limited waivers that will help to build the sort of knowledge base that will give the Commission the insight needed to proceed with further consideration of UWB regulations and begin to bring these benefits to the users of the technology. The UWBWG offers its services to the FCC as a newly formed Ad Hoc Technical Group to evaluate and advise on technical issues involving UWB.

UNIQUE CHARACTERISTICS OF UWB

The benefits of UWB technologies are derived from its unique characteristics. These characteristics include:

- An inherent capability for integration in low cost, low power IC processes;
- Huge RF bandwidths at relatively low frequencies;
- Extremely fine time and range resolution even through lossy, opaque media;
- Large processing gains;
- Immunity from multipath;
- Grating lobe mitigation in sparse antenna arrays;
- Non-interfering operation with existing services; and

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[2] Many individual members of the UWBWG are expected to offer their own views on issues presented in the NOI in order that the Commission may develop a comprehensive record that will be useful in future proceedings involving UWB technologies. A list of the members of the (Continued...)

- Low probability of detection and interception.

UWB technologies offer major enhancements in three application areas: communications, radar, and positioning/ranging. The unique value of UWB for each of these applications is outlined below.

Communication systems

With large RF bandwidths available through use of UWB techniques, ultra-broadband communications links become feasible, e.g., hundreds of megabits per second and even giga-bits per second.

This bandwidth is available at relatively low frequencies, so attenuation due to building materials is significantly lower for UWB transmissions than for millimeter wave high bandwidth solutions. Additionally, by operating at lower frequencies, path losses are less and so the required emitted power to achieve a desired performance is reduced.

By trading data rate for processing gain, UWB radios can operate in the presence of high levels of interference.

The attributes of low emitted power and wide signal bandwidth result in a very low spectral power density of the UWB signal which means that UWB radios can operate in the same spectrum space as narrowband radios on a non-interfering basis.

Sparse antenna arrays ,when combined with UWB waveforms, an mitigate or eliminate the grating lobes associated with sparse antenna arrays when used with narrowband

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UWBWG is attached at Appendix A.

transmissions. This allows for more efficient utilization of the spectrum through more optimal spatial reuse of the spectrum.

Radar systems

For radars, the very large bandwidth translates into superb radar resolution (the ability to differentiate between closely spaced targets). When combined with the relatively low operating frequencies, this high resolution can be obtained even through lossy media such as foliage, soil, and building walls and floors.

UWB radars can, therefore, "look" into and through walls that would attenuate millimeter wave signals to spot closely spaced, small objects. Additionally such radars are being used to image the ground and could even be used in fresh water.

UWB antenna arrays are especially important in radars where it is desirable to have both fine range resolution, but also fine angular resolution. Electronically steered arrays can be light and inexpensive, yet still provide exceptional angular resolution.

Positioning systems

As has been demonstrated by the Global Positioning Satellite System (GPS), location and positioning requires the use of time resolved signals. In the case of GPS, the signal allows position determination to within tens of meters and with special techniques significantly greater accuracy is possible. Since there is a direct relationship between bandwidth and precision (i.e., increasing bandwidth increases positional measurement precision), with UWB techniques extremely fine positioning becomes feasible, e.g., sub-centimeter and even sub-millimeter.

Architectures for UWB position-determination systems would resemble traditional systems, e.g., multi-lateration like GPS or radio ranging like the military's Enhanced Position Location and Reporting System (EPLRS).

Again, the relatively low frequency of operation means that such a system has the potential to work within buildings with minimal attenuation of the signal.

It must be noted that with UWB techniques, it becomes feasible to fuse these unique capabilities into a single system. Thus, it is possible to create communications systems in which position is determined to within less than a centimeter. Moreover, it is possible to build radars (proximity sensors) that communicate simultaneously.

UWB exhibits all of these characteristics while allowing spectrum reuse, i.e., UWB emissions can coexist with other emissions on a non-interfering basis.

Example Applications

These enhancements to communications, radar and positioning applications are made possible by the unique characteristics of UWB. Moreover, there is the potential to provide not only improvements to current devices and services, but also to create new and beneficial products. For example:

- Asset tracking and RF ID Tags for inventory control in warehouses, shipyards, and railroad yards;
- Wireless LANs for consumer, commercial, and industrial environments;
- Covert Communications for law enforcement and public safety;
- Position determination for consumer (e.g., skiers trapped in an avalanche), commercial (e.g., medical personnel and equipment in a hospital), industrial, law

enforcement and public safety;

- Advanced security sensors and systems for highly reliable security and access control systems;
- Automotive Sensors for pre-crash sensing, optimal airbag deployment determination and overall safety improving functions;
- Wall sensors to map internal structures for the construction industry to improve construction quality and reduce accidents;
- Through-wall radars for law enforcement and public safety;
- Ground Penetrating Radars (GPRs) for utilities location, bridge and roadway inspection, law enforcement, scientific and humanitarian purposes such as unexploded ordnance and landmine detection;
- Virtual and augmented reality sensors for teleoperated equipment and games;
- Biometric telemetry systems for the elderly, the physically disabled, and persons with medical conditions; and
- Virtual electronic fences for improving security at critical industrial facilities.

UWB technologies employ a variety of methods to place small amounts of energy within a given amount of spectrum at a particular time. These include short pulses, "noise" signals, very high chip rate direct sequence spread spectrum systems, swept frequency systems, and stepped frequency systems. No doubt other approaches will also emerge. The key to the successful introduction of an ultra-wideband technology should be its ability to provide important, critical, and beneficial services to society while minimizing interference to incumbent spectrum users. This inquiry sets the stage for the establishment of a regulatory framework that will foster the development of such beneficial innovative technology without impairing the performance of systems that operate successfully today in the face of a plethora of radio noise that bears a great resemblance to UWB signals, which, unlike noise, can perform a variety of useful tasks.

By establishing provisions by which UWB technologies can be introduced, the Commission will not only provide a direct benefit to those who will use these technologies, it will also fuel the engine of innovation across many segments of the American economy. These include, without limitation, the software industry, the development of microwave semiconductors, the construction industry and the automobile and other transportation-related industries.

Many potential applications of UWB technologies are not feasible today because the regulatory structure does not accommodate bandwidths that may involve 1 GHz or more of spectrum at low frequencies. For example, future applications of UWB to measure short distances to fine range accuracy through lossy , opaque media cannot be carried out with current technology. Under a revised regulatory framework, however, UWB technologies will find their way into applications such as pre-crash sensors for automobiles,[3] be used to define security precise zones with centimeter accuracy around sensitive areas such as parked aircraft, and support short range high capacity data links that today can be addressed only through fiber optic and hardwired systems.

At this time, North America has the lead in the development of UWB technologies. Much of the development work has been done in the United States and Canada. At the same time, the Working Group FM of the European Radio Office has recently been asked to study UWB issues. Asian Pacific nations are expected to follow suit. Now is the time for the Commission to exercise leadership in fulfilling the mandate of Section 7 of the Communications Act to foster the development of beneficial technologies. The UWBWG urges the Commission to seize this opportunity to set the course for the regulation of UWB technology so that it can yield its benefits to consumers, commercial and industrial users, public safety sector and beyond. To this end, the UWBWG is pleased to offer these comments on certain questions raised by the Commission in the NOI.

REGULATORY TREATMENT

Definition of an Ultra-Wideband Signal

UWB technologies will not be operating in virgin spectrum. The spectrum in which UWB technologies will likely have their first and perhaps most beneficial applications falls below 30 GHz and is used heavily for many vital applications. As such, it is important that UWB technologies be compatible with existing users. Because UWB will be an exception to existing models of frequency management and regulation, it is important that the Commission settle on a

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[3] This application should be distinguished from those addressed in the vehicle radar systems envisioned for the millimeter wave bands. Both types of sensing will enhance the safety of vehicle operation.

definition of “ultra-wideband” systems that can be readily understood and applied. This definition will effectively open the door to application of any UWB regulations that may, for example, allow for energy from UWB intentional radiators to fall within certain of the bands now designated as “restricted bands” in Section 15.205 of the Commission’s rules.

The UWBWG suggests that any definition of “ultra-wideband signals” include the concept that the fractional bandwidth of the emitted signal be greater than or equal to 25%[4] . This could be set forth in the expression in which fractional bandwidth is defined as

$$\text{fractional bandwidth} = 2(f_H - f_L) / (f_H + f_L).$$

In this case, the upper limit of the signal is the frequency expressed as f_H while the lower limit is the frequency expressed as f_L. The range of f_H to f_L should be defined as being the frequency range in which a specified percentage of the energy of the emitted signal falls. If f_H to f_L were to be specified as “occupied bandwidth,” then 99% of the energy would fall within this range. Alternatively, f_L and f_H could be expressed in terms of the frequencies at the -20 dB bandwidth points, which is more straight forward to measure. Technologies that would fall within this classification include short pulse techniques, time dithered short pulse techniques, noise signal, high chip rate direct sequence spread spectrum, and swept and stepped frequency systems.

The UWBWG proposes the following definition of an “ultra-wideband signal” for

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[4] Assessment of Ultra-Wideband (UWB) Technology, OSD/DARPA Ultra-Wideband Radar Review Panel, R-6280, Defense Advanced Research Projects Agency (July 13, 1990); see also
(Continued...)

purposes of the Commission's Rules:

> *Ultra-wideband signal*. An ultra-wideband signal is an intentionally radiated signal with a fractional bandwidth greater than or equal to 25%.

Where the term "fractional bandwidth" would be defined in the Commission's Rules as follows:

> *Fractional bandwidth*. The bandwidth defined by the expression $2(f_H - f_L) / (f_H + f_L)$ in which f_H is defined as the highest frequency limit and f_L is defined as the lowest frequency limit, which mark the frequencies that are 20 dB below the maximum of the power spectral density envelope.

Conditions on Operation of UWB Devices

As a general principle, UWB devices should be regulated under Part 15 of the Commission's Rules. UWB equipment will consist generally of low powered short range devices. This equipment should operate on a secondary basis subject to the conditions that it not cause harmful interference to existing services and that it accept any harmful interference from existing services and from other operations authorized under Part 15.

Restricted Bands

As the NOI notes, the restricted bands set forth in Section 15.205 and the television broadcast bands merit special consideration in the case of UWB signals.[5] For most UWB applications, it is not possible to avoid all of the restricted bands. Some UWB applications such as ground penetrating radars, for example, may also need to place emissions into the television

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Introduction to Ultra-Wideband Radar Systems, James D. Taylor, ed., CRC Press, at p. 2 (1995).

broadcast bands.[6] If the benefits of UWB technology are ever to be realized, operation in this spectrum must be accommodated under reasonable regulations designed to minimize the likelihood of harmful interference.

UWB signals generally look like the signals commonly encountered from unintentional radiators operated under the Commission's Rules. For example, impulse radar systems generate signals that look much like the sort of timing pulses commonly emitted from personal computers. Under the Commission's Rules, such unintentional radiators are not prohibited from placing signals in the restricted bands or the television broadcast bands. Instead, such radiated signals are subject to the field strength limits set forth in Section 15.109 of the Commission's Rules. This rule sets forth two limits. The more restrictive limit (the Class B digital device limit) applies to digital devices marketed for use in residential as well as commercial and industrial environments. The rule also sets forth the Class A digital device limits which are about 6 dB less restrictive than the Class B limits. The Class A limits, however, apply only to digital devices that are marketed for use in commercial and industrial environments. These limits, first adopted in 1979, have proven effective over nearly 20 years of explosive growth in the number of digital devices. As

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[5] NOI, ¶ 5.

[6] In fact, the principal regulator issue confronting UWB technologies under Part 15 involves the fact that the rules distinguish between *intentional* and *unintentional* radiators. With few exceptions, only emissions from intentional radiators that meet the definition of *spurious* in Part 2 of the FCC Rules are permitted in the TV bands and the restricted bands set forth in Section 15.205. This holds despite the fact that unintentional and incidental radiators are allowed to place noise signals into these bands that are as strong or stronger than the signals that would be generated by UWB devices and also fall both within and outside of these bands.

such and because UWB emissions generally resemble digital device emissions, the UWBWG submits that the same limits should apply in the case of UWB devices.

The NOI asks about the possibility of notch filters as a means to lower emissions in the television and the restricted bands. Unfortunately, notch filters will degrade the performance of UWB systems to the extent that the enhancements this technology provides over traditional approaches, and the unique applications that only UWB can support, will be nullified and the systems no longer be viable. Notch filters that would not significantly distort UWB waveforms would not be true "notch" filters but rather filters with large stop bands. Between 1.0 GHz and 5.0 GHz, the restricted bands take up almost 50 % of the spectrum. Thus, if multiple notch filters were required, the overlapping filters would effectively become an attenuator. This would result in a significant loss of energy if UWB technologies were forced to notch out the restricted bands, and would also greatly distort the waveforms that make the technology so unique and beneficial. The insertion of filters with their inherent losses and distortions to suppress emissions in these multiple non-adjacent bands would so impair the technology as to render it impractical.

The television bands present a similar challenge. When the Commission revised the Part 15 regulations in 1989, it appears that a concerted effort was made to avoid allowing the use of television broadcast spectrum for most intentional radiators because of the fear that Part 15 devices would gravitate generally to vacant TV channels without regard to interference to TV reception or the other uses being made of that spectrum. UWB use, however, is not likely to move toward the TV bands for the same reason. Instead, UWB emissions that fall into the TV bands will do so because of the particular nature of the UWB application and the UWB waveform. For example, a radar designed to look into the ground may need to operate across certain portions of the HF, VHF, and UHF spectrum. Although the vast bulk of the energy from such devices would be directed toward the ground and away from victim receivers, limiting the field strength of signals that fall into the VHF and UHF bands generally to levels consistent with Section 15.109 would be a means for restricting the interference potential of such radars to no more than that of Class A and Class B digital devices.[7]

EMISSION LIMITS

As suggested above, the UWBWG recommends that the Commission proceed with the issuance of a notice of proposed rule making that would subject UWB devices to operating limits that are consistent with the Class A and Class B digital device limits for radiated emissions . The Commission should also maintain the requirement that emissions measured in the peak mode cannot be more than 20 dB above the average limit. The current digital device emissions limits on AC line conducted emissions should continue to apply.

In certain carefully defined and controlled circumstances, UWB emissions greater than those set forth in Section 15.109 may be appropriate if implemented on the basis of *in situ* measurements. For example, it may be possible to implement systems inside commercial offices and industrial buildings in which the emissions outside of the buildings do not exceed those now

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[7] The concept is hardly novel. Section 15.211 already allows for systems in mines and tunnels to radiate at field strengths far greater than the Part 15 levels provided that the measured emissions at openings do not exceed the limits set forth in Section 15.209, which are equal to the Class B

(Continued...)

set forth in Section 15.109 of the Rules. Such an approach would be similar to that employed in the case of certain perimeter protection systems that operate in VHF TV spectrum and campus wide carrier current AM band radio broadcasting systems.[8]

By proceeding with the regulations based on these limits, the Commission will provide a framework in which commercially viable products can be developed. At the same time, the similarity of UWB emissions to digital device emissions (i.e., broadband noise-like spectra) provides assurance that the proposed limits would adequately protect licensed services and operations conducted in the restricted bands.

The NOI also asks about the possibility of cumulative effects from UWB emissions.[9] If there were likely to be adverse cumulative effects from UWB emissions, these effects would likely have shown up with the proliferation of unintentional radiators. Nevertheless, if this concern persists, the Commission should as part of its inquiry gather field data from UWB operations in order to analyze and, if necessary, simulate the cumulative effects, if any, from a

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digital device limits.

[8] See Sections 15.201(c) and (d), 15.209(g), and 15.221(b)(2) of the Commission's Rules. In situations involving installations that are uniquely configured to buildings, the authorization could be conditioned on *in situ* testing for the particular installation as is now done in the case of certain ISM devices. *See* FCC Methods of Measurements of Radio Noise Emissions from Industrial, Scientific, and Medical Equipment, FCC/OST MP-5 (Feb. 1986), ¶ 6.2. In other cases in which the system cannot be tested on an open range, it may be appropriate to conduct tests of three installations as part of the approval testing. Once the device had been found compliant in three such sites, it would be approved for use in similar sites without the necessity for additional testing. *See* American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz, ANSI C63.4-1992, § 5.6.

large number of UWB devices operating in relatively close proximity.

MEASUREMENTS

Limits applied to UWB emissions take on meaning only when the measurement technique has been specified. As a goal, the Commission should strive for easily understood and readily implemented measurement techniques that can be employed by test labs with a minimum of additional training and equipment.

The UWBWG recommends that the average and peak measurement techniques specified in ANSI C63.4-1992 be used with resolution bandwidth of 1 MHz for frequencies above 1 GHz. No pulse desensitization factor should be applied. For frequencies below 1 GHz, measurements should be made using the quasi-peak detector and measuring bandwidths specified in ANSI C63.4-1992, but without applyng a pulse desensitization factor. Devices designed to operate while in contact with specified surfaces should be measured while in contact with such surfaces. For example, ground penetrating radars should be allowed to place energy into the ground at levels in excess of the Part 15 limits provided that the equipment is designed so that it operates only while in contact with such a surface. Any energy that leaks into the atmosphere from such radars should be measured using conventional techniques adjusted for the placement of the radar unit.

As stated above, the UWBWG believes that no pulse desensitization factor should apply

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[9] NOI, ¶ 12.

to UWB waveforms. Application of pulse desensitization as is now done for certain Part 15 measurements would not accurately reflect the interference potential of UWB devices. It makes no sense to back out to the full bandwidth of the UWB signal unless the victim receiver's bandwidth were equal to that of the UWB signal. Moreover, if that were the case, the victim receiver would be intercepting much higher power from licensed stations and from unlicensed devices operating in Part 15 bands set aside for higher power operation.

The Commission noted in the NOI that UWB devices could run afoul of the prohibition on damped sine waves.[10] This is largely a semantic issue brought about by the fact that the prohibition on damped sine waves came about in an effort to transition from high powered spark gap transmitters(where receivers had narrowband front ends) to vacuum tube power amplifiers in the early days of radio. The Commission should reaffirm its tentative decision not to apply the damped sine wave prohibition to UWB emissions. Unlike the roar of spark, the whisper of UWB emissions is designed not to interfere with other services. Spectrally efficient UWB systems, unlike an antique spark system, will by design capture most of the emitted energy and use it in the communications or radio location function performed by the UWB system. Accordingly, the Commission should find that the damped sine wave prohibition does not apply to ultra-wideband signals.

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[10] NOI, ¶14.

Conclusion

Section 7 of the Communications Act states that it "shall be the policy of the United States to encourage the provision of new technologies and services to the public." 47 U.S.C. § 157 (1998). By implementing a regulatory framework that will provide for the regular authorization of ultra-wideband technology for a host of beneficial applications, the Commission will fulfill this statutory mandate. In so doing the Commission should move forward with the issuance of a notice of proposed rule making designed to bring the benefits of UWB technology to the American people.

Respectfully submitted,

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By:______________________________

Appendix A

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