Response to FCC 98-208 Notice of Inquiry in the Matter of Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems

John Benway, Engineering Manager
Magnetrol International
5300 Belmont Road
Downers Grove, IL 60515-4499
630-969-4000 ext. 321
Fax: 630-969-9489

Magnetrol International is a leading supplier of industrial level and flow instrumentation serving the chemical, petrochemical, petroleum, power and wastewater markets worldwide. We believe that short range UWB radar technology can supply innovative new products capable of making reliable level measurements with features and benefits not available from other measurement technologies.

The most common electronic level measurement devices that make contact with the material are differential pressure transmitters and capacitance transmitters. Differential pressure transmitters are subject to error due to changing specific gravity and changing pressure. Capacitance devices require the liquid to have a constant relative dielectric constant. UWB radar systems are insensitive to these parameters.

Conventional radar and air sonar are the commonly used non-contact measurement technologies for industrial level measurement. Air sonar devices generate mass waves whose transmission is dependent on the vapor space between the transducer and the material level. Radar generates an electromagnetic wave that is comparatively insensitive to the parameters of the vapor space. Conventional air radar transmitters are very expensive and consume relatively large amounts of power. UWB transmitters are low power devices that can be loop powered. A loop-powered device receives its power from the same two wires that transmit the level information. This typically requires the transmitter to operate on 12 to 15 VDC at less than 4 mA. Loop powered transmitters are preferred in the industrial market because they are less expensive to install and operate.

The existing Part 15 rules do not prevent the production and sale of short range UWB radar level sensors, but they unnecessarily complicate the design and limit the performance of the sensors.

The following sections refer to the numbered sections and unnumbered questions in the Notice of Inquiry.

9A. What types of UWB devices can we expect to be developed?

Magnetrol is investigating the possibility of developing, manufacturing, and selling a short range non-contacting radar level sensor for use in sensing the level of liquids and possibly solids in a variety of industrial applications. These level sensors are typically installed and maintained by trained personnel in large industrial facilities located a considerable distance from residential, commercial, and office buildings. The purchasers of these sensors require that they operate without a site license and without frequency coordination. Ultra-short pulse, ultra-wideband radar is one promising technology on which a low cost level sensing radar could be based. The radio frequency emissions generated by the UWB pulses are applied directly to an antenna, the resonant frequency of which determines the center frequency of the radiated emission. The bandwidth characteristics of the antenna will act as a low-pass filter, further affecting the shape of the radiated signal.

9B. What are the frequency ranges and bandwidths expected to be used by UWB devices?

The central frequency of an UWB radar level sensor would be selected based on the specific level measurement application. There is no one central frequency that is optimum for all applications. Parameters that influence the optimal frequency in any given application include the properties of the materials to be measured, the presence and properties of any secondary layers including foam on the surface, the presence and properties of dust in the gas space between the materials being sensed and the antenna, and the need for narrow beamwidths to minimize clutter echoes. It is expected that the center frequency of most or all UWB pulse radars will fall between 2 GHz and 60 GHz.

Bandwidths are determined largely by the pulse rise times and widths, which in turn are driven by the need for high accuracy level measurements and the resolution of closely spaced echo sources. The measurement of levels to an accuracy of one to two centimeters is the minimum that would be acceptable to our customers. Some customers and some applications may demand level measurements accurate to 0.1 centimeters. If we assume that pulse travel times can be measured to an accuracy of one tenth of the pulse rise time, then the maximum allowable pulse rise times must range from 1.3 ns for a 2 cm accuracy measurement to 66 ps for a 0.1 cm accuracy. The maximum allowable pulse widths are limited by the need to resolve target echoes in the presence of closely spaced clutter echoes. In some cases 60 cm of clutter resolution may be adequate. In other applications, clutter resolutions of 1 cm may be needed. This implies that maximum pulse widths may range from 4 ns to 66 ps. Using the formula presented in footnote 9 of the Notice of Inquiry, the 20 dB bandwidth will then range from 160 MHz to 27 GHz.

The limitation to the resolution and accuracy of this technology is the rise time and pulse width. As the technology advances, these parameters will decrease. Whatever the Commission decides today should consider this.

9C. What are the expected total power levels and spectral power densities, peak and average, of UWB devices?

Peak power levels are determined primarily by the maximum operating range of the UWB pulsed radar and by the reflection efficiency of the target. Maximum operating ranges for our products are expected to run from 20 meters for low cost, liquid level sensing devices to 50 meters for the detection of the level of solids in silos. Target reflection efficiency depends primarily on target conductivity, dielectric constant, and surface smoothness. Nonconductive materials with low dielectric constants such as petroleum products may reflect only 10% of the incident energy. Likewise, the presence of ripples on the surface of a liquid may reduce the reflectivity of the surface to 10% of what might be obtained from a smooth surface.

Preliminary path loss calculations indicate that -41 dBm peak transmitter power will be required assuming a 19 dB gain transmit/receive antenna (central frequency of 6.3 GHz), a perfectly reflecting target, 4 dB receiver noise figure, 500 MHz receiver bandwidth, a 20 meter range, and 0 dB signal to noise ratio at the receiver output. Allowing an additional 8 dB path loss for ranges up to 50 meters, target reflection efficiency as poor as -20 dB, and 11 dB additional receiver noise power for a bandwidth of 6 GHz gives a worst case required peak transmitter power of -2 dBm. The use of bandwidths larger than 6 GHz would require higher center frequencies and therefore allow the use of a higher gain antenna. The increased antenna gain would more than compensate for the increased noise bandwidth and result in lower peak transmitter power. Note also that a peak transmitter power of -2 dBm is only required in the unlikely event that an application requires very long ranges to a very low reflectivity target, bandwidth of 6 GHz (pulse widths of 1.1 ns and corresponding clutter resolution of 16 cm), and materials or cost constraints which require operating at 6.3 GHz where higher gain antennae are not readily available. No application known to Magnetrol simultaneously combines all these constraints. It is expected that peak transmitter power for most applications will range from -20 dBm to -40 dBm.

Peak spectral power density is expected to range from about 0.2 µW/GHz (-40 dBm, 500 MHz bandwidth) to about 20 µW/GHz (-20 dBm, 500 MHz bandwidth), assuming uniform power distribution within the bandwidth. Spectral power density will be only slightly dependent on bandwidth since the required power increases roughly linearly with the receiver and transmitter bandwidth.

Pulse duty cycles might range from 10^{-2} to 10^{-4}, depending on the application and required pulse width. Therefore, average transmitted power and average spectral power density will range from 20 dB to 40 dB below the peak transmitted power and peak spectral power density.

9D. What are the expected or desired operating distances?

Maximum operating ranges for Magnetrol's UWB radar products are expected to run from 20 meters for low cost, liquid level sensing devices to 65 meters for the detection of the level of solids in silos.

10A. Are there certain types of UWB devices or applications that should be regulated on a licensed basis under some other rule part? If so, which rule parts?

Magnetrol accepts the basic premise for the licensing of all Part 15 devices, which is that the operator must accept whatever interference is received and must correct whatever interference is caused, even including termination of operation of the Part 15 system, if necessary. Magnetrol feels that the potential for UWB radar level sensors to interfere with other, non-Part 15 devices is very low. This is because of the low spectral energy density and low radiated power of the UWB level sensors and the relatively large distances between the sensors and devices under the control of others. Therefore, the Part 15 limitation on the operation of UWB radar level sensors is not expected to be a problem for the users of these systems. However, the purchasers of these sensors require that they operate without the inconvenience of obtaining a site license and without frequency coordination. Therefore, it is appropriate that these UWB radar level sensors be licensed under a modified version of Part 15.

10B. If provisions are made for UWB technology under Part 15, how should we define UWB technology?

Magnetrol sees no need for a technical definition of UWB technology. Rather, the regulations should be modified as discussed below so as to allow UWB and any other as yet undefined technologies to operate if the technologies can accept the limitations on generating and receiving interference which form the basis for the existence of Part 15.

11A. Should the rules generally continue to prohibit operation of UWB systems within the restricted bands and the TV broadcast bands?

Part 15 should be modified so as to remove the distinction between intentional radiation and spurious emissions in the restricted and TV bands. The purpose of the restricted bands is to prevent interference with certain sensitive and safety related operations. This purpose can be best met by restricting the allowable radiation in a restricted band without regard to whether the radiation is intentional or spurious. After all, intentional radiation in a restricted band is no more likely to cause interference to a sensitive or safety related operation than is a spurious signal of the same amplitude in the same band. This simple change would allow UWB level sensors to operate in the

restricted bands at spectral power levels equal to or below the spurious levels now allowed without causing interference to the sensitive or safety related operations.

11B. Are there certain restricted bands where operation could be permitted, but not others? If so which bands and what is the justification?

Intentional radiation should be permitted in all restricted bands provided that the levels do not exceed those now allowed for spurious radiation.

11C. If certain restricted bands were retained, what impact would this have on the viability of UWB technology?

That would depend on the number and placement of the restricted bands. The center frequency and bandwidth of an UWB radar level sensor will be limited by the size of the windows between the restricted bands. This limit on bandwidth translates directly from a limit on pulse width and pulse rise time (as discussed in footnote 9 of the Notice of Inquiry), to a limit on the maximum accuracy and clutter rejection performance of the level sensor. These limitations will restrict the applicability of UWB technology to industrial level measurement applications.

12A. Are the existing general emission limits sufficient to protect other users of the spectrum, especially radio operations in the restricted bands, from harmful interference?

Magnetrol lacks the experience to comment on this issue.

12B. Should different limits be applied to UWB systems?

As discussed above, the minimum limitations should be applied that are sufficient to protect the licensed users and operations in the restricted bands. These limitations should be sufficiently well defined so as to be applicable to all transmitter types, including UWB, without specifically referring to any transmitter type, including UWB.

12C. Should we specify a different standard for UWB devices based on spectral power density? Should these standards be designed to ensure that the emissions appear to be broadband noise?

It may be desirable to add a standard based on spectral power density if such a standard is required to protect licensed users and operations in the restricted bands. However, all standards should apply to all radiators, not just to UWB systems. Ensuring that emissions appear to be broadband noise is probably not sufficient to protect other

users since broadband noise of sufficient amplitude will still disrupt other operations. The broadband noise must still remain below the noise level that is acceptable to the user.

12D. 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 an unacceptably high increase in the background noise level? Should the Commission limit the proliferation by restricting the types of products or should the rules permit manufacturers to design products for any application as long as the equipment meets the standards?

Magnetrol is not familiar with the universe of potential UWB products and therefore can not comment on this question in general. However, UWB radar level sensors are used primarily to sense the level of liquids and possibly solids in a variety of industrial applications. These level sensors are typically installed and maintained by trained personnel in large industrial facilities located a considerable distance from residential, commercial, and office buildings. The sensors are frequently, but not always, installed in metal tanks, which act as radiation shields. Therefore, there will never be a large proliferation of UWB radar level sensors within the distance at which they may cause an increase in the noise background seen by other receivers. One possible exception is in a large industrial plant that uses a large number of such sensors in unshielded applications in a small area. However, since both the sensors and the equipment which is potentially interfered with are under the control of the same organization and since industrial facilities are familiar with interference and interference control within their plants, this should cause no additional problems.

If further regulation is necessary to limit the cumulative impact of a proliferation of UWB devices on the background noise, Magnetrol proposes that two different standards be written, one for devices used in the home and a more lenient one for industrial devices. This would be similar to the regulation of class A and class B computing devices. UWB devices designed for and used in an industrial environment are unlikely to add to the background noise in the home environment because of the usually large distances and the short range of the UWB radar sensors.

12E. Should a limit on the total peak level apply to UWB devices?

It would seem that there should be a limit on the peak power transmitted by a UWB device. However, that peak should be based on the potential for the pulse to overload the front end of a receiver and cause non-linearities and pulse stretching effects. Therefore, the peak limit should be a fixed power level and not a multiple of the average transmitted power.

12F. Can emissions below or above a certain frequency range be further filtered to reduce the potential for interference to other users of the radio spectrum without affecting the performance of the UWB systems?

Frequencies outside of a certain band can be filtered without affecting the function of a UWB radar level sensor. However, providing appropriate filters may add significant cost to the sensor, depending on the regulatory requirements. As long as these spurious emissions fall within the current requirements of Part 15, they should cause no problems and should not require additional filtering.

12G. Are the existing limits on the amount of energy permitted to be conducted back onto the AC power lines appropriate for UWB devices?

Industrial UWB radar level sensors usually operate in electrically noisy industrial environments where any contribution they may have to electrical noise on the AC power lines is negligible. If such limits are necessary for UWB devises used in the home, separate standards for home and industrial environments should be adopted.

12H. What operational restrictions, if any, should be required to protect existing users?

Magnetrol is not aware of any operational restrictions to UWB radar level sensors that may be needed to protect existing users.

12I. Is the use of UWB modulation techniques necessary for certain types of communication systems; if so, for what purposes?

We have no expertise in this area.

13A. 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?

The ratio of peak to average power levels in a UWB radar level sensor may be in the range of 100 to 10,000. This makes measurement of the peak power level impossible with a spectrum analyzer. A technique needs to be developed using a fast sampling oscilloscope or similar device. Alternatively, for devices with peak power levels that are at least one order of magnitude below the allowed peak, inspection of the circuit schematics should be sufficient to assure compliance with this requirement.

13B. Would another measurement procedure that does not apply a pulse desensitization correction factor be more appropriate for determining the interference potential of an UWB device?

Yes. See the answer to 13A above.

13C. The frequency range over which measurements are required to be made depends on the frequency of the fundamental emission. Is the frequency of the fundamental emission readily discernible for UWB devices? Are the current frequency measurement ranges specified in the rules appropriate for UWB devices or should these ranges be modified?

There is no clearly defined fundamental emission frequency for a UWB device, and the concept of a fundamental frequency has no real meaning for a UWB device. Rather, the highest frequency that is intentionally radiated should be used to determine the frequency range over which measurements are required to be made. This highest frequency is determined from the pulse widths used and the formula in footnote 9 of the Notice of Inquiry.

13D. Are the measurement detector functions and bandwidths appropriate for UWB devices? Should these standards be modified and, if so, how?

Use of a spectrum analyzer to measure peak and average power levels and bandwidths is difficult or impossible because of the low duty cycle and low spectral energy density. New measurement techniques must be developed, possibly based on the use of a fast sampling oscilloscope, to make time based measurements and, then, calculate the equivalent frequency components and energy densities.

13E. Are there any other changes to the measurement procedures that should be applied to UWB devices?

Magnetrol is not an expert on FCC emissions measurements and has no additional suggestions.

14A. 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?

The prohibition against Class B, damped wave emissions should not be applied to UWB systems. In fact, this prohibition is now obsolete and is poorly defined. It was apparently intended to prohibit the use of spark gap type transmitters in the early 1900s

and is now redundant since the rules regarding spurious emissions also prohibit spark gap transmitters. The prohibition should be deleted from the rules.

14B. Comments are invited on any other matters or issues that may be pertinent to the operation of UWB systems.

Magnetrol has no other comments.