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July 13, 2001

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

VIA MESSENGER

Ms. Magalie Roman Salas, Secretary
Federal Communications Commission
Office of the Secretary
445-12th Street, S.W.
Washington, D.C. 20554

RE: Notice of Ex Parte Presentation
ET Docket 98-153

Dear Ms. Salas:

On behalf of Delphi Automotive Systems Corporation ("Delphi"), and in accordance with Section 1.1206(b) of the Commission's Rules, 47 C.F.R. §1.1206(b), undersigned counsel hereby submits the instant notice of *ex parte* presentation.

Specifically, today undersigned counsel forwarded copies of the attached "Ex Parte Comments of Delphi Automotive Systems Corporation" and the accompanying "Engineering Study" to Mr. Julius Knapp, Ms. Karen Rackley, Mr. John Reed, Mr. Michael Marcus, Ms. Lisa Gaisford, Mr. Bruce Franca, Mr. David Means and Mr. Ronald Chase of the Commission's Office of Engineering and Technology ("OET").

In accordance with 47 C.F.R. §1.1206(b), it is noted that an original and one (1) paper copy of this letter and the attached documents are being filed herewith. Please do not hesitate to contact the undersigned with any questions which may arise with respect to this filing.

Respectfully submitted,

Alan G. Fishel
Jeffrey E. Rummel

Attorneys for Delphi Automotive Systems Corporation

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JUL 13 2001
FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

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	)))	ET Docket 98-153

EX PARTE COMMENTS OF
DELPHI AUTOMOTIVE SYSTEMS CORPORATION

Delphi Automotive Systems Corporation ("Delphi"), by its undersigned attorneys, hereby submits these *ex parte* Comments with respect to the above-referenced proceeding.[1]

As a leader and innovator in the design and manufacture of automotive radar, Delphi is in an excellent position to advise the Commission as to the impact of this rulemaking proceeding on the development and implementation of vehicular radar sensors.[2] The record in this proceeding, as in prior Commission proceedings,

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[1] On September 12, 2000, and October 12, 2000, Delphi submitted its "*Comments*" and "*Reply Comments*", respectively, with respect to the issues raised in the Commission's *Notice of Proposed Rule Making*, ET Docket 98-153, FCC 00-163 (rel. May 11, 2000) ("*Notice*") in this docket.

[2] Delphi has developed and introduced to the marketplace numerous automotive radar products using a wide variety of both pulsed and non-pulsed waveforms in various frequency bands, and Delphi continues to do research and advanced development in the field. Delphi is an expert in interference issues regarding radar devices and it conducts extensive research, analysis, and testing of interference phenomena between Delphi's designs and existing products and services. Delphi thoroughly designs against interference issues by carefully selecting the type of waveform, frequency, and power levels to be transmitted, carefully designing product packaging, and ensuring strict compliance with FCC requirements. As a result Delphi's products have an excellent track record of avoiding interference. Among the automotive radar devices developed by Delphi are a "School Bus Sensor", a "Side Detection System", an "Adaptive Cruise Control" radar product and a Radar Backup Aid ("BUA"). The BUA serves as a sensor

unambiguously confirms the public interest benefits of automotive radar applications, such as those developed by Delphi.[3] In order to avoid substantially hindering the development and deployment to U.S. consumers of high-performance, low-cost automotive radar devices, Delphi strongly urges the Commission to adopt an order in this ultra-wideband ("UWB") rulemaking proceeding that is consistent with Delphi's comments herein.

Delphi submits these *ex parte* Comments, with an attached detailed engineering study (the "*Study*") prepared by Delphi's engineering staff, in further support of Delphi's previously-filed *Comments* and *Reply Comments*. Collectively, Delphi's filings (including the attached *Study*) and the administrative record in this proceeding demonstrate the following:

I. UWB Should Include Radar Devices Employing PN DS BPSK Waveforms

In the Notice, the Commission requested comments as to whether it "should define UWB devices as limited to devices that solely use pulsed emissions...."[4]

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to assist a driver when backing up and parking and assists the driver in avoiding collisions with people, vehicles, or other objects when the car is operating in reverse, such as when the driver is backing out of a driveway or backing into a parking space. In the United States, Delphi has received Commission authorization under Part 15 for a BUA device that employs a pseudo-noise direct sequence binary phase shift key ("PN DS BPSK") waveform and operates at 17 GHz with a bandwidth of less than 1.5 GHz. Delphi plans a European version of the BUA that will operate at 24.125 GHz.

[3] *See* Notice, ¶11; Delphi's *Comments*, p.2-7; "Reply Comments" of Mercedes-Benz, USA, LLC, p.5-8; "Amendment of Parts 2, 15 and 97 of the Commission's Rules to Permit Use of Radio Frequencies Above 40 GHz for New Radio Applications", First Report and Order and Second Notice of Proposed Rulemaking, 11 FCC Rcd 4481, ¶¶9-20 (the "*40 GHz Order*").

[4] *Notice* at ¶21.

Accordingly, pursuant to the strict requirements of the Administrative Procedure Act ("APA"), the Commission's rules and established precedent, the issue of whether non-pulsed waveforms should be included in the UWB definition must be resolved by the Commission in this proceeding in light of the record established by commenting parties.[5] As demonstrated herein, the Commission should include the PN DS BPSK non-pulsed waveform in the definition of UWB. Specifically, Delphi submits that the record in this proceeding establishes the following:

- Pulsed waveforms and the PN DS BPSK signal employed by Delphi are virtually identical in the frequency domain. *See* Delphi's *Study*, p. 2-5.
- The PN DS BPSK signal is as close to thermal noise in physical properties as has been invented, and is more noise-like than proposed pulse type signals. *Id.* at 3-4.
- Due to its noise-like properties, the interference risk presented by the PN DS BPSK signal to existing receivers is no greater than, and ordinarily will be less than, the interference risk presented by proposed pulsed type signals. *Id.* at 3-4, 5-10.
- As attached *Study* shows, the impact of PN-DS-BPSK radar signals on government receivers will be unmeasureable in a practical sense. Specifically, Delphi has analyzed the calculated interference power of Delphi's PN DS BPSK wideband signals vis-à-vis the SARSAT LUT (Land User Terminal), the government receiver most susceptible to interference from Delphi's PN DS BPSK signal, of those identified by NTIA in its Special Publication 01-43 Report. As demonstrated by Delphi, the calculated interference power of Delphi's PN DS BPSK wideband signals vis-à-vis the SARSAT LUT (Land User Terminal) receiver, in the worst case scenario, is well under the limit of –126 dbm specified by NTIA. *Id.* at 5-10.

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[5] *See* 5 U.S.C. §553; 47 C.F.R. §1.399, 1.425; *Office of Communication of the United Church of Christ v. FCC*, 707 F.2d 1413, 1424-5 (D.C. Cir. 1983); *Telocator Network of America v. FCC*, 691 F.2d 525, 537 (D.C. Cir. 1982).

- The use of the PN DS BPSK signal in the automotive radar context further mitigates interference risks due to the fact that automotive radar applications operate near the ground, well below the thirty meter (30m) level that is of most concern to NTIA.[6]

- There is no evidence in the record that either contradicts any of the above conclusions or demonstrates that the use of the non-pulsed waveform PN DS BPSK at frequencies above 5 GHz could present a risk of harmful interference to GPS, PCS or government operations. In this regard, other commenters either support Delphi's request for the inclusion of the PN DS BPSK waveform in the definition of UWB or do not object to such waveform as long as the relevant devices are consistent with the Commission's power limits and the anticipated operating characteristics of UWB devices.[7]

Accordingly, excluding the PN DS BPSK waveform from the definition of UWB, particularly in the automotive radar context, would constitute an arbitrary, impermissible distinction unsupported by the technical characteristics of the signal when compared to pulse-type signals. Such an approach would not only be an arbitrary, impermissible distinction, but it would also violate the public interest. In connection with the above, Delphi must note that not only does Delphi's BUA device currently utilize the PN DS BPSK signal, the waveform has the potential to be employed in connection with the following safety-related automotive radar devices:

Trapped Occupant Sensors. These devices will protect automobile occupants from being injured due to extreme heat in the auto interior. By setting of alarms when the car is occupied and the temperature rises above specified limits, this

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[6] *See* Delphi's attached *Study* at 7.

[7] *See* "Reply Comments" of Krohne, Inc. ("Krohne") dated October 27, 2000, p.1-3; "Reply Comments" of the National Association for Amateur Radio dated October 27, 2000, p.8-9; "Reply Comments" of Time Domain Corporation dated October 27, 2000, p. 36-37.

technology will clearly apply where children or pets have been left unattended in vehicles in hot weather.

Security Systems. These systems will detect intrusion into the automobile interior and will not "false alarm" as readily as existing alarm devices.

These additional planned applications confirm the public interest in including the PN DS BPSK signal in the definition of UWB.

II. The Commission Should Utilize A Minimum Bandwidth Requirement of 500 MHz for UWB Devices

In adopting a minimum bandwidth requirement, the Commission's analysis should not be limited solely to its observation that "most of the UWB systems that have been brought to [its] attention employ fundamental emissions greater than 1.5 GHz."[8] In fact, the record in this docket demonstrates that the Commission should utilize a minimum bandwidth requirement of 500 MHz for UWB devices, for the following reasons:

- **Less Interference**

  In the attached Study, Delphi demonstrates that the utilization by UWB devices of a minimum bandwidth of 500 MHz would "produce signals of lower total power, that have lower power spectral densities over broad ranges of the frequency spectrum, and therefore have a lower probability of causing interference than the wider [proposed] bandwidth signal." *See* Delphi's *Study* at 11-13.

- **Greater Functionality**

  Delphi further demonstrates in its *Study* that automotive radar devices capable of operating at lower bandwidths provide improved performance and response times for consumers because lower bandwidths permit radar devices to partition coverage zones into larger range bins. *Id.* at 11. In fact, the BUA device, as well as the planned Trapped Occupant Sensors

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[8] *Notice* at n.51.

and Security System devices described above, depend on emissions rules which do not restrict the radiated bandwidth to a minimum of 1500 MHz.

- **The Commission Should Encourage, Rather Than Frustrate, The Development And Deployment Of Devices With Less <u>Interference Potential and Greater Functionality</u>**

Should the Commission adopt a minimum bandwidth requirement for UWB devices of 1.5 GHz, many lower bandwidth devices with less interference potential and greater consumer benefits would be excluded from the definition of UWB.[9] Under that scenario, companies such as Delphi that are capable of producing high-performance, low interference devices, and indeed for many years have expended substantial resources doing so, would be required to begin developing devices with artificially inflated interference potentials and less functionality in order to fit under the definition of UWB and bring these devices to the marketplace. This result is patently against the public interest and it unfairly penalizes companies such as Delphi that have spent millions of dollars developing innovative non-pulsed, narrower band radar technologies that are consistent with the characteristics of anticipated UWB applications, yet have less overall interference potential to existing operations.

- **A 1.5 GHz Minimum Bandwidth Requirement <u>Artificially Inflates the Costs Of UWB Devices</u>**

As explained above, the Commission's proposed bandwidth requirement, if adopted, would encourage the development of radar devices with artificially inflated interference potentials and less functionality. The additional engineering required to meet a 1.5 GHz limit in such devices would require significant increased cost to manufacturers, which would have to be passed along to consumers. The increased marketplace cost of these devices would be an obstacle to the widespread acceptance of these devices, thereby severely limiting the broad-based public safety potential of these devices. *See* Delphi's *Study* at 14.[10] Adoption of the proposals

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[9] *See* Delphi's *Comments*, p.12-17; *See also* Krohne's "Reply Comments" at 1-2.

[10] In addition, as further explained in Delphi's *Comments* and the attached *Study*, many radar sensors operating at 24 GHz can be licensed in Europe, and as a result Delphi has designed 24 GHz radar sensors for the European market. However, due to U.S. frequency band restrictions around 24 GHz, Delphi has had to develop devices utilizing other frequency bands (*i.e.* 17 GHz) for the same application in the United States. The broader definition of UWB suggested by Delphi would permit Delphi to produce one higher performance device for both the U.S. and European markets at 24 GHz, thereby decreasing the per unit cost of production due to economies of scale. *See* Delphi's *Comments* at 16-17; Delphi's *Study* at 14-15. The consideration of such economic factors

suggested by Delphi, on the other hand, would ensure that high-performance, lower cost radar devices would reach the greatest number of consumers possible.

In light of the above, it is clear that the Commission should not arbitrarily limit UWB devices to pulsed waveforms with a minimum bandwidth of 1.5 GHz. As demonstrated above, adoption of the Commission's proposed UWB definition would likely deprive U.S. consumers of higher performance, low cost next-generation automotive radar devices. Such results are clearly not in the public interest and are inconsistent with the Commission's statutory obligation to encourage the provision of new technologies.[11]

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in adopting technical parameters applicable to the operation of automotive radar systems is consistent with Commission precedent. *See 40 GHz Order* at ¶15-17 (where the Commission considered economies of scale as a major factor in allocating the 76-77 GHz vehicle radar system band).

[11] *See* 47 U.S.C. §7. In this context, the Commission should be guided by its decisions in prior rulemakings where broader, rather than narrower, service definitions were adopted. *See* "Amendment of the Commission's Rules to Establish New Narrowband Personal Communications Services", First Report and Order, 8 FCC Rcd 7162, ¶13 (1993) (in the PCS context, the Commission concluded that "we continue to believe that a broad definition of PCS is warranted. We find that our concept of PCS as family of services is appropriate and will permit PCS to encompass a wide array of mobile, portable and ancillary communication services to individuals and businesses, and be integrated with a variety of competing networks... We decline to adopt the suggestions of some commenters to limit narrowband PCS to advance paging and messaging services."); *See also* "Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 GHz for Mobile and Fixed Services to Support the Introduction of New Advanced Wireless Services, including Third Generation Wireless Systems", Notice of Proposed Rulemaking and Order, FCC 00-455, ¶13 (2001) (in the 3G proceeding, the Commission concluded that a flexible allocation approach will allow licensees to make the most efficient use of their assigned frequencies in response to market forces.")

III. The Commission Can Minimize Interference Risks By Further Limiting Absolute Peak Emissions And Restricting High Power UWB Devices To Existing ISM Bands Such As 24.125 GHz

In its prior filings, Delphi demonstrated its unwavering support of the Commission's proposals to reduce interference by adopting strict limits on peak emissions.[12] By these *ex parte* Comments, Delphi hereby reiterates and clarifies its position with respect to UWB power limits:

- Consistent with the Commission's proposal, peak level emissions of UWB devices should be limited to 20 dB above the general emissions average power limit, when measured over a 50 MHz bandwidth.

- The Commission should impose more stringent limits on absolute peak emissions by reducing peak levels to 30 dB above the permitted average limit, rather than 60 dB as proposed by the Commission.

  Further, in order to ensure that interference risks are ameliorated for high power devices, Delphi further suggests that where the absolute peak emissions of a UWB device exceeds 20 dB above the permitted average limit, the Commission should require such devices to operate at existing high power ISM frequency bands and employ appropriate emissions masks. In the case of automotive radar applications, for example, the Commission should require the center frequency of such devices to operate at the ISM band of 24.125 GHz.[13] For that ISM band, any wideband waveform conforming to the Commission's UWB rules should be allowed.

By adopting these conservative approaches, the Commission could ensure that all types of waveforms and devices, including Delphi's non-pulsed, narrower bandwidth devices, would not pose an unacceptable threat of interference to existing operations.

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[12] *See* Delphi's *Comments* at 7-9, 17-18; Delphi's *Reply Comments* at 7-8.

[13] *See* Delphi's attached *Study* at 13-14.

IV. Conclusion

For the reasons set forth herein, the Commission should adopt rules consistent with the comments and proposals of Delphi, as specified in Delphi's *Comments*, *Reply Comments*, the instant *ex parte* Comments and the attached engineering *Study*.

Respectfully submitted,

DELPHI AUTOMOTIVE SYSTEMS CORPORATION

By: ______________________

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Its Attorneys

Dated: July 13, 2001

Engineering Study of
Delphi Automotive Systems Corporation
ET Docket 98-153

Prepared by Nicholas P. Morenc, Director of Engineering
and John C. Reed, Senior Staff Engineer

I. Position Statement and Executive Summary

As set forth in its previous filings, the attached "Ex Parte Comments" and this Engineering Study ("Study"), Delphi Automotive Systems Corporation ("Delphi") suggests modifications to the Commission's proposed rules for ultra-wideband ("UWB") technology. Delphi's purpose in this proceeding is to support the Commission's attempts to promulgate a new and beneficial technology as widely as possible, while minimizing risk to existing services.

Any emissions rulemaking involving wideband technology must address the following critical issues: (i) defining UWB too narrowly will result in limiting the benefits of the technology to the public, favoring certain manufacturers, and penalizing other manufacturers; and (ii) existing services must be protected from interference, particularly when a multiplicity of waveforms and frequencies is considered. Delphi's proposals in this proceeding sensitively address and resolve both of these issues.

In this Study, Delphi provides detailed technical support for the following positions:

A. The Commission should include in the ultra-wideband ("UWB") definition devices employing the pseudo-noise direct sequence binary phase shift key ("PN DS BPSK") non-pulsed waveform at any frequency where pulse waveforms are permitted. Delphi will show that pulsed waveforms and the PN DS BPSK signal employed by Delphi are not only virtually identical in the frequency domain, but the interference risk presented by the PN DS BPSK signal to existing receivers is no greater than, and ordinarily will be less than, the interference risk presented by proposed pulsed type signals. Delphi will further show that its PN DS BPSK non-pulsed waveform is noiselike in characteristic and will not interfere with GPS or government receivers. In this regard, in the analysis contained herein, which is conservative, Delphi demonstrates that the interference from the Delphi non-pulsed device, when operated at 24 GHz, is greater than 20 dB below the protection level of the SARSAT LUT receiver.

B. The Commission should decrease the minimum bandwidth requirement for devices covered by the UWB definition to 500 MHz, from the 1.5 GHz minimum proposed by the Commission. Delphi will show that lower bandwidth devices will have less potential for interference than wider band devices where the two devices emit the same total power.

C. With respect to UWB power limits, Delphi's position is as follows:

1. Consistent with the Commission's proposal, peak level emissions of UWB devices should be limited to 20 dB above the general emissions average power limit, when measured over a 50 MHz bandwidth.

2. The Commission should impose more stringent limits on absolute peak emissions by reducing peak levels to 30 dB above the general emissions average power limit, rather than 60 dB as proposed by the Commission.

3. In order to ensure that interference risks are ameliorated for high power devices, Delphi further suggests that where the absolute peak emissions of a UWB device exceeds 20 dB above the general emissions limit, the Commission should require such devices to operate at existing high power ISM frequency bands and employ appropriate emissions masks. In the case of automotive radar applications, for example, the Commission should require the center frequency of such devices to operate at the ISM band of 24.125 GHz. For that ISM band, any wideband waveform conforming to the Commission's UWB rules should be allowed.

II. The Commission Should Include Non-Pulse Wideband Waveforms In Its Definition of UWB

The key issues in both of Delphi's prior submissions in this docket responses were inclusion of multiple waveforms and reduction of the minimum bandwidth in the UWB definition. Various commenters either support or do not object to the inclusion of multiple waveforms in their comments, and the Krohne America, Inc also supports a lower bandwidth definition for UWB. In the paragraphs that follow, Delphi will show that the PN DS BPSK non-pulsed signal exhibits noise like spectral emissions and that certain features of this waveform are indistinguishable from pulsed waveforms. The PN DS BPSK waveform is described in detail herein.

A. Waveform Description

In order to obtain the benefits of UWB, *i.e.,* to utilize very wide bandwidths in conjunction with very low overall radiated power levels, it is not necessary for the Commission to exclude all non-pulsed waveforms. Delphi presents a phase modulated waveform (PN DS BPSK) which, functionally, satisfies the Commission's criteria for UWB. The waveform is commonly known to those skilled in the art, and has been the basis of numerous government communications systems designed to be hidden from "enemy" receivers. It has lower peak power than many proposed UWB pulse waveforms, hence poses a lesser interference potential to existing services than devices employing pulse waveforms.

The PN DS BPSK waveform is created by bi-phase modulating an RF carrier with a digital sequence, where the sequence is a "maximal length" code. The RF carrier is reversed in phase 180° according to the digital sequence : a digital sequence of 1, 0, 1, 1, 1, 0, 1, 0, ... would result in a transmitted carrier with phase states 0°, 180°, 0°, 0°, 0°, 180° , 0°, 180° , ... accordingly. Each code bit state and corresponding carrier phase state is called a "chip", where the time duration of the chip is called the chip period. The code sequence has a finite length. When the entire code sequence has been applied to the RF carrier, the process is repeated in most communications and radar applications.

B. Noiselike Properties Of Non-Pulsed Waveforms Such As PN DS BPSK

The PN DS BPSK signal is as close to thermal noise in physical properties as has been invented, and is more noise-like than proposed pulse type signals. Due to its noise-like properties, the interference risk presented by the PN DS BPSK signal to existing receivers is no greater than, and ordinarily will be less than, the interference risk presented by proposed pulsed type signals.

By virtue of using a maximal length code to define the modulating digital sequence, the RF waveform has many of the properties of white noise and as far as interacting with RF receivers, the signal appears to the receiver as would true white noise. This is accomplished by designing the code such that it has noise properties. In fact, "maximal length" refers to the type of code sequence that is most noise-like, i.e. the most random bit sequence as can be designed, barring a true noise sequence itself. Hence the name "pseudo-noise".[1] Even though the signal is extremely similar to noise, it is not rigorously pure noise as may be found routinely in nature. A spectrum analyzer is a good representative receiver, where the receiver center frequency, pre-detector bandwidth ("resolution BW"), and post detector bandwidth ("video" BW) are easily and accurately adjusted. By observing the way a PN-DS-BPSK signal interacts with a spectrum analyzer, the noise-like properties of the signal are demonstrated by physical means.

1. First we compare the effect of changing the video bandwidth of the analyzer when observing the PN-DS-BPSK signal and noise.[2] In figure 1, the response of a spectrum analyzer is shown where the video bandwidth is reduced between figures 1a and 1b. Both white noise signal and PN-DS-BPSK signal traces are shown in the figures. Both signal traces react the same way to changing the analyzer video bandwidth; moment to moment fluctuations of the display trace are reduced by reducing the video bandwidth. With a very small video bandwidth, the trace has little fluctuation and represents the true average power density versus frequency of the respective input signal, be it white noise or the signal under study. It must be noted that a deterministic signal (a signal which is *not* noise-like) will not exhibit such amplitude fluctuation behavior dependence on video bandwidth.

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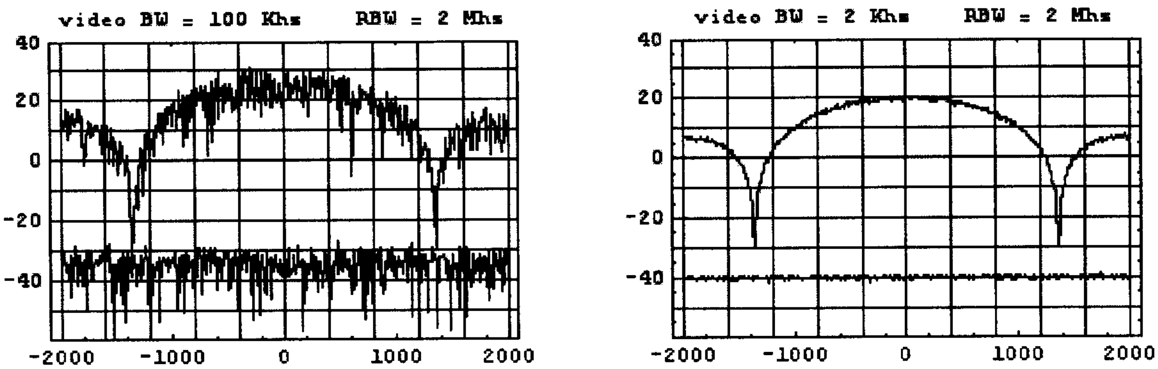
[1] Dixon, R.C., *Spread Spectrum Systems* . New York, J. Wiley, 1976

[2] The following discussion assumes frequency sweep width and frequency sweep time settings on the analyzer such that the full amplitude response of the analyzer receiver is always achieved.

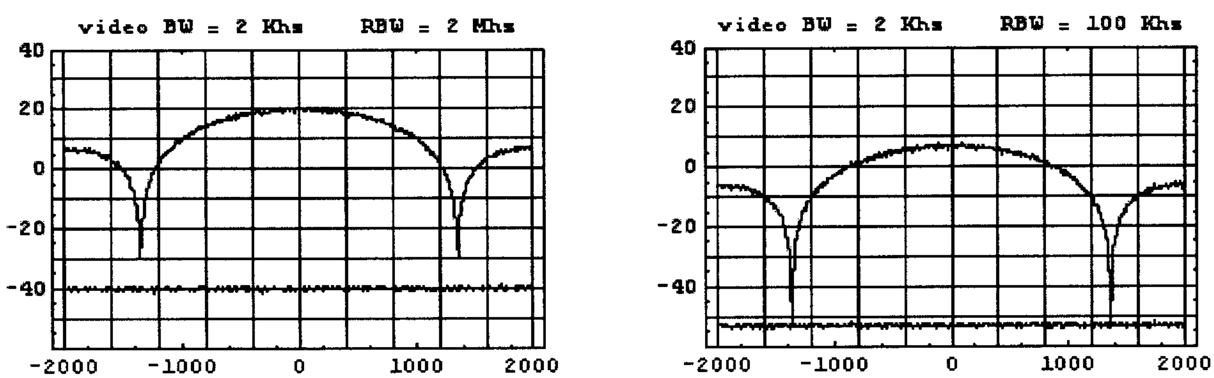


(1a) (1b)

Figure 1. Spectrum analyzer displays showing the effect of changing the video bandwidth when observing the PN-DS-BPSK signal and a true noise signal. In both displays, the upper curve is the PN-DS-BPSK signal and the lower curve is a white noise signal.

Figure 2 illustrates how changing the resolution bandwidth (RBW) of the analyzer influences the receiver response to both of the PN-DS-BPSK and white noise signals. The resolution bandwidth is the IF bandwidth of the analyzer receiver, and corresponds to IF bandwidths of government receivers which are considered below.

2. The important point is that the PN-DS-BPSK signal, like noise, has an effective power directly proportional to receiver bandwidth, so long as the receiver bandwidth is somewhat more narrow than the signal bandwidth – typically the case for both the PN-DS-BPSK and pulsed-type signals. In figures 1 and 2, the frequency axis is in MHz away from the PN-DS-BPSK signal carrier frequency.



(2a) (2b)

Figure 2. Using the narrow band video BW for good fidelity, we reduce the receiver IF bandwidth (RBW) by a factor of 20. Both the noise and the PN-DS-BPSK signal power traces drop 13 dB.

C. Comparison of Delphi's PN DS BPSK Signal with Pulse Waveforms

In this section a pulse type signal is compared to the PN DS BPSK signal in the frequency domain. As demonstrated herein, there is no physical or technical reason to believe that one signal would cause more or less interference to a receiver than the other. Close inspection of the signal spectrum for both types will reveal a line spectrum, where usually the spectral lines are quite close together. Figure 3 compares the two signal types where both signals have equal total radiated power, and illustrates the remarkable similarity of the spectral details of the two signals.

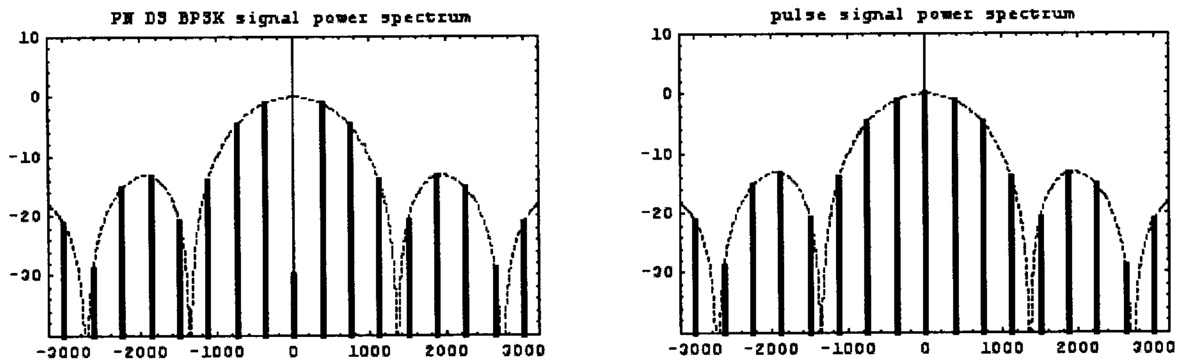


Figure 3. Side by side detailed view of both pulse and PN direct sequence bi-phase shift key signal spectra. The frequency axis is in MHz away from the RF carrier. The difference between the two lies only in the spectral line amplitude at the RF carrier frequency. The pulse repetition frequency in the pulse waveform and the code repetition frequency in the PN DS BPSK waveform are equal, as are the pulse width and chip width.

For clarity, the above figure shows fewer spectral lines than would be typically emitted by the subject devices of the proposed rule-making. Both signals exhibit the $\left[\frac{\sin(x)}{x}\right]^2$ spectral envelope which governs the amplitude of the spectral lines.

The only difference between the two spectra is the value of the spectral line at the rf carrier frequency, where the PN DS BPSK signal has a substantially lower value.

By limiting the maximum spectral density amplitude to - 41 dbm/MHz EIRP, and limiting a "peak to average" ratio for both the signals, the interference power experienced by a receiver cannot be distinguished by said receiver. Favoring or approving one signal type over the other has no basis when considering potential interference issues. A signal's power – bandwidth product is truly the most influential parameter regarding interference issues; the two signals in figure 3 have the same power – bandwidth product.

D. Analysis of Interference to Government Receivers from Delphi's PN-DS-BPSK Radar signals

There are three main reasons why the impact of the Delphi PN-DS-BPSK radar signals on government receivers will be minimal to the point of unmeasureable, in a practical sense:

- Delphi's signal is characterized by very low power density emissions.
- There are large frequency separations between the Delphi emitters and potential "victim" government receivers.
- Delphi's emitters are characterized by narrow elevation antenna patterns.

In the sections below, Delphi will examine each of the above factors. In addition, Delphi will present an analysis of potential interference between Delphi's non-pulsed devices and the SARSAT LUT (Land User Terminal) government receiver operating at 1545 MHz. As demonstrated in this conservative analysis, the calculated interference power for the worst case scenario is well under the limit of –126 dbm specified by NTIA.

1. Low Power Emissions of Delphi's Non-Pulsed Signal

Delphi's existing and future automotive radar products do not require excessive peak to average power ratios. Delphi successfully operates the 17 GHz BUA radar within the existing peak to average power ratio limit of 20 db. Cost reduction measures in this design could exploit a slightly higher absolute peak to average ratio, but a 30 db absolute peak to average power ratio is entirely adequate. Delphi's position is that a 30 db limit on this ratio is appropriate, and that higher limits embody unnecessary interference risk.

The contemplated emissions limits for "UWB" devices, and presently governing limits for "any" modulation outside restricted bands of 500 uV/m maximum average E field as measured at 3 meters from the emitter defines a very low power level. The effective isotropic radiated power (EIRP) density to comply with the limits is –41 dbm/MHz, or roughly 80 nW average radiated power in a 1 Mhz measurement bandwidth. By all standards this is an extremely low level of radiation. As demonstrated by the Delphi 17 GHz BUA radar, these power levels can be quite useful and beneficial to society while being so low that interference with previously existing services is highly unlikely. The next generation design of the BUA radar, centered at 24 GHz, has been developed using the same power limits.

2. Frequency Separation Between Delphi's Emitters and Potential "Victim" Receivers

The factor of frequency separation is of primary importance in interference studies. As illustrated in figure 7 (see "Bandwidth Considerations"), the farther one departs in frequency from the center frequency of the PN DS BPSK wideband emission, the lower the power spectral density, hence the lower potential for interference.

Figure 7 shows a very wide band spectral picture of two PN-DS-BPSK emitters operating at 24 GHz; one with a 1 GHz bandwidth and the other with a 4 GHz bandwidth (null-to-null). Note that the curves are computed, as power spectral densities beyond the first spectral sidelobe are difficult if not impossible to measure with the most sensitive receiver and high gain horn antenna at a distance of 1 meter when the signals comply with the proposed "UWB" power density limits.

Due to the shape of the power spectral density of the PN DS BPSK emission, the effective EIRP spectral density at 5.0 GHz of the emission is –82 dBm/MHz for the 1 GHz null to null bandwidth signal, and –70 dBm/MHz for the 4 GHz null to null bandwidth signal. This is marked in figure 7 for reference, where both example signals comply with the average power density limit.

It must be noted that practical hardware in the emitter will band limit the emissions well below the levels shown in figure 7; this is depicted in figure 5. Measurements of transmit power for compliant PN DS BPSK signals beyond the first spectral sidelobe are difficult to make due to the very small signal levels at those frequencies. Between the two effects of transmit band limiting and spectral power roll-off as one departs in frequency from the emitter carrier, the emissions at frequencies away from the emission center frequency become undetectable at any practical separation distance (> 3 meters).

3. Narrow Elevation Pattern in Delphi's PN DS BPSK Emitters

The Delphi radars using PN-DS-BPSK waveforms have directive antennas, especially in the elevation plane. Delphi's automotive radars operate very near the ground always, between 10 and 24 inches above the ground. These two factors combine to present typically unmeasurable interference power to government receivers.

For the government receivers cited in NTIA Special Publication 01-43 that operate at elevated heights, and have directive antennas in elevation, the narrow elevation patterns of the "on the ground" Delphi radars become key in substantially reducing the emitter power that could impact upon the government receiver. Clearly the summary charts in the NTIA report indicate that the emitter height is of substantial importance, *i.e.,* when the emitter and receiver antenna boresights line up, the interference levels are at a maximum. The "antenna" factor discussed here will be quantified in the interference power calculation below.

a. The use of directive antennas results in the reduction of power well below maximum limits. As demonstrated below, where adherence to an EIRP of –41 dBm / MHz occurs on the antenna boresight (maximum gain angle), radiated power in other elevations is rapidly reduced as one departs in angle from boresight. Figure 4 shows typical elevation antenna patterns used in the Delphi designs, where at all angles past 20 degrees from boresight, radiated power is no more than 1/100 th (-20 db) of the allowed maximum.

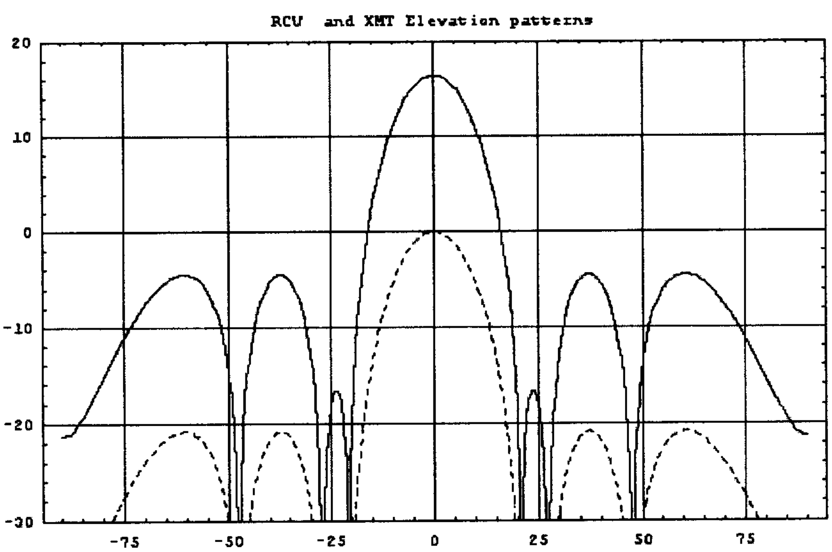


Figure 4. Elevation plane patterns for receive and transmit antennas in the 17 GHz BUA radar. The dashed line is a transmit elevation pattern, normalized to 0 dB. This allows power radiation calculations relative to –41 dBm/MHz vs elevation angle. The transmit antenna elevation 3 dB beamwidth is 16 degrees.

4. Incident Power Calculation - the SARSUT LUT Receiver

In this section, Delphi will demonstrate that the calculated interference power of Delphi's PN DS BPSK wideband signals vis-à-vis the SARSAT LUT (Land User Terminal) receiver, in the worst case scenario, is well under the limit of –126 dbm specified by NTIA.

a. It should be noted that the analysis in this section is very conservative nature, as demonstrated by the following factors:

i. A survey of the government systems cited in the NTIA Special Publication 01-43 indicates that, for the Delphi radars using PN DS BPSK wideband signals, the most interference susceptible receiver would be the SARSAT LUT receiver operating at 1545 MHz. The reasons for this are clear: the receiver antenna is only at 5 meters height, the system has a moderately high gain antenna which is pointed at the horizon, and the receiver sensitivity is very good. Also the "protection" factor cited in the report for the SARSAT – LUT is relatively high among the group of systems studied.

ii. The analysis assumes an unobstructed line of sight between the emitter and the receiver in question. Since both units are on or near the ground, this is highly unlikely. Typically there will be numerous ground obstructions such as buildings between the two units.

iii. The bandwidth limiting effect of real hardware in a 24 GHz transmitter is modeled by a single order filter, where the actual hardware attenuation of frequencies out of the design frequency band are much more severe than the model provides for.

b. The following are certain technical considerations underlying this analysis.

i. The incident power to a SARSAT LUT receiver from a Delphi wideband emitter operating at 24 GHz, compliant with the maximum power density limit of –41 dbm/MHz EIRP will be calculated. The example unit has a ½ nsec chip period which corresponds to a 2920 MHz 10 db bandwidth. The unfiltered signal spectrum of the example signal is shown as the solid line in figure 7.

ii. The following analysis must account for the fact that real practical hardware in the emitter which is designed to transmit at 24 GHz has bandwidth properties such as to decrease the emissions power at 1545 MHz far below the levels indicated in figure 7. The band limiting hardware model is a single pole highpass filter of 18 GHz in the 24 GHz transmitter. This filter response in conjunction with the waveform emissions power roll-off indicated in figure 7 results in the response of figure 5.

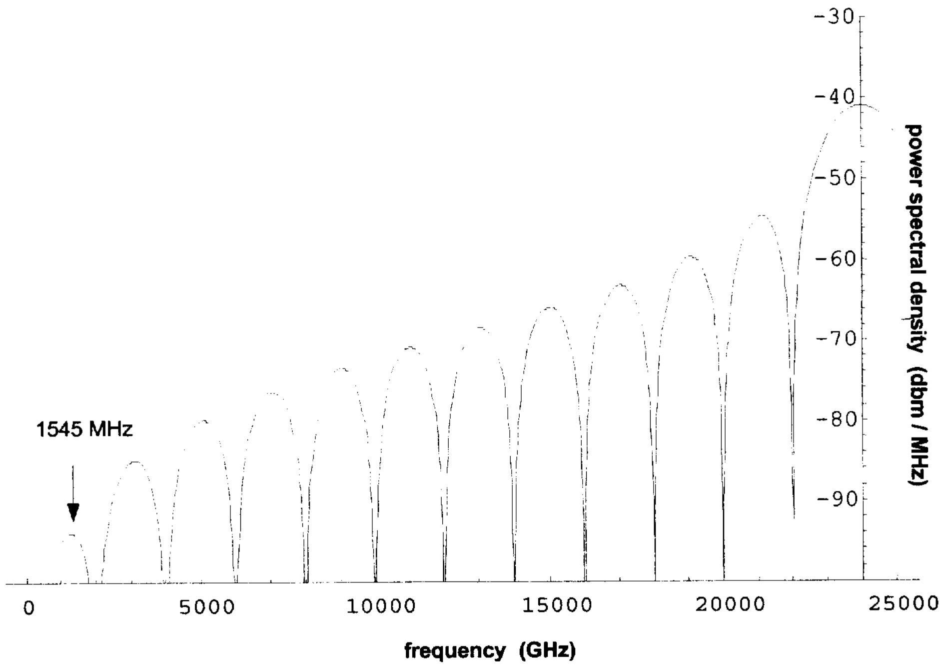


Figure 5. Filtered PN DS BPSK emission power spectral density in a 1 Mhz bandwidth. The unit is operating at 24 GHz, and uses a single pole high pass function in its transmitter. The pole frequency is 18 GHz.

c. Calculation of Received Interference Power

Using all the considerations enumerated above, antenna directivity, frequency separation, and low peak spectral density, an example calculation of received interference power will be made. Data will be taken from NTIA Special Publication 01-43 regarding the example receiver, that of the SARSAT-LUT receiver. The antenna height is 5 m, boresight gain of 26 dB, elevation beamwidth of 8 degrees. The receiver IF bandwidth is 0.8 MHz which we approximate to be 1 MHz. The emitter radiation pattern is that shown in figure 4, where "0" db represents a boresight radiated power density of –41 dbm/MHz.

The example scenario is an emitter on the ground, as all Delphi emitters are, at a range such that a receiver at 5 meter height will be on the –3 db angle (8 degrees) of the emitter antenna. At this elevation position, the SARSAT antenna gain is 15 dB, and the range between the two units is 36 meters. Moving the units closer would actually create less power in the SARSAT receiver, since antenna gain factors vs angle would overwhelm the lessor losses due to decreased propagation distance. For instance, if the units were 8.66 meters apart, the height difference being 5 meters and the range being 10 meters, the angle between the antenna boresights would increase from 8 degrees to 30 degrees, the SARSAT antenna gain would be reduced to 0 db at this angle (15 db less than at 8 degrees), and the emitter antenna gain would be reduced from –3 to –20 db, a 17 db link loss. The range losses between 10 meters and 36 meters difference in range are reduced by only 11 db.

The frequency separation between the emitters and the government receiver is 22.5 GHz. From figure 5, which charts power spectral density in dbm/MHz, we can see that for the wider band PN DS BPSK signal, the effective radiated power spectral density at 1545 MHz is –93.6 dbm / Mhz.

The link budget quantifies and adds all these factors in table 1.

Table 1. Interference Link Budget

Parameter	Value	Units
Emissions at 1.545 GHz (figure 5) for 4 GHz BW emitter at 24 GHz	-93.6	dBm/MHz
Receiver bandwidth	0	dB MHz
Emitter antenna gain (at 24 GHz), + 8 deg elevation	-3	dB
Receive antenna gain, -8 deg elevation	+15	dB
λ^2, λ of 19.2 cm	-14	dB
$(1/4\pi)^2$	-22	dB
$(1/R)^2$, R = 36 meters	-31.6	dB
Total received interference power	-149.2	dBm

As demonstrated above, the calculated interference power for the worst case scenario, (most sensitive receiver closest to the ground) is 23 db under the NTIA report's limit of –126 dbm. For less conservative analyses, the margin of safety increases.

III. A Minimum Bandwidth of 500 MHz Should Be Employed

The minimum radiated bandwidth of a UWB device should be 500 MHz. Otherwise, higher performing lower cost devices *that present less interference potential* than the proposed minimum 1500 MHz bandwidth device will be precluded to the detriment of the public interest. There are numerous situations where a low power device with a radiated bandwidth of less than 1500 MHz, that otherwise would qualify to be a UWB device under the proposed rules, would be an advantage to the end user either in cost or performance or both. Such devices also present less risk of interfering with existing services than a wider bandwidth device. As explained herein, devices employing a lower bandwidth also provide consumers with devices with greater utility and flexibility, and will present economic benefits due to lower costs of production.

A. Automotive Radar Applications Benefit from a Lower Bandwidth Allowance

As described herein, automotive radar devices capable of operating at lower bandwidths provide improved performance and response times for consumers because lower bandwidths permit radar devices to partition coverage zones into larger range bins. In fact, the Delphi 17 GHz "Back Up Aid" (BUA), as well as Trapped Occupant Sensors and Security System devices, depend on emissions rules which do not restrict the radiated bandwidth to a minimum of 1500 MHz.

The BUA device, for example, is a radar located on the rear of a vehicle, and is activated when the vehicle driver puts the vehicle's transmission into "reverse". The BUA radar scans an area behind the vehicle that extends slightly over 5 meters to the rear by positioning a range bin at a particular distance for a time, then re-positioning the bin in a contiguous position for a time, and repeating the bin repositioning process until the entire 5 meter depth of coverage is realized, see figure 6.

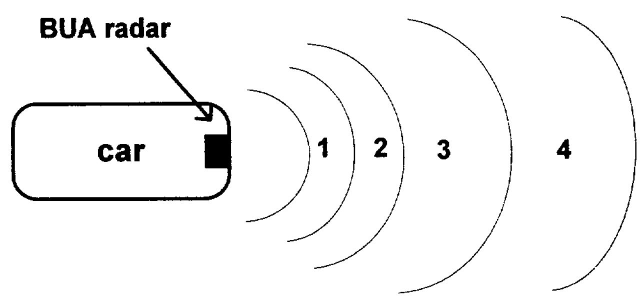


Figure 6. The BUA radar sequentially positions its single range bin to cover the entire desired area to the automobile rear. Using a variable width range bin vs. bin position preserves both response time and range data accuracy where needed.

The above figure illustrates the benefit of allowing smaller bandwidth, when we realize that the range bin depth is inversely proportional to bandwidth. The figure shows the usage of wider range bins at longer distances from the car (positions 3 & 4), and thinner range bins close to the car (positions 1 &2). This is driven by the need to have more accurate ranging data when objects are closer to the car. By using wider range bins (lower radiated bandwidth) in positions 3 and 4, the entire area can be covered more quickly, and system response time becomes more favorable. The radiated bandwidth needed to achieve the wider range bins in positions 3 and 4 is less than the proposed minimum bandwidth requirement of 1500 MHz for a UWB device.

The system response time (time delay between first presence of an object in the zone of coverage and the radar detecting the object) is of critical importance in automotive radar products. Using the scheme in figure 6 we can shorten response times without sacrificing the range data accuracy required at only the close ranges. This is an example of improved performance that cannot be achieved without reduction of the minimum bandwidth requirement for a UWB device to 500 MHz, as the "thin" range bins would require greater than 2 GHz bandwidth hence the device could only be licensed as a UWB device.

B. Radar Devices With Lower Bandwidths Have Less Interference Potential To Existing Operations

A lower bandwidth signal relative to a higher bandwidth signal (where both signals have the same maximum power spectral density) radiates less total power and will cause less interference to receivers than the wider band emission. A direct comparison between two wideband emissions is given in figure 7.

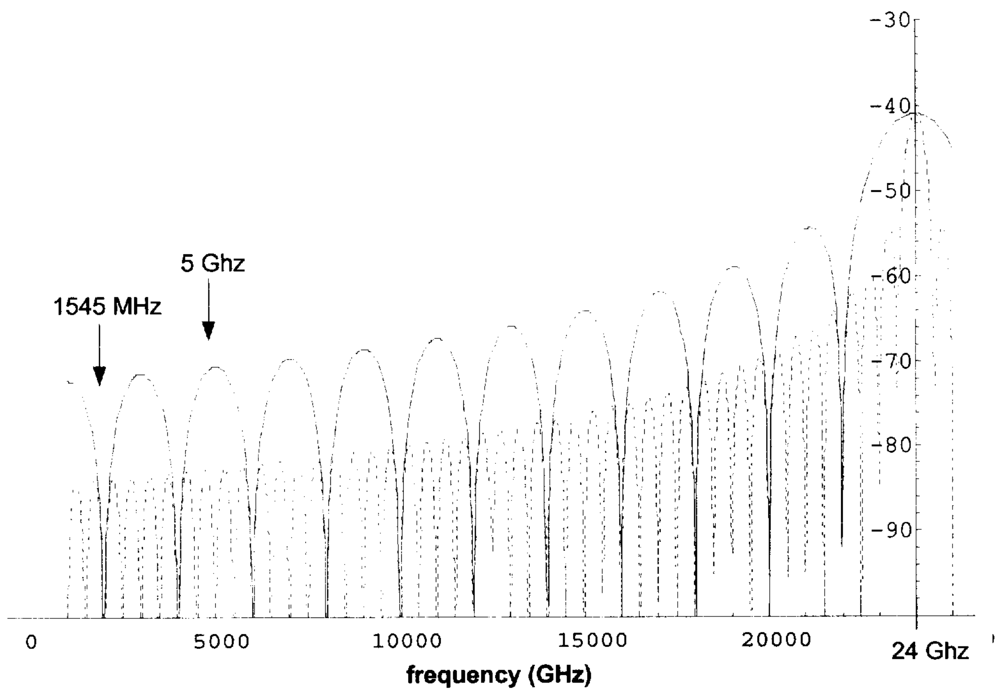


Figure 7. Power spectral density plot from 1 GHz to 25 GHz (where the main lobes are centered at 24 GHz) of two wideband signals. The dashed line signal has a mainlobe null to null bandwidth of 1 GHz. The solid line signal has a mainlobe bandwidth of 4 GHz (null to null).

Delphi's suggestion that the Commission include in the definition of UWB those signals with bandwidths less than 1500 MHz does *not* imply that higher peak or average power allowances should be made for these relative to the wider bandwidth signal. **As illustrated in figure 7, the result of Dephi's proposed 500 MHz bandwidth signal would be to produce signals of lower total power, that have lower power spectral densities over broad ranges of the frequency spectrum, and therefore have a lower probability of causing interference than the wider bandwidth signal**. Delphi envisions adherence to the maximum average power spectral density limit *and* the maximum peak power limits eventually applied to "UWB" type signals, regardless of bandwidth.

C. Average, Peak, and Total Power vs Bandwidth

It is interesting to note the differences between the two signals regarding peak power, total power, and average power. The discussion assumes that the "average power" of a signal is determined by measuring the average E field of a device using a 1 Mhz measurement bandwidth, that the "peak power" is interpreted as the maximum instantaneous carrier power, referred to in the FCC's NPRM as "absolute peak power" [3] (i.e. is equal to $\frac{1}{2} V_{pk}^2 / 377$, where V_{pk} is the instantaneous peak carrier E field voltage and 377 ohms is the free space wave impedance), and that total power is the integrated power spectral density of the emissions over all frequencies, as might be measured by a very broadband total power meter.

[3] See *Notice of Proposed Rule Making,* ET Docket 98-153, FCC 00-163, May 11, 2000.

The two signals shown in figure 7 have equal *total* radiated power, as integration of their power spectral densities over all frequencies will result in the same number. The wider band signal and the narrower band signal both have the same *peak* power, their carriers have the same amplitude. There is a distinct difference between the two signals in the average power reading on a spectrum analyzer however, where the wider band signal will have an average power reading 6 db *less* than the narrower band signal. As a consequence, the narrower band signal has a 6 db lower peak to average power ratio: the wider band signal has a peak to average power ratio of 32 db, where the narrower band signal has a peak to average power ratio of 26 db. Given these two equal power signals, the maximum of an average power vs frequency reading on a spectrum analyzer would be 6 db lower for the wider band signal than for that of the narrower band signal.

A converse view: *if the curves in figure 7 were average power readings* vs frequency from a spectrum analyzer set to a resolution bandwidth of 1 MHz (as opposed to true power spectral densities), the two signals would then have the same maximum average power reading of –41 dbm. The wider band signal would have 6 db higher peak power, 6 db higher peak to average power ratio, and would have a 6 db higher total radiated power than the narrower band signal.

IV. Interference Risks Can Be Ameliorated By Restricting High Power UWB Devices To Existing ISM Bands, Such As 24.125 GHz

Delphi shares the Commission's concern over potential interference caused by high peak power levels, even when average power levels are small. In this regard, in Delphi's filings with the Commission in this docket, Delphi suggested restricting operation of high power UWB devices to have a center frequency in presently allocated higher power ISM bands such as 24.125 GHz. This suggestion was based on limiting the new UWB devices that have significantly higher peak to average power ratios to bands where the higher peak power is already allowed. This approach would minimize the risk for interference caused by high peak power, as opposed to allowing high peak power devices to operate at any frequency.

Delphi's proposal to have high power devices restricted to existing ISM bands involves employing emissions "masks" as illustrated in figure 8.

An example of the suggested specification approach is given in figure 8; the key feature being an emissions "mask". The suggested rule has the same allocations considerations as the proposed "UWB" device rules, but simply adds certain presently allocated bands (with their current limits) to the UWB allocation. Figure 8 shows how this proposed rule would not allow emissions in the restricted bands (shown in gray) any more than the proposed rules. Delphi urges this regulation viewpoint be adopted, as a minimum, in the ISM frequency band at 24.125 GHz. Delphi urges that pulse waveforms, as well as the non-pulse PN DS BPSK waveform, be allowed in the 24 GHz band so long as it conforms to both peak power rules, conforms to the general emissions average power rules, and has its center frequency within the range of 24.0 GHz to 24.25 GHz.

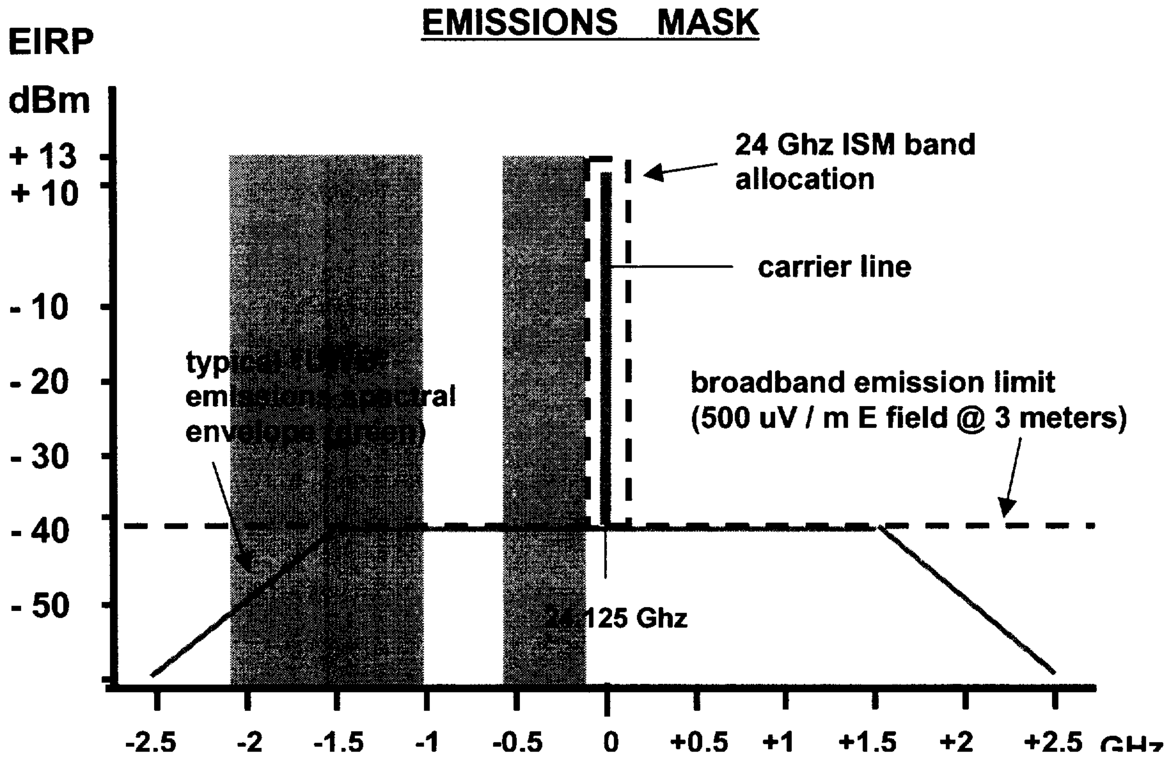


Figure 8. Example of proposed rule for UWB devices with peak to average power ratios greater than 30 db. The example is given in the allocated 24.0 – 24.25 GHz ISM band. All of the allowed spectral content in the Delphi proposal is below the broadband limit of –41 dbm EIRP, except emissions in a presently allocated band. Restricted (spurious emissions only) bands are shown in gray.

V. Delphi's Proposals Will Result In Direct Public Interest Benefits

If the Commission adopts a minimum bandwidth requirement for UWB devices of 1.5 GHz, many lower bandwidth devices with less interference potential and greater consumer benefits would be excluded from the definition of UWB. Under that scenario, companies such as Delphi that are capable of producing high-performance, low interference devices, and indeed for many years have expended substantial resources to do so, would be required to begin developing devices with artificially inflated interference potentials and less functionality in order to fit under the definition of UWB and bring these devices to the marketplace. The additional engineering required to meet a 1.5 GHz limit in such devices would require significant increased cost to manufacturers, which would have to be passed along to consumers. The increased marketplace cost of these devices would be an obstacle to the widespread acceptance of these devices, thereby severely limiting the broad-based public safety potential of these devices. Adoption of the proposals suggested by Delphi would avoid this undesirable result.

The above-described proposals of Delphi would allow the introduction of many new low interference, high performance UWB devices utilizing the PN DS BPSK signal with narrow bandwidths. In addition, Delphi's proposals would allow introduction into the United States of a 24 GHz Back Up Aid (BUA) automotive short range radar, the higher performing next generation of Delphi's 17 GHz Back Up Aid radar presently in production. Given the proposed rules interpretation, the second generation design of the BUA will be substantially less expensive to produce than otherwise, as suppressing carrier leakage at 24 GHz is more expensive and difficult than such function at 17 GHz.

A 24 GHz version of Delphi's BUA would not only provide U.S. consumers with greater flexibility and performance, it would have a larger market base if Delphi's proposals are adopted. A larger market would exist because the Commission's regulatory approach to these devices would become compatible with European emissions regulations, and the 24 GHz device would therefore become available to both European and American automobile drivers. In addition to economic benefits resulting from economies of scale, a larger market base for these devices would create greater incentives for all manufactures to bring safety devices to the market. In such a scenario, development costs would not impact the delivery of these devices to the public to the extent that they currently do.

Adoption of Delphi's proposals would create an environment where the BUA device would be available to the largest possible segment of the driving public at the lowest possible cost *without requesting more power or bandwidth than is presently allocated or contemplated.* This is the essence of the Delphi proposal – more technology benefits are brought to more people without interfering with existing services by 1) allowing "UWB" devices to include the non-pulse PN DS BPSK waveform in addition to pulse types; 2) reducing the minimum required bandwidth for a UWB device from 1500 MHz to 500 MHz; and 3) requiring high power UWB devices to operate in presently existing allocations in order to ensure that interference concerns are mitigated.