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November 13, 1998

Commissioners Secretary
Magalie Roman Salas
Office of the Secretary
Federal Communications Commission
1919 M Street N.W.
Rm. 222
Washington, D.C. 20554

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Dear Ms. Salas

Re: **Notice of Inquiry** –UWB
ET Docket No. 98-153

ANRO Engineering is pleased to have the opportunity to respond to the FCC **Notice of Inquiry** dated September 1, 1998 concerning the licensing of UWB transmissions under Part 15 regulations. Let us state directly that we are totally in favor of this action by the FCC; it has taken a long time for the FCC to reach this position I have been involved in UWB technology since its inception circa 1965. We have at earlier meetings with FCC personnel consistently taken the position that (1) UWB signals generated were not class B emissions outlawed by international treaties, (2) they were noninterfering with other devices located in the bands from 1-3 Ghz because the signals were either below the noise levels of receivers in the field, or (3) could not be detected by conventional receivers because of their very short duration.

I would like to congratulate the person(s) who wrote the **Notice of Inquiry** for their grasp of the technology and the clear way in which they described the background.

For many years the FCC and NTIA (its military equivalent) have been using CW frequency domain definitions to measure interfering signals for Part 15 application, including the use of certain antennas. The use of these procedures to determine the possible interference caused by UWB signals were and are insufficient. Clearly, signals should be defined and measured in the domain where their properties are most compactly contained. One would not want to describe the properties of a narrow band filter in the time domain--its impulse response would "ring" for a long time and is therefore not well contained in this domain. Using the same

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logic, one would describe the properties of a matched filter in the frequency domain where the amplitude spectrum and phase function of the line must be described over large bandwidth when the impulse response of the line is contained in a narrow region of the time domain.

The probability that many of the UWB systems that are being currently used today might interfere with other equipment either operating in or near the range of frequencies containing the bulk of the pulse energy is remote at best. There are exceptions to this, of course, that should be noted for the record. The military has researched the use of very high peak power generators of UWB energy (e.g., 10-100 Gw) to disable or destroy electronic equipment. The hand held devices or small sensors used for intrusion detection that are being proposed for use under modified Part 15 regulations have many orders of magnitude less power. To detect these low-level signals, specially designed receivers must be used. Interference between many UWB systems has a very low probability because of coding employed by the different UWB receivers. In your **Notice of Inquiry** you indicate that "...Most of the current equipment designs that have been investigated by the Commission contain high level, distinct spectral lines concentrated near the center (frequency) of the emission. Such spectral lines are proportional to the pulse burst length and separated in frequency by the pulse repetition frequency or PRF. It is not difficult to show that by appropriately randomizing the PRF of the transmission by 90% or greater the spectral lines completely "smear" and their levels down are reduced by 20-30dB or greater. But you correctly conclude that "... Such signals are not easily detected or interpreted".

ANRO Engineering is currently involved in research and development of UWB radar and communication systems. Although our work is primarily funded by military contracts there is no question in our minds that there are civilian application, as well, that can benefit from the use of this technology as clearly stated in the Discussion Section of the Notice. I will try to answer in the paragraphs below some of the questions that were asked in the **Notice of Inquiry** in an attempt to help you formulate realistic rules for UWB signals.

Q1- What type of UWB devices can we expect to be developed?

ANRO is currently developing intrusion sensors for military customers, which may also have commercial application, devices designed for protecting defined perimeters on water and on land. These are small units less than 1 cubic foot in volume with peak powers in the order of 1 kw for a pulse duration in the order of 1ns and at a nominal PRF of 1kHz. The nominal center frequency of operation is 2.25 Ghz.

ANRO is also developing hand-held covert radios operating in the S band region of the spectrum for voice only. The devices are self-powered and are for use by downed pilots in hostile areas, for example.

Q2-What are the frequency range and bandwidths expected to be used by UWB devices?

Both the radar and communication systems can operate efficiently over a 1-1-3 Ghz nominal band with bandwidths of 500-1000 MHz.

Q3-What are the expected total power levels and spectral power densities, peak and average of UWB devices?

The average power levels for our devices are less than 1mw. The peak power levels are in the order of 1kw. The bandwidth is in the order of 1 Ghz. Hence, the average power density for the equipment that we develop is 10^{-12} watts/Hz.

Q4-What are the expected or desired operating distances?

The intrusion radar systems have a range in the order of 300-400 feet on a one square meter target. The communication systems have a range of 20 km.

Q5- Are there certain types of UWB devices or applications that should be regulated on a licensed basis under some other rule part? If so what rule parts?

Clearly, high peak and average power devices used for countermeasures or destruction purposes and only useful during military operations are not to be considered here. For average power devices of 10 mw or less and with rms pulse widths of 2 nanoseconds or less in the 1-3 Ghz nominal frequency range (i.e., a UWB signal), it is difficult to see how these could cause interference with other electronic systems. In addition, it should be noted that radiated power falls off as the square of the distance so that power levels that were measured at 1 meter drop off an additional 20 dB, for example, at 100 meters .And the chance alignment of the antenna pattern for both the transmitting antenna is a probable cause of further loss. All these factors lead us to believe that a UWB system having the parameters indicated should require no licensing.

We are not sufficiently familiar with the other rules to address the second part of your question.

Q6- If provisions are made for UWB technology under Part 15, how should we define UWB technology?

We defined the parameters for a microwave signal as one whose fractional bandwidth is 25% or greater. This was the definition agreed to by the special DARPA Committee headed by Mr. Burt Fowler circa 1990 . We would suggest a measurement scheme similar to that described in Part 15 but in the time domain to assure that the signals do not exceed peak and average power limitations as well as the pulse width. Note that we do not recommend specifying the bandwidth for this class signal . Overlap with some of the so-called forbidden bands must occur because the time and frequency responses are related by Fourier Transforms. And if the UWB signal is time limited (i.e., a short pulse) then it cannot mathematically be frequency limited! Practically speaking, however, the spectral energy for these signal in the forbidden bands are so low that they can be ignored.

We would suggest placing a standard dipole antenna whose lengths are cut to be half wavelength resonant at the nominal center frequency of the pulse packet at distance of 1 meter from the source and properly terminated . A sampling Oscilloscope or other time domain measurement system should be used to measure the rms pulse width. The time domain residues of the pulse packet should be down by 15 dB or greater from the main pulse packet (note: this determines only the shape of the passband of the transmitted pulse). The peak voltage squared divided by the matched termination, e.g., 50 ohms, and modified by the receive dipole gain on boresight determines the effective radiated peak power. Multiplying this number by the rms pulse width divided by the nominal pulse repetition period yield the approximate average power. And if this number is 10 mw or less at any microwave frequency, it should fall under the "new" modified Part 15 regulations for UWB signals. For systems operating below 1 Ghz, it is likely that the problems of interference will fall on the UWB receiver. Here the radio and TV bands not to mention other phone systems would represent a true challenge for the decoding networks in the UWB receiver(s).

Q7-Should the rules generally continue to prohibit operation within restricted bands and the TV broadcast bands?

No. No such restriction is required to prevent interference by UWB signals.

In fact, theoretically, the transmission of *any* time limited signal must produce some spectral energies in so called restricted bands because the properties of the Fourier Transform do not permit a signal to be both time limited and band limited. Pulsed rf signals are used every day!

Q8- Are there certain restricted band where operation could be permitted but not others? If so, which bands and what is the justification?

There are certain bands designated for radio astronomy that may have a justification for some form of band limiting or spectrum separation. Some consideration could be given to limiting spectral energy further for UWB signals operating near these band either in frequency or physical separation.

Q9- If certain restricted bands were retained, what impact would this have on the viability of UWB technology?

No significant impact. The nominal center frequency of transmission of a UWB system where the transmission results from "impulse" exciting its antenna can simply be moved by changing the dimensions of the antenna(i.e., by changing its natural resonance frequency). The natural resonance frequency of an antenna generally depends on its size. And for hand held devices one generally tries to use small device-hence the use of S or C band. For ground penetrating radar one needs to lower the frequency to achieve maximum ground penetration. Just small changes in dimensions can result in changes in the nominal center frequency and by shaping of the pulse , the spectral spread can be reduced at the cost of resolution. We have never had problems translating the signal spectrum band when necessary.

Q10- Are the existing general emission limits sufficient to protect other uses of the spectrum, especially, radio frequency operations in the restricted bands, from harmful interference?

The present Part 15 general emission is inappropriate and should be modified to accommodate UWB transmissions as outlined in the above paragraphs. The extra 20 dB provided for pulsed operation as currently provided is not necessary if the specifications for a limit of 10 mw average power are adhered to.

Q11-Should different limits be applied to UWB systems.

Yes, see above.

Q12-Should we specify a different standard for UWB systems based on power density? Should these standards be designed to ensure that the emissions appear to be broad band noise?

By specifying the maximum pulse duration and peak power levels, which can easily be measured in the time domain, we are essentially defining a spectral power density. We prefer keeping the definition, however, in the time domain where the measurements are more easily contained. To minimize spectral lines in the spectrum, we suggest the PRF of the signal be randomized to reduce the central lines by more than 20dB with all other spectral lines falling off more quickly. The resulting spectrum is , essentially, white noise.

Q13- What is the potential for harmful interference due to the cumulative impact of emissions if there is a large proliferation of UWB devices? Could the cumulative impact result in a high increase in the background noise level? Should the Commission limit proliferation by restricting the types of Products or should the rules permit manufactures to design products for any application as long as the equipment meets the standards.?

I see no harm in the proliferation large numbers of these short-range products. Since they are spatially widely dispersed and nonsychronized sources the powers probabilistically add as the square root of the number of sources. And since these are digital signals, they are not on at the same time! The Commission should not limit the number of these units offered for sale. The Commission should retain the right to change these rules if the results do indeed either show interference or problems that are not apparent at this time. For this reason we would recommend that any rule change be made subject to change after some trial period.

Q14-Should a limit on the total peak power level apply to UWB devices?

We believe that a limit of 10 mw should be placed on average power. And a peak effective radiated power might be limited to 2 kW in a trial phase.

Q15--Can emissions below or above a certain frequency range be further filtered to reduce the potential to other users of the radio spectrum without affecting the performance of the UWB system

Not without burdensome difficulty. Ideally, constraint of the UWB spectrum would be realized through time domain shaping of the transmitted pulse.,. This usually results in loss of transmitted energy and target resolution in the radar mode. It is more convenient to move the entire band by changing the resonant frequency of the antenna. We discussed earlier that that dispersing the pulse in the time domain will directly reduce bandwidth at the cost of resolution for a radar system. For a communication system increasing the pulse width, results in some loss in covertness.

Q16-Are the existing limits on the amount of energy permitted to be conducted onto the AC power lines appropriate for UWB devices.

Totally. Dispersion characteristics of these lines preclude the propagation of short pulse packets over any appreciable distance.

Q17-What operating restrictions, if any, should be required to protect existing uses.

By limiting peak power (2 kW), average power(10 mw), and pulse duration 2 Ns) as discussed earlier, we believe that users will be adequately protected. We see no further restrictions necessary.

Q18-Is the use of UWB modulation techniques necessary for certain types of communication systems; if so for what purposes?

Yes. The use of so called spread spectrum or low probability of intercept/low probability of detection (LPI/LPD) communication systems for covert transmissions are a natural application for this technology. Not only are the signals difficult to detect except by the use of an energy measurement device such as a radiometer over a long time period (depending on the power levels and word lengths), but with proper time varying coding are non-interfering with other UWB transceivers. Special military and anti-crime applications exist for this technology which cannot be described in the document because of security restrictions.

Q19- Is a pulse desensitization correction factor appropriate for measuring emissions from a UWB device? Should any modifications be made to this measurement procedure for UWB devices?

A 20-dB pulse desensitization factor as used for quasi-CW signals makes no sense here. We believe that if the peak and average power and pulse durations are limited in the time domain as described earlier there is no need for the correction factor now used. We prefer a limit on peak power (e.g., 2 kW) and average power (e.g., 10 mw) to prohibit the use and location of certain " UWB destruction" systems in civilian areas and place a limit on pulse duration to an rms pulse width less than 2 Ns in a 1-3 Ghz microwave band: for signals in higher or lower bands the fractional band width criteria of 25% or greater should determine the maximum pulse width. The limit on average power provides a means for high data rate communication system (e.g. 1-2 Mbytes) or a low duty cycle radar (e.g., 1 kHz) to operate by varying peak power to still fall within a new Part 15 regulation for UWB systems without causing interference with other devices.

Q20-Would another measurement procedure that does not apply a pulse sensitivity factor be more appropriate for determining the interfering potential of a UWB device?

As described earlier, we prefer to measure the actual radiated signal on a standard dipole antenna at 1 meter (taking into account the small amount of distortion introduced here) to determine the peak power, rms pulse width, and average power :the limits set above. Some prefer to use a UWB horn for this application. We prefer the dipole because it is the most well analyzed element and is easy to specify for any given measurement.

Q21- The frequency range over which measurements are required to be made depends on the frequency of the fundamental emission. Is the fundamental emission readily discernible for UWB devices? Are the frequency measurement ranges specified in the rules appropriate for UWB devices or should these ranges be modified?

It is difficult to specify the location of the nominal center frequency of a UWB transmission using current definitions. For example, one can certainly measure the 3 or 6-dB bandwidth of the radiated signal using a spectrum analyzer, but should we use the arithmetic or geometric definition to determine the nominal center frequency of the burst:? For large fractional bandwidth signals, these measurements are different. We prefer to view the pulse burst on a sampling oscilloscope and take the reciprocal of the period at the center oscillation within the pulse packet. This measurement , falls, generally, between the arithmetic and geometric means mentioned

Since the UWB signal inherently overlaps into other bands because of the time limited nature of the transmission as described earlier, one can only specify the location of the nominal center frequency of the burst as described in the paragraph above.

Q22- Are the measurement detector functions and bandwidth appropriate for UWB devices? Should these standards be changed and, if so, how?

It is appropriate , as explained earlier, when measuring these signals to perform all of these measurements in the domain where the signals appear compactly. For UWB signals, this is the time domain. To detect and view these signals one must use a device that does not distort the transmission. For this reason, we use a 100 MHz-18 Ghz sampling oscilloscope to view signals in the 1-3 Ghz band. By specifying a standard dipole antenna or perhaps a horn connected to the 50 ohm input terminals of a sampling oscilloscope with sufficient bandwidth to faithfully display the transmission, and use the peak voltage, and rms pulse width, and average power of the pulse transmission are correctly characterized.

Q23- Are there any other changes to the measurement procedures that should be applied to UWB devices?

Only that pertinent signal measurements are to be performed in the time domain as suggested here, it is important to use a measurement instrument such as a sampling oscilloscope that has a flat amplitude spectrum and a linear phase function over the 3 or 6 dB bandwidth of the signal transmitted; i.e., it is, practically, distortionless.

Q24-Should the prohibition against Class B, damped wave emissions apply to UWB systems or is the prohibition irrelevant especially in light of the relatively low power levels employed by UWB devices?

No. The prohibition against Class B emissions clearly does not apply for the low power devices that we have addressed. There is little similarity between the manner in which we currently generate time limited UWB signals and the old spark gap generators. Indeed, the waveform that we generate has a Gaussian envelope in both the time and frequency domains. However, some words are appropriate to address the concerns of Article 5, Section 1 of the 1938 regulations pertaining to damped waves because there are significant other difference besides the low power here that should be noted.

The damped waves described in the aforementioned treaty pertains to "...waves composed of successive series of oscillations the amplitude of which, after achieving a maximum decreases gradually ;the wave trains being keyed according to a telegraph code." The ideal pulse packets generated by UWB radar and communication systems are of the form $[U(t) - U(t - \tau)]\sin\omega_o t$, where τ is the pulse duration and U(t) is the unit step function and ϖ_o is the nominal center frequency of the burst.. Because of bandwidth constraints, the pulse packet rise and fall times are rounded, approximating a Gaussian shape. In fact, it is difficult to discern whether or not the radiated signal is a result of impulse exciting the antenna structure using a baseband pulse or is a result of gating a microwave oscillator. The IEEE definition of a damped wave from its Standard Dictionary of Electrical and Electronic Terms (IEEE Std 100-1972) describes a damped wave as a wave in which, at every point, the amplitude of each sinusoidal component is a decreasing function of time. This also does not fit what is generally radiated as a UWB signal. Our conclusion is that the treaty of 1938 does not apply to current UWB technology.

The last item in the Notice seeks comments on any other matters or issues that may be pertinent to the operation of UWB systems.

We support the work done by U.S. Radar, Time Domain Systems, Zircon, and others persevering with the Commission over the years to try to change Part 15 regulations to accommodate UWB technology. ANRO, in conjunction with Sperry Marine Inc, Charlottesville, Virginia, addressed Part 15 changes for UWB transmissions circa 1988. At that time ,we were trying to offer for sale to the public a UWB intrusion sensor developed for the then Defense Nuclear Agency under a Small Business Innovation Research program. The last memorandum that we have in our files dated December 1989 from Mr. Richard Engleman, the Chief of the Technical Standards Branch, Office of Engineering and Technology, Federal Communications Commission indicated a sympathy for accepting this technology using existing Part 15 definitions. The reason this sensor system was not accepted by the Commission at that time was that the Part 15 regulations ,written to be applied in the frequency domain, could not readily be understood or applied to UWB technology.

For your information, I have attached a copy of my resume to give you a some insight into my background and qualifications to respond to this Inquiry.

The correct approach that is now being taken by the Commission through this **Notice of Inquiry** is to be commended.

Sincerely,

Gerald F. Ross, Ph.D.
CEO

Attachment (Resume)

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GERALD F. ROSS

EDUCATION:

1979	Industrial Research Management Course (Summer) Harvard University
1963	Ph.D., Electrical Engineering - Polytechnic University, New York
1955	M.S., Electrical Engineering - Polytechnic University, New York
1952	B.S., Electrical Engineering - City College of New York

MEMBERSHIPS:

Member, National Academy of Engineering, Class of 1995
University Fellow, Polytechnic University, New York, 1990
IEEE, Fellow, 1970
Sigma Xi
Tau Beta Pi
Eta Kappa Nu
IEEE, Antennas and Propagation Society; Microwave Theory and Techniques Society
Polytechnic University, New York, Adjunct Professor
Member, IEEE Subcommittee on Pulse Definitions, PGIM
Member, Commission B and C United States National Committee, URSI
K.C. Black Memorial Award for the best NEREM, IEEE Paper, 1974
Professional Engineer, State of New York, Lic. No. P.E. 050081
Professional Engineer, Commonwealth of Massachusetts, Lic. No. 27289
Technical Evaluation Panel, National Bureau of Standards,
(3 year appointment by the National Research Council)

EXPERIENCE:

1996 -	CEO & Chairman of the Board, ANRO Engineering, Inc., Sarasota, FL
1981 - 95	President, ANRO Engineering, Inc., Sarasota, FL
1980 - 81	Manager, Electromagnetics, Sperry Research Center
1970 - 80	Manager, Sensor Systems, Sperry Research Center
1965 - 70	Department Head, Microwave and Antenna Research, Sperry Research Center, Sudbury, MA
1958 - 65	Research Section Head, Sperry Gyroscope Co., Great Neck, NY
1954 - 58	Senior Engineer, W.L. Maxson Corporation, New York, NY
1953 - 54	Lieutenant USAF, Air Research and Development Command, Alamogordo, New Mexico (Captain, USAF Ret.)
1952 - 53	Research Assistant, University of Michigan, Willow Run Research Center

FIELDS OF RESEARCH:

Microwave Networks, Impulse (Ultra-Wideband) Radar and Carrier-Free Communications Systems, Gigabit Pulse Technology, Batteryless Sensor Systems

PUBLICATIONS/PATENTS:

70 Technical papers in accredited journals; 57 patents granted, 2 pending (classified); Contributing Author to Text, *"Time Domain Measurements in Electromagnetics"*, Van Nostrand, 1986; *Radar Handbook*, Artech House, 1990; *Ultra-Wideband, Short-Pulse Electromagnetics* (Plenum, 1993).