Before the
Federal Communications Commission
Washington, DC 20554

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

Comments of David L. Wright, Ph.D.

David L. Wright, Ph.D., submits these comments in response to the Notice of Proposed Rule Making (NPRM), FCC 00-163, in the proceeding referenced above, and a more recent request for comments on testing by NTIA and others, and in response to recommendations and conclusions of others concerning proposed changes to Part 15 rules. The comments I offer here are based on my own experience and observations and do not necessarily reflect official positions of the U.S. Geological Survey.

Statement of Background and Interest

By education and practice I am a physicist, electronics engineer, and geophysicist. Since 1977 I have been primarily involved in the development of specialized electromagnetic geophysical equipment for earth science applications. With colleagues at the U.S. Geological Survey (USGS), I designed, built, and operated the first airborne radar system to successfully profile the bottom topography of a temperate glacier, the Columbia, in Alaska. We also developed perhaps the first borehole radar system capable of operating in deep wells (exceeding 5000 feet), and have pioneered the use of real-time full waveform digitizing (no analog sampling circuits) and averaging for improvement of geophysical radar signal-to-noise ratio. We built and used a high-performance, relatively low frequency "impulse" or "short-pulse" radar system for research on basal condition controls on ice stream dynamics in Antarctica. Recently we have developed a very early time electromagnetic (VETEM) system for shallow subsurface imaging in conductive soils where ground penetrating radar (GPR) does not see deep enough and conventional time-domain electromagnetic (TDEM) induction systems do not have enough resolution.

I have personally operated, or been part of field parties that operated, commercial GPR units, university-built geophysical radars, and USGS prototype radar and EM equipment of my own design, in Alaska, Hawaii, Greenland, Antarctica, and many states within the continental United States. Some of these systems were aircraft-mounted (Fairchild-Porter, Twin Otter, and LC-130) and interactions between geophysical radar and aircraft communication and navigation electronics, including a Global Positioning System (GPS), was of paramount concern to ensure the safety of the aircraft and military or civilian aircrews as well as that of the scientists, including myself, aboard the aircraft. In all cases it was found that with proper installation and operational procedures the geophysical systems were compatible with the aircraft avionics. In some cases it was necessary to ask the pilot to give us advance notice when he needed to transmit, because aircraft radio transmissions saturated the sensitive geophysical radar receiver. Could some geophysical systems cause interference? If improperly operated, some high-power prototype systems could cause interference, but geophysicists take care to avoid improper operation. High-power airborne ice-penetrating radars, for example, are operated only in remote regions, such as over polar ice caps. Common ground-based commercial UWB geophysical systems apparently have relatively little interference potential. I have heard no report, in over 23 years of experience with both commercial and prototype UWB electromagnetic geophysical equipment, of any UWB geophysical equipment-generated interference with GPS, commercial broadcasting or any other interference.

Most of the comments I offer here are in regard to geophysical time-domain UWB radar and TDEM systems with which I have had experience over the past 23 years. Many of my comments consider potential harmful interference to GPS from UWB GPR and EM geophysical systems because the integrity of the GPS is clearly an overriding concern for all users, including the geophysics community.

Benefits of Geophysical UWB Electromagnetic Systems

Electromagnetic UWB subsurface imaging has been practiced for decades, and for many applications there are simply no available substitute methods. Some long-established or feasible applications include:

1. Imaging and assessment of condition of runway, highway, and bridge pavements.
2. Location and identification of buried unexploded ordnance (UXO) and mines. Decades after cessation of hostilities, landmines exact an horrific toll on residents of areas contested in prior wars. In the United States, landmines are not a great problem, but buried unexploded ordnance on formerly used defense facilities is a large problem, especially now that such facilities are being transferred to civilian agencies and the public for recreational, residential, and commercial use. UWB GPR and EM are widely used in UXO location. Proposed UWB rules changes should be implemented in such a way as to ensure that landmine and UXO decontamination activities not be hindered, in view of the fact that UWB GPR and EM have not, to the best of my knowledge, caused harmful interference and are unlikely to cause harmful interference.
3. Subsurface direct detection of toxic substance leaks and spills, when possible.
4. Imaging of subsurface geology that may act as the control on water flow and toxic substance transport.
5. Imaging the contents of hazardous materials waste pits.
   For example, see pages 45-53 in http://www.osti.gov/em52/final_reports/60162.pdf
6. Imaging subsurface man-made structures. See pages 53-54 in above report.
7. Archeological applications.
8. Rapid location of avalanche and other natural disaster burial victims.
9. Imaging of subice topography for geologic and climate change research.

A more detailed list with emphasis on public health and safety applications and reference to the federal agencies involved has been given in comments by Gary R. Olhoeft. Also *see comments or reply comments by Dwain K. Butler, Lee Slater, A. Peter Annan, and others.*

Ground Penetrating Radar

Most of the comments I have seen with respect to geophysical applications have to do with GPR. Relevant information includes the following points:

1. GPRs are not intended to radiate into the air. *A. Peter Annan* argues that GPRs should therefore be classified as unintentional, not deliberate, radiators.

2. GPR antennas are not isotropic radiators. In fact, GPR manufacturers often go to great lengths to shield their antennas against radiation into, and from, the air. They have good reason to do so. Any such radiation is a loss from the energy propagated into the ground and also causes undesired and confusing reflections from trees, buildings, overhead power lines, and vehicles. Radiation into the air is to be avoided to the maximum extent possible. Of course minimal radiation does inevitably escape into the air. Some GPR antennas, especially those for lower frequency GPRs, perhaps below a center frequency of about 50 MHz, may be physically large and shielding may be impractical. However, even under those conditions, the radiation will be preferentially into the ground because the earth has the higher dielectric permittivity and the antennas are closely coupled to the earth. Exceptions to the closely earth-coupled cases are airborne operations, generally in remote regions such as over ice, and other applications where some standoff is required for safety reasons. An example of the latter would be the use of "cherry-picker" mounted antennas for landmine and UXO detection from an adjacent safe road or area. Airborne and elevated antenna GPR uses are relatively rare.

3. Especially for low frequency GPRs, as pointed out by Annan, it would be prohibitively expensive, if not altogether impossible, to adequately measure GPR emissions while realistically taking into account effects of the earth that vary from location to location. Indoor test cells might not be large enough to get outside the near-field zone of the GPR antennas. With the advent of accurate Finite Difference Time Domain (FDTD) code, the numerical electromagnetics code (NEC) and other electromagnetic modeling codes developed by universities, government agencies, and commercial companies, some combination of measurement and modeling might demonstrate that GPR poses no significant interference hazards. It is my opinion, however, that long, past "no complaints" history should not be ignored in these considerations.

4. Most, though not all, GPRs are of the short-pulse (impulse) variety. These are sometimes described as carrierless or baseband systems and have pulse repetition frequencies (PRFs) that are often less than 300 kHz. An exception is the micropower impulse radars and variants that are intended for short-range operation and often not into the earth. Some of these devices have been implemented as proximity warning sensors in automobiles as a parking aid, and as high-tech stud finders, for example. There are several reasons why conventional earth-imaging impulse GPRs do not generally exceed a PRF of about 200-300 kHz. One is the ability of a pulser, often a very small avalanche

transistor or step recovery diode pulser, to dissipate heat (a non-radiated form of energy). An additional reason is to allow enough time to fully recharge the capacitors that store charge between pulses. A third, and fundamental, reason is that, particularly for lower frequency GPRs capable of greater ranges, enough time must elapse between pulses that reflections from the greatest range of interest have enough time to propagate back to the receiving antenna before the transmitting antenna is excited by the next pulse. Since impulse GPRs utilize no carrier wave, once the transient currents on the transmitting antenna have been damped, there is no radiation from the GPR until the next pulse. For this reason, I urge that no criterion be applied to impulse GPRs that specifies an upper limit on the ratio of peak to average power, if "average" is defined over a full period. For a constant peak pulse power, as the PRF approaches zero the average power also approaches zero and thus the ratio of peak to average power approaches infinity!

Spectrum and Earth Parameters

In the report "Assessment of Compatibility between Ultrawideband Devices and Selected Federal Systems" (NTIA Special Publication 01-43) on page X of the executive summary, the following statement is made, "*This report shows that operation of UWB devices is feasible in portions of the spectrum between about 3.1 and 5.650 GHz at heights of about 2 meters with some operating constraints. Operations of UWB devices below 3.1 GHz will be quite challenging and any policy developed will need to consider the results of the analyses of interactions of GPS and UWB systems underway at NTIA and other facilities.*"

However, probing the earth is simply not possible at such high frequencies because of the electromagnetic properties of the earth, and any regulation that had the unintended effect of prohibiting UWB geophysical operations below 3.1 GHz would almost eliminate electromagnetic subsurface imaging, because the vast majority of GPRs and many other EM systems are time-domain UWB systems that operate with center frequencies from less than 1 kHz to as much as 2.5 GHz. But are UWB geophysical systems actually a problem? In the above-quoted statement, GPS interference is singled out as of particular concern. Indeed, GPS does use very sensitive receivers designed to reliably operate down to power levels as low as –130dBm. Low operating received power levels with the consequent requirement of high sensitivity receivers is unavoidable because the GPS satellites are far away and have limits on their transmitted power. ***To be concerned is not unreasonable, but to adopt a "UWB only above 3.1 GHz" policy without an exemption for geophysical systems designed to look into the earth would be unreasonable*** both for reasons cited above and for some to follow. The lowest frequency considered for possible interference with Federal Systems in Table 1, page VIII of the above report is 960 MHz, at the low end of the Distance Measuring Equipment (DME) Interrogator Airborne Receiver band. In fact, most GPRs and other EM geophysical systems have the majority of their low average power below, often far below, 960 MHz. In addition, everything else being equal, the higher the center frequency of an impulse radar, the lower the radiated peak and average power. This is partly because the faster a pulse has to be, the lower the possible amplitude, at least with common electronic devices such as avalanche transistors and step recovery diodes, and because high frequency antennas are generally physically small and have a small effective area.

<u>Compatibility of GPS Receivers and UWB from "Pulse-Like" Sources</u>

There are many reasons why protection of the GPS is of paramount concern. The GPS is crucial to military, civilian government, and a host of commercial systems and applications. The GPS has become a premier "enabling technology" with innovative new applications continually following in its wake. Its role in military and civil aviation, terrestrial, and marine navigation is large and growing, and some older radio navigational systems are being rendered obsolete by the GPS. What, then, is the potential for GPS interference from UWB signals, and are there factors that can reasonably distinguish GPR and geophysical EM systems from other UWB systems? Since the potential for UWB interference with GPS receivers is a dominant concern, several investigations on that subject have been conducted. One such study is reported in NTIA Special Publication 01-45, "Assessment of Compatibility Between Ultrawideband (UWB) Systems and Global Positioning System (GPS) Receivers." In that report, tests were conducted to assess potential UWB interference. UWB signals were classified as "pulse-like", "CW-like, and "noise-like". Section 2.2.2 of Publication 01-45 contains the following:
"*The measured UWB interference effect on the GPS receiver for each UWB permutation considered was classified as either pulse-like, CW-like, or noise-like. The pulse-like category is primarily developed as a result of the bandlimiting filter in the GPS receiver. That is, the bandwidth of the UWB signal is typically several orders of magnitude wider than the bandlimiting filters in the GPS receiver. Thus the pulse shape and bandwidth of the bandlimited pulse corresponds to the impulse response of the receiver filter. Pulses are independent when the filter bandwidth is greater than the pulse repetition rate. That is consecutive independent pulses, at the output of the bandlimiting filter, do not overlap in the time domain. …If the bandlimited pulse is independent and of sufficient amplitude, it will saturate one or more elements in the receiver during the pulse period. This will result in "holes" in the GPS signal. If these "holes" are relatively short and of a relatively low duty cycle, they will not seriously degrade the GPS performance. An increase in the amplitude of the pulse will not significantly increase the width of the "holes" and thus the interference effect is somewhat independent of UWB signal strength as long as the amplitude is below the receiver peak pulse power limit (+20 dBm). These effects are represented in the RTCA interference limits for pulsed interference.*

Typical GPS receivers have an IF bandwidth on the order of several MHz to 20 MHz, therefore, the pulses for most of the 0.1 MHz and 1.0 MHz PRF UWB signal permutations are independent and can be classified as pulse-like."

Table 2-5 of the above report shows that for all permutations of UWB signals considered, the interfering signal effect was classified as pulse-like at a PRF of 100 kHz, and all but one were pulse-like even at a PRF of 1 MHz.

What is the significance of this for impulse GPR and time-domain EM? First, because most GPRs use antennas that are coupled into the earth and shielded from radiation into the air, it is doubtful that in most cases enough power could get into the pass band of GPS receiver filters to saturate the receiver. *The finding above, however, argues that at moderate PRFs (somewhat less than 1 MHz), even if the interference were to temporarily saturate the GPS receiver, the interference is not expected to significantly degrade the GPS performance* ***essentially independent of peak power****, so long as the GPS received peak pulse power limit of +20 dBm (a comfortably high value) is not exceeded.*

The report, "*Potential Interference to GPS from UWB Transmitters, Phase II Test Results, Accuracy, Loss-of-Lock, and Acquisition Testing for GPS Receivers in the Presence of UWB Signals", by Luo, Koenig, Akos, Pullen, and Enge, Stanford University, 16 March, 2001,* contains a similar conclusion. On page 31 of that report we read, "*The next case of interest is the 100 kHz constant PRF UWB waveform. For this signal, the discrete spectral lines appear at 100 kHz. These lines are so close together that they appear more like broadband noise than any of the previous cases tested. More importantly, at this low PRF the UWB waveform appears as pulsed interference, even after the GPS L1 bandpass filter. GPS receivers are more tolerant of pulse interference and this aspect was first highlighted in the Phase I testing."*

This finding lends support to our field experience that moderate PRF UWB GPR and TDEM systems, even with unshielded antennas, can routinely operate in very close proximity to a GPS receiver without detectable degradation of GPS performance.

Operationally Realistic Measurements of Emissions from Geophysical Equipment?

One difficulty in extrapolating laboratory measurements to actual field performance is formulation and application of realistic attenuation factors for antenna shielding and ground coupling, propagation losses over a wide range of earth electrical and surface conditions, and near-field vs far-field issues. This is not entirely straightforward and to ignore or underestimate these factors could lead to significant overestimation of the emissions of UWB GPR and TDEM systems which, in turn, could lead to unnecessary restrictions on those devices.

Some commercial GPR systems were tested outdoors by the Applied Research Laboratories of The University of Texas at Austin, Laboratory Report 26 February 2001, TL-SG-01-01, *"Final Report Data Collection Campaign for Measuring UWB/GPS Compatibility Effects" by Cardoza, Cummings, and Kerkhoff.* Analysis of these data is evidently in another report.

The measurements described in NTIA Special Reports 01-43 and 01-45 describe tests and measurements designed to simulate wide classes of existing and possible UWB devices. I did not, however, immediately identify a test of any particular geophysical product.

However, in another report, NTIA Report 01-383, *"The Temporal and Spectral Characteristics of Ultrawideband Signals", William A. Kissick, Ed., Jan. 2001,* Section

1.2 is titled “Specific Ultrawideband Systems Measured.” The systems are left unidentified both as to manufacturer and specific use, but in Section 8 and Appendix D of that report, one of the systems, “Device E,” appears to be a GPR unit from one of the major manufacturers of GPR systems. I conclude this based on the general description, intended use, nominal center frequencies listed, and recorded waveforms. The radiated waveforms are shown in the report, and a number of analyses performed on the UWB radiation. The emissions from devices, “A” through “E” plus an electric drill, were analyzed in various ways, including a category called “***FCC Part 15 measurements.”*** On page 8-38 it is reported that ***“The signal from Device E was apparently below measurement system noise and Part 15 measurements could not be performed”*** (emphasis mine). If Device E is indeed a GPR, this test supports our field experience that UWB GPR is not likely to produce harmful interference.

Surface Time-Domain UWB EM Geophysical Systems

In the NPRM and in responses from the geophysics community the focus has been dominantly on GPR. There are, however, time-domain pulsed systems that operate below, mostly well below, the part of the spectrum occupied by GPR. Yet these are also UWB systems if defined by the proposed fractional bandwidth criterion. If the electrical conductivity of the earth were always low, such systems might not be needed because GPRs could achieve sufficient penetration. However, such is not the case. In order to achieve greater depths of penetration in high conductivity earth, lower frequencies are required. Time-domain EM systems induce local currents in the earth, and the behavior of these currents provides information about geological structure and objects buried in the earth. What can be noted about these systems relative to potential interference? With respect to spectrum, most of the power is usually below 100 kHz, and almost always below 5 MHz. These systems usually use induction loops. The loops are generally quite small electrically (<< 1 wavelength), and produce little radiation. The fields they generate are local. Treatment of the loops as small ideal magnetic dipoles with a quasi-static analysis should usually be sufficient to describe the main features of their behavior with regard to potential interference. The physics of current induction in the earth in this case, described by a diffusion equation, is decidedly different from propagation, described by a wave equation, produced by GPR and so is that of above ground fields generated by such systems. TDEM systems induce local currents in the earth by means of near-zone fields generated by the loops. Near-zone fields fall off with distance much faster than radiated (far-zone) fields. Specifically, radiated far-zone fields in air decay as $1/r$ ($1/r^2$ in power), but quasi-static (near-zone) magnetic dipole fields fall off as $1/r^3$ ($1/r^6$ in power). In fact, this rapid decay is a decided limitation for TDEM system depth of investigation, but it does greatly reduce any possibility that such systems could produce fields of sufficient amplitude to interfere with any other electromagnetic systems at distances of more than a few meters or, at most, tens of meters. Any truly radiated far-zone fields are quite small. They could be modeled and/or measured, but are very unlikely to produce significant interference. In addition, the above comments do not take into account any additional mitigating factors. Any propagation along the air-earth interface will be additionally attenuated by conductive losses in the earth and by vegetation, buildings, and topographic relief, for example.

TDEM systems generate power at frequencies well below those of the particular critical systems identified in NTIA Special Reports 01-43 and 01-45. Any interference would therefore be in lower frequency bands and might include AM radio, for example. However, I know of no complaints in that regard. One imprecise, but quick, check for possible broadcast radio interference from commercial or prototype geophysical systems is to turn on an AM, then an FM, radio receiver and put them in the near vicinity of a transmitting loop. In one such informal test of a prototype TDEM system, we could not detect any interference in the FM band. AM interference could be detected only when the AM radio receiver was within 6 m of the transmitting loop.

Field Procedures and Experience using GPS

GPS is increasingly the method of choice for acquiring and recording essential position information when using TDEM and GPR systems. It is common to place the GPS receiving antenna very close to the transmitting antenna of these systems, sometimes in a backpack, sometimes mounted on top of a GPR antenna. To allow geophysical system emissions to interfere with the GPS receiver would be self-defeating. The geophysics community is increasingly dependent on GPS for positioning. When using a GPS system, emissions are being constantly monitored for interference by the co-located, or closely located, GPS receiver. A recent example use of a real-time kinematic GPS (RTK-GPS) system, integrated into the prototype VETEM system, is illustrated in Figure 1 where the VETEM cart is shown over a metal calibration plate.

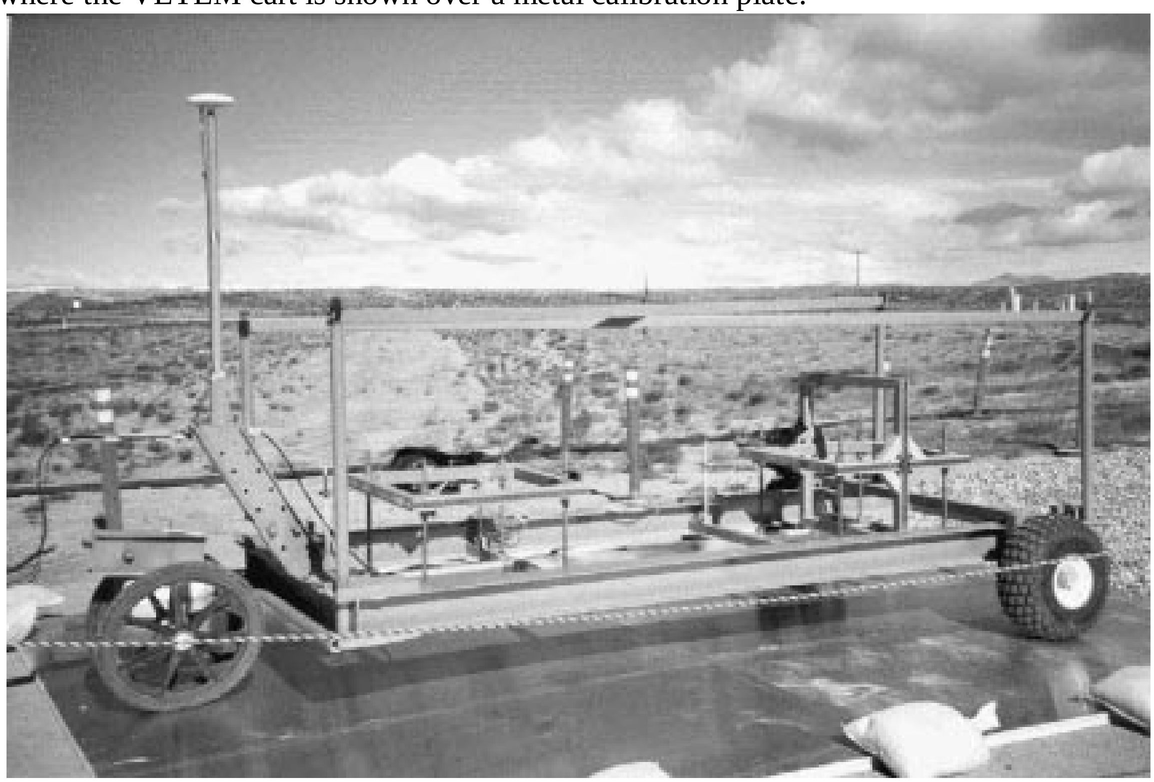

Figure 1. The GPS antenna on the mast at the left of the prototype VETEM cart is only about 2 m from the transmitting loop, yet the RTK-GPS operates without interference.

Is the Use of UWB in Subsurface Electromagnetic Imaging Systems New?

No. Some of the comments and replies I have read urge that rule changes to Part 15 to expressly permit UWB be made without delay and will open a host of new applications, including imaging in the earth. A few comments even seem to suggest that UWB subsurface imaging is an original and wonderful new idea and fail to mention the existence of extensive prior art. Correspondingly, those who oppose changes to allow UWB may fear that geophysical applications might introduce unknown new interference. Perhaps some of this is semantics and hinges on definitions of what constitutes "UWB". Some, no doubt, is due to a general unawareness of geophysics and its past and current practice. However, as has been pointed out by *Olhoeft, Slater*, and many others, there are decades of practice with UWB GPR and TDEM systems and none, so far as I know, has been shown to cause interference problems.

Comments Submitted by Others

Most comments from the geophysics community have correctly pointed out the benefits of systems that probe the earth, and most have also pointed out the outstanding record of geophysics practice with respect to generation of electromagnetic interference. From the geophysics side, interference with our systems is something we live with constantly, and it sets limits on what we can achieve. It has also been pointed out that earth imaging with GPR and EM systems is not a huge "growth industry," nor would rules changes to explicitly permit the use of UWB for earth imaging cause an explosive growth in the number of such systems. Of the comments I have read I especially recommend and endorse most, if not all, of the comments of *Gary R. Olhoeft, and Dwain K. Butler.* The comments of *A. Peter Annan*, although limited specifically to "impulse" GPR, are especially complete and lucid on that subject. In an earlier submission on behalf of the *U.S. Geological Survey (P. Patrick Leahy)*, it was recommended that "*UWB devices designed to put energy into the ground should be separated from those that transmit into the air*." Separate treatment is technically reasonable, desirable, and perhaps necessary.

Why UWB Geophysical Systems will not Proliferate

The NTIA reports 01-43 and 01-45 consider not only potential interference from single devices, but also analyze the possible interference that could be caused by several such devices in close proximity. UWB consumer electronic devices could, indeed, be built in the millions. In about July of 2000, the number of cellular telephone contracts passed the 100,000,000 mark. Each cellular telephone has a higher average power than that of most GPRs. Wireless internet and other applications are generating strong new demands for broadband/UWB. In contrast, someone estimated that there might be as few as 2,000 operational GPR systems in the world. The number of geophysical systems will not explode. Even if such equipment could be sold for $10 each, or even given away, the fact remains that almost all such systems:

A. Require human operators.
B. Require computer software to operate and to produce images from data.

C. Require human intervention to examine and interpret the images.

Thus, unlike other possible UWB devices, geophysical UWB equipment designed to look into the earth is not expected to operate continuously, or independently. The need for trained human intervention will limit the possible number of such units. The probability of having a significant number of such devices close together is low and in practice occurs only at training sessions, demonstrations, professional meetings, and trade shows, where perhaps up to a dozen manufacturers might display or operate UWB geophysical equipment (without mutual interference, it might be noted).

UWB TDEM and GPR and Restricted Bands of Operation

It has already been recognized in the NPRM that many pulsed UWB devices, such as impulse GPR and TDEM, simply cannot "notch out" restricted bands of operation because of the physics of how the impulses are generated. As it stands now, Part 15 generally allows only "spurious emissions" in the Section 15.205 Restricted bands of operation. However, Section 15.205 (d)(1) is an exemption, with conditions, to permit swept frequency field disturbance sensors operating between 1.705 and 37 MHz to radiate in restricted bands of operation. Perhaps an analogous exemption should be crafted specific to UWB geophysical survey systems.

Recommendations

In these recommendations I take no position on UWB electromagnetic systems other than geophysical systems and their common uses.

The status of UWB devices, including UWB geophysical equipment, is not clearly addressed in Part 15 and changes are needed to bring clarity, as was noted in the original NOI and NPRM. I urge that no unnecessary restrictions be placed on UWB geophysical equipment and use in view of the fact that apparently no harmful interference has resulted from decades long use of such equipment. That might require that UWB equipment intended to look into the earth be treated separately from UWB equipment intended to radiate into the air.

I recommend that changes to Part 15 rules regarding UWB use should give explicit permission for the development, manufacture, sale, and operation of UWB geophysical systems, i.e. those that are designed to put energy into the earth, on an unlicensed basis.

Of course, operation of unlicensed systems must not cause harmful interference for GPS, broadcasting, radio navigation, communications, or any other assigned and licensed electromagnetic uses. Prohibition of harmful interference is already part of the language of Part 15 and should be sufficient protection against fears of "letting the genie out of the bottle" by permitting some UWB uses. The fact is that, with respect to UWB geophysical GPR and TDEM equipment and use, the genie has been out of the bottle for decades and has proven to be a beneficent and productive genie with no known bad habits. Continued unlicensed use of UWB geophysical systems would preserve subsurface imaging and other vital applications without requiring onerous testing and regulation by the NTIA and FCC. Since unit sales of geophysical UWB systems are small, the costs of licensing might be prohibitive for both manufacturers and users, and in the absence of any demonstrated harmful interference, licensing does not seem necessary for such devices.

If power limits are imposed on GPR, I concur with the comments of *A. Peter Annan* that GPRs of lower center frequencies should be permitted higher power levels than those operating at higher center frequencies. Also see my comment with regard to PRF below.

I urge that, in the case of "impulse" ("carrierless" or "baseband") GPR and other such pulsed EM systems, no regulation should be adopted limiting the ratio of peak to average power. If peak pulse power must be limited, it should be done directly, without reference to average power, for baseband systems.

Recent tests, cited above, indicate that with respect to the critical GPS systems, UWB signals at PRFs less than about 1 MHz, and certainly at 100 kHz or below, cause much less interference than UWB signals at higher PRFs, ***essentially independent of peak pulse power***. I therefore recommend that consideration be given to allowing higher peak pulse powers for UWB geophysical systems ***that operate with a PRF no higher than perhaps 300 kHz***, than for UWB systems that operate at higher PRFs.

I recommend most urgently that geophysical systems be exempt from prohibition or severe restriction of the use of UWB below 3.1 GHz.

Respectfully Submitted,

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