UNITED STATES DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Washington D C 20230

January 15, 2004 EX PARTE OR LATE FILED

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Federal Communications Commission
Office of Secretary

Ms Marlene H Dortch
Secretary
Federal Communications Commission
445 Twelfth Street, S.W
Washington, DC 20554

RE *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, Memorandum Opinion and Order and Further Notice of Proposed Rulemaking, ET Docket No 98-153

Dear Ms Dortch

Enclosed please find an original and four (4) copies of the late-filed comments of the National Telecommunications and Information Administration in the above-referenced proceeding. You will also find an electronic file containing the comments on the enclosed diskette in WordPerfect.

Please direct any questions you may have to the undersigned.

Respectfully submitted,

Kathy Smith

Kathy Smith
Chief Counsel

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Federal Communications Commission
Office of Secretary

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

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

COMMENTS OF THE NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION

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January 15, 2004

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EXECUTIVE SUMMARY

The National Telecommunications and Information Administration (NTIA) supports the Federal Communications Commission (Commission) in its efforts to continue evaluating the rules for ultrawideband (UWB) transmission systems. NTIA believes that the rules adopted by the Commission in the First Report and Order for UWB strike a balance between protecting critical federal systems while permitting UWB technology to evolve. NTIA also agrees with the Commission that significant changes to the rules should not be considered until more experience has been gained with UWB technology.

In the Further Notice of Proposed Rulemaking (FNPRM) in this proceeding, the Commission is proposing additional rules to address issues regarding the operation of low pulse repetition frequency (PRF) UWB transmission systems, including vehicular radars in the 3.1-10 6 GHz frequency range, the operation of frequency hopping vehicular radars in the 22-29 GHz frequency range as UWB devices; the establishment of new peak power limits for wideband Part 15 devices that do not operate as UWB devices, and the definition of a UWB device. NTIA offers the following comments in response to specific issues raised in the FNPRM for UWB transmission systems.

NTIA believes that if the Commission adopts the hand-held UWB device emission limits for expanded outdoor device applications, no restrictions on the PRF are necessary. NTIA agrees with the Commission that this proposal should be limited to UWB systems that employ impulse modulation or high speed chipping rates with a fractional bandwidth equal to or greater than 0.20 or a minimum bandwidth of 500 MHz, as they are currently defined in the Commission's rules NTIA also believes that if the hand-held emission limits are adopted, there is no technical reason to further limit UWB device applications, as long as the Commission retains the current restrictions forbidding the use of a fixed outdoor infrastructure and the operation of UWB devices in toys.

NTIA supports the Commission's goal of clarifying its guidance set forth at 47 C.F.R. §15.35(b) for properly measuring the emission limits established to ensure compatible operation of Part 15 transmission systems However, NTIA believes that additional changes to the text are necessary to clarify the existing requirements of the Commission's rules to standardize the compliance measurements and to ensure predictability and certainty for applicants seeking to certify Part 15 devices.

Analyses performed by NTIA indicates that the distance separation required for compatible operation between federal systems and narrowband Part 15 devices meeting the proposed peak power definition (e.g., measured in a 1 MHz bandwidth) are greater than those for narrowband Part 15 devices meeting the current definition, which is based on the total peak power of the signal. The analysis did take into account a few variations of receiver signal processing, which is difficult to quantify and is strongly dependent on the characteristics (pulse width, PRF, duty cycle) of the pulsed interfering signal. In general, there are numerous signal processing features of receivers that can be expected to help suppress low duty cycle pulsed interference, especially from a few isolated sources. A pulsed duty cycle, as determined in the victim receiver bandwidth, that is less than 1% and is asynchronous with the desired signal is not expected to impact receiver performance. Therefore, NTIA believes that defining the peak power in a 1 MHz bandwidth will not adversely affect federal systems, if limits are placed on the allowable duty cycle of the Part 15 device. Since this proposal pertains to the general category of Part 15 devices, adequate measurement procedures would need to be developed to certify compliance with the allowable duty cycles.

NTIA believes that the emission spectrum characteristics of a pulsed frequency hopping (FH) transmitter can vary depending on the following system parameters: pulse width, PRF, frequency hopping bandwidth, frequency hopping pattern, number of frequency hopping channels, hopping channel frequency separation, and the time length of the hopping sequence. NTIA performed measurements to gain further insight into the proper techniques to be used for measuring the emissions of devices employing pulsed FH modulation and to examine the impact that various combinations of the pulsed FH system parameters will have on the compliance measurements. Based on the results of these measurements, NTIA has developed a measurement procedure to be used to demonstrate compliance for 24 GHz vehicular radars employing pulsed FH signals. NTIA has also identified a recommended list of system parameters that should be included for device certification.

An NTIA analysis shows that the interference power level of the pulsed FH signals are comparable to the non-dithered and dithered impulse signals permitted under the Commission's UWB Rules. For the pulsed FH signal characteristics considered, one pulsed FH radar should be no worse, from an interference perspective, than one impulse radar. This analysis is applicable only to assessing the interference impact to an Earth Exploration-Satellite Service sensor because the effective interference signal at a space-borne sensor is an aggregate from a large number of vehicular radars. In addition, this aggregate signal is of concern over an extensive frequency range because the sensors have wide bandwidths of approximately 400 MHz. Thus, the frequency hopping of an individual vehicular radar as a part of an aggregate signal received at a satellite orbit has a different impact than frequency hopping devices would have in other frequency bands where they might operate in close proximity to relatively narrowband ground-based receivers. For ground-based receivers, a single frequency hopping transmitter would be dominant Thus, setting the effective interference power level in only a relatively narrow frequency range is of primary concern. Therefore, the results of the NTIA analysis cannot be extended to assess the potential interference of a pulsed FH signal on ground-based receivers. Based on the results of the comparative interference analysis, NTIA believes that the operation of pulsed FH vehicular radar systems that comply with the technical standards specified in Section 15 515 of the Commission's Rules is possible. In addition to the technical standards in Section 15.515, the rules must ensure that each hopping channel is used once and only once during the hopping sequence. The same hopping sequence is to be repeated each time.

NTIA believes that technical and economic factors may result in the transition of vehicular radar operations to the 77-81 GHz frequency range. These factors include technology and manufacturing advances in the 77 GHz frequency range and cost reduction from economies of scale achieved through common frequency allocations. NTIA and the Commission should continue to monitor the deployment of vehicular radars in the 24 GHz band, the technology advancements in the 77-81 GHz band, and the development of vehicular radars outside the United States. NTIA will also work with the Commission to ensure that an adequate frequency allocation in the 77-81 GHz band is available for the operation of vehicular radar systems.

NTIA does not support the Commission's proposal to eliminate the minimum bandwidth requirement from the definition of a UWB transmitter nor does there appear to be any public filings in the Docket for this proceeding providing technical support for the change. Such a change could be disruptive to current industry product development and ongoing standards development activities such as those in the Institute of Electrical and Electronics Engineers 802.15 Task Group 3a. NTIA believes that the Commission has established a stable regulatory framework to facilitate the development of a broad range of UWB device technologies, and should allow industry to begin developing products.

Finally, in the Memorandum Opinion and Order, the Commission stated that the wording in 47 C.F.R. §15.521(c) was unclear and made modifications to provide clarification without seeking public comment. The intent of §15 521(c) is to permit emissions from digital circuitry contained within the UWB device to be at a higher level than those specified in SubPart F, as long at it can be clearly demonstrated that those emissions are due solely to the digital circuitry and are not to be radiated from the transmitter antenna. NTIA agrees with the Commission that the language of §15.521(c) required clarification. However, NTIA suggests that further text modifications are necessary in order to achieve the intent of this section of the Commission's rules. NTIA's suggested revisions will ensure predictability and certainty for applicants seeking to certify UWB devices.

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

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

COMMENTS OF THE NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION

The National Telecommunications and Information Administration (NTIA), an Executive Branch agency within the Department of Commerce, is the President's principal adviser on domestic and international telecommunications policy, including policies relating to the nation's economic and technological advancement in telecommunications. Accordingly, NTIA makes recommendations regarding telecommunications policies and presents Executive Branch views on telecommunications matters to the Congress, the Federal Communications Commission (Commission), and the public. NTIA, through the Office of Spectrum Management, is also responsible for managing the Federal Government's use of the radio frequency spectrum NTIA respectfully submits the following comments in response to the Commission's Memorandum Opinion and Order and Further Notice of Proposed Rulemaking in the above-captioned proceeding.[1]

I. BACKGROUND

In the MO&O, the Commission amended Part 15 of its rules regarding the unlicensed operation of ultrawideband (UWB) transmission systems. These amendments responded to fourteen petitions for reconsideration that were filed in response to the First Report and Order

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[1] *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, Memorandum Opinion and Order and Further Notice of Proposed Rulemaking, ET Docket No 98-153, (released March 12, 2003) ("MO&O/FNPRM")

(R&O) in this proceeding.[2] Based on these petitions, the Commission, in the MO&O amended the rules to facilitate the operation of through-wall imaging systems used by law enforcement, emergency rescue and fire fighter personnel in emergency situations; eliminated the requirement that the -10 dB bandwidth for ground penetrating radar (GPR) systems and wall imaging systems be located below 960 MHz or above 3.1 GHz; clarified the limitations on which parties may operate GPR systems and for what purposes; eliminated the requirement for non-hand-held GPR systems to employ a "dead man" switch; clarified the coordination requirements for imaging systems; and clarified the rules regarding emissions produced by digital circuitry used by UWB transmitters [3]

The Commission as part of the FNPRM in this proceeding now proposes additional rules to address issues raised by petitioners regarding the operation of low pulse repetition frequency (PRF) UWB transmission systems, including vehicular radars in the 3.1-10 6 GHz frequency range; the operation of frequency hopping vehicular radars in the 22-29 GHz frequency range as UWB devices; the establishment on new peak power limits for wideband Part 15 devices that do not operate as UWB devices; and the definition of a UWB device.[4]

NTIA supports the Commission in its efforts to continue evaluating the rules for UWB transmission systems. NTIA believes that the rules adopted by the Commission in the First R&O strike a balance between protecting critical federal systems and allowing UWB technology to evolve. NTIA also agrees with the Commission that significant changes to the rules should not be considered until more experience has been gained with UWB technology. NTIA offers the following comments in response to specific issues raised in the FNPRM for UWB transmission systems.

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[2] *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, First Report and Order, ET Docket No 98-153, 17 FCC Rcd 7435 (2002) *Erratum* in ET Docket 98-153, 17 FCC Rcd 10505 (2002)

[3] MO&O/FNPRM at ¶ 2

[4] *Id* at ¶ 153

II. RESTRICTIONS ON PULSE REPETITION FREQUENCY OR DEVICE APPLICATION ARE NOT NECESSARY IF THE COMMISSION ADOPTS THE EMISSION LIMITS FOR HAND-HELD UWB DEVICES FOR EXPANDED OUTDOOR USE.

The Commission proposes to amend the UWB rules to permit any product under the UWB standards currently designated for hand-held devices as long as the PRF does not exceed 200 kHz and pulsed or impulse modulation is employed.[5] The Commission requests comment on whether a different PRF limit should be employed, if any other changes to the standard, including changes to the emission limits, are necessary to incorporate this addition to the type of UWB devices permitted to operate outdoors, or if the addition to the operation of outdoor UWB devices should be expanded only to include low PRF vehicular radar systems [6]

The Commission's proposal to establish a PRF limit for UWB device operation is based on the measurements of interference to Global Positioning System (GPS) receivers. The measurements performed by NTIA and the Department of Transportation showed that GPS receivers could tolerate higher signal levels from impulsive signals operating with a PRF of 100 kHz, than from impulsive signals with higher PRFs.[7] In the NTIA measurement program, the 100 kHz PRF UWB signal caused a pulse-like interference effect in the GPS receiver. The pulse-like interference category is primarily a result of the bandlimiting filter in the GPS receiver. The bandwidth of the impulse 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 GPS receiver filter. Pulses are independent (resolved) when the filter bandwidth is greater than the pulse repetition rate. Pulses

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[5] MO&O/FNPRM at ¶ 155

[6] *Id*

[7] NTIA Special Publication 01-45, *Assessment of Compatibility Between Ultrawideband (UWB) Systems and Global Positioning System (GPS) Receivers*, National Telecommunications and Information Administration (February 2001) ("NTIA Special Publication 01-45").

that were independent and resolved without dithering can overlap when dithering is introduced.[8] To remain resolved, the pulse repetition period must be greater than the sum of the duration of the filter impulse response and the maximum dither time. The bandlimited pulse will saturate one or more elements in the receiver during the pulse period, if it is resolved and it is of sufficient amplitude. This will result in "holes" in the received GPS signal. If these "holes" are relatively short and of a relatively low duty cycle, they will not seriously degrade GPS receiver performance.[9] 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. These interference effects are consistent with the documented GPS interference limits for pulsed interference.[10] NTIA did not develop relationships between PRF and maximum allowable interference power levels for the other federal systems analyzed in its assessment of UWB technology. Therefore, it is not possible to use the NTIA measurements to determine the potential impact on federal systems for establishing a PRF limit of 200 kHz.

The Commission's proposal would require that the UWB device meet the average and peak equivalent isotropically radiated power (EIRP) limits established for hand-held devices that are permitted to operate outdoors.[11] Based on the analyses performed by NTIA, the emission limits for hand-held UWB devices are adequate to protect federal systems from interference independent of the PRF or device application.[12] Therefore, NTIA believes that if the

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[8] Dithering refers to the random or pseudo-random spacing of the pulses. Dithering of the pulses in the time domain spreads spectral line content of a UWB signal in the frequency domain making the signal appear more noise-like.

[9] The duty cycle of a pulsed electronic device is the ratio of the average pulse duration to the average pulse spacing. This is numerically equivalent to the ratio of the average power to peak pulse power, and also to the product of the average pulse duration and the pulse repetition rate. Duty cycle is usually expressed in percent.

[10] Document RTCA/ DO-229B, *Minimum Operational Performance Standards for GPS/Wide Area Augmentation System Airborne Equipment* (January 1996) at 38.

[11] The average power is based on root-mean-square voltage. The limits for outdoor hand-held devices appear at 47 C.F.R. § 15.519.

[12] NTIA Special Publication 01-45, NTIA Special Publication 01-43 *Assessment of Compatibility Between Ultrawideband Devices and Selected Federal Systems*, National Telecommunications and Information Administration (January 2001) ("NTIA Special Publication 01-43").

Commission adopts the hand-held UWB device emission limits for expanded outdoor device applications, no restrictions on the PRF are necessary. NTIA agrees with the Commission that this proposal should be limited to UWB devices that employ impulse modulation or high-speed chipping rates as currently permitted under the Commission's rules.[13] If the Commission adopts the UWB hand-held emission limits there is no technical reason to limit further the UWB device applications, as long as the Commission retains the current restrictions on fixed outdoor infrastructures and use in toys.[14]

III. MODIFICATIONS TO THE COMMISSION'S PROPOSAL TO AMEND SECTION 15.35(b) ARE NECESSARY TO STANDARDIZE THE COMPLIANCE MEASUREMENT PROCEDURES FOR PART 15 DEVICES.

The Commission proposes to amend 47 C.F.R. § 15.35(b) to clarify the text for the existing requirements and to provide an alternative standard for wideband Part 15 transmission systems.[15] The Commission's proposal addresses the measurement bandwidths and detector functions used in the compliance measurements of Part 15 transmission systems.

NTIA supports the Commission's goal of clarifying the language in §15.35(b). This section provides guidance for properly measuring the emission limits established to ensure compatible operation of Part 15 transmission systems. However, NTIA believes that additional changes to the proposed text are necessary and specifically recommends the following modifications to the Commission's proposal:

> (b) Unless otherwise specified on any frequency or frequencies above 1000 MHz, the radiated emission limits are based on the use of ~~the~~ measurement instrumentation employing an ~~average~~ root-mean-square detector function to measure average power. Unless otherwise specified, the average power measurements above 1000 MHz shall be performed using a ~~minimum~~ RBW of 1 MHz. When the average radiated ~~emission~~

[13] The transmitter would have a fractional bandwidth equal to or greater than 0.20 or would have a UWB bandwidth equal to or greater than 500 MHz, regardless of the fractional bandwidth.

[14] 47 C.F.R. §§ 15.519(a)(2) and 15.521(a).

[15] MO&O/FNPRM at ¶ 164

power measurements are specified in this part, including emission measurements below 1000 MHz, there also is a limit on the peak radio frequency emissions. UWB devices operating under Subpart F of this part shall comply with the peak limits specified in that subpart. For all other Part 15 devices subject to limits based on average radiated emissions, the peak level shall comply with one of the following two levels, at the option of the responsible party.

> (1) Unless a different peak limit is specified in the rules, *e g.*, §15.255 of this chapter, the total peak power shall not exceed by more than 20 dB the average limit permitted at the frequency being investigated. Note that a pulse desensitization correction factor is ~~may be~~ required to measure the total peak emission level if the bandwidth of the signal is greater than the RBW.
> (2) The peak power shall not exceed an EIRP of -34 ~~20 Log (RBW/50)~~ dBm where ~~RBW is~~ the peak power is measured in a 1 MHz resolution bandwidth. ~~in MHz employed by the measurement instrument. The RBW may not be lower than 1 MHz or greater than 50 MHz. Further, the RBW used in the measurement instrument shall not be greater than one-tenth of the -10 dB bandwidth of the device under test.~~[16]

NTIA believes that these proposed changes are necessary to clarify the existing requirements of the Commission's rules, to standardize the compliance measurements, and to ensure predictability and certainty for applicants seeking to certify Part 15 devices.

IV. THE PROPOSAL TO DEFINE THE PEAK POWER IN A 1 MHZ BANDWIDTH WILL NOT IMPACT COMPATIBILITY WITH WIDEBAND FEDERAL SYSTEMS IF LIMITS ARE PLACED ON THE PART 15 DEVICE DUTY CYCLE.

The Commission requests comment on whether their rules should be amended to permit devices operating above 1000 MHz under the Part 15 general emission standards 47 C.F.R. §15 209 to comply with a peak emission limit of 5000 μV/m at 3 meters based on a measurement using a peak detector, a 1 MHz resolution bandwidth and a video bandwidth of no less than 1 MHz.[17]

Several commenters have stated that from an interference perspective, the full bandwidth peak power is somewhat irrelevant, as it is only the power received within the victim receiver's

[16] *Id* (NTIA edits appear in redline/strikeout text)

[17] *Id* at ¶ 165

bandwidth that causes interference.[18] The Commission currently requires that a pulse desensitization correction factor (PDCF) be used to determine the total peak power of the signal based on the peak power measured using a spectrum analyzer.[19] NTIA believes that the Commission's proposal to specify the peak power measurement in a 1 MHz resolution bandwidth, instead of specifying the total peak power, will have a greater impact on receivers with bandwidths that are much wider than 1 MHz. For receivers with wider bandwidths, the spectrum analyzer measurement in a 1 MHz resolution bandwidth would underestimate the actual peak power of the signal, possibly increasing the potential for interference. There are also signals that may appear noise-like and follow a 10 Log bandwidth relationship when measured in a 1 MHz receiver bandwidth (e.g., dithered impulse signals). However, when measured using a wider receiver bandwidth, where pulses can be resolved, the signal will appear pulse-like and follow a 20 Log bandwidth relationship.

The impact of the Commission's proposal to specify the peak power in a 1 MHz bandwidth will also depend on the type of signal (*e g.*, pulsed, noise, continuous wave). For example, noise-like signals will have values of peak-to-average ratio that only range from 10 dB[20] to 14 dB.[21] Pulsed signals on the other hand, can have peak-to-average ratios that vary over a much wider range depending on the duty cycle (e.g., combination of pulse width and PRF).

Measurements and analyses performed by NTIA have shown that the undesired signal level of a pulsed signal at which bit errors start to occur (e.g., interference threshold) in a

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[18] Petition for Reconsideration (Reply Comments), Multispectral Solutions, Inc., ET Docket No. 98-153 (July 29, 2002) at 2, Reply Comments, Preco Electronics Inc , ET Docket No 98-153 (January 3, 2003) at 2, Written Ex Parte Presentation, Synergent Technologies, ET Docket No 98-153 (January 12, 2003) at 1

[19] *Spectrum Analysis of Pulsed RF*, Hewlett Packard Spectrum Analyzer Series, Application Note 150-2 (November 1971)

[20] M Engelson, *Modern Spectrum Analyzer Measurements* (1991) at 73

[21] Report No FAA-RD-72-80 I, *Radio Frequency Emission Characteristics and Measurement Procedures of Incidental Radiation Devices and Industrial, Scientific and Medical Equipment* (September 1972) at 2-38.

digitally modulated signal is based on the peak power of the undesired signal.[22] For example, assuming no bit error correction and a low duty cycle (e.g., 0.01 percent) pulsed undesired signal, measured bit errors would start to occur at a certain peak undesired signal level. However, receiver performance degradation is not a simple function of the bit error rate (BER). Error correction and interleaving of bits can make a digital modulated system more robust to the occurrence of an undesired pulsed signal exceeding the interference threshold. Moreover, the relationship of a digital receivers performance degradation is not directly related to the average BER, bursts of errors can have a catastrophic effect on performance degradation. Once, the undesired signal peak power has exceeded the interference threshold, the occurrence of receiver performance degradation is a function of the undesired signal duty cycle. However, there is no simple undesired signal-duty cycle relationship. Factors such as receiver digital modulation type, bit error correction scheme, and interleaving depth need to be considered. This uncertainty in the undesired signal duty cycle which causes receiver performance degradation can be bounded by placing limits on both the peak and average power levels of the interfering signals.

For UWB transmission systems, the Commission's rules limit the peak power as measured in a 50 MHz resolution bandwidth. Since all of the federal systems analyzed had receiver bandwidths much less than 50 MHz, NTIA's analysis focused on the average power limits and did not address the impact of peak power. However, based on the proposal to measure the peak power in a 1 MHz resolution bandwidth, the impact to federal systems must be addressed The federal systems considered by NTIA in its assessment of UWB compatibility and their corresponding receiver intermediate frequency (IF) bandwidths measured at the 3 dB point are provided in Table 1. The Federal Aviation Administration (FAA) provided an additional list of systems shown in Table 2, which NTIA did not consider in its assessment of UWB transmission systems These systems are different versions of the systems previously analyzed by NTIA, therefore, the analysis results and the UWB average power emission limits

[22] NTIA Special Publication 01-43 at A-21

established for compatible operation are the same.

As shown in Tables 1 and 2, the following federal systems have receiver bandwidths wider than 1 MHz, and could be impacted by the Commission's proposal to measure the peak power in a 1 MHz resolution bandwidth. ATCRBS (Interrogator); ATCRBS (Transponder); GPS receivers; maritime radionavigation radars, aircraft altimeters; TCAS; Mode-S; ASR-7; and ASR-8. Appendix A provides an analysis of the impact of the Commission's proposal on these federal systems. As discussed in Appendix A, GPS, pulsed radar altimeters, ATCRBS ground-based Interrogator, ATCRBS Transponder, Mode S, and TCAS airborne receivers will not be impacted by the proposal to define the peak power in a 1 MHz bandwidth. For the remaining federal systems, the analysis in Appendix A indicates that the required separation distances that are necessary for compatible operation will be increased if the peak power is defined in a 1 MHz bandwidth compared to the current definition of Part 15 peak power, which is based on the total peak power of the signal. Table 3 provides a summary of the analysis results for the federal systems considered

TABLE 1.
Federal Systems Considered in NTIA UWB Compatibility Assessment

System (Operating Frequency Range)	Receiver IF Bandwidth (MHz)	Function
Distance Measuring Equipment (DME) Airborne Interrogator (969-1215 MHz)	0 65	Provides civil and military aircraft pilots with distance from a specific ground beacon (transponder) for navigational purposes
DME Ground Transponder (1025-1150 MHz)	0 8	Ground transponder component which replies to interrogations from the DME airborne component
Air Traffic Control Radio Beacon System (ATCRBS) Ground Interrogator (1090 MHz)	9	Used in conjunction with the ASR and ARSR radars to provide air traffic controllers with location, altitude and identity of civil and military aircraft
ATCRBS Airborne Transponder (1030 MHz)	5 5	ATCRBS airborne transponder component of ATCRBS system which replies to the ground interrogator and provides altitude and aircraft identity information in the reply signal
Air Route Surveillance Radar-4 (ARSR-4) (1240-1370 MHz)	0 69	Used by the FAA and Department of Defense (DoD) to monitor aircraft during en-route flight to distances of beyond 370 km (200 nm)
Search and Rescue Satellite Land User Terminal (1544-1545 MHz)	0 8	Provides distress alert and location information to appropriate public safety rescue authorities for maritime, aviation, and land users in distress

Global Positioning System (GPS) (L1 1559-1610 MHz) (L2 1215-1240 MHz) (L5 1164-1188 MHz)	1 - 20[23]	Provides precise position velocity, and time information on a continuous, worldwide basis. Applications include, air and maritime navigation, position location for Enhanced 911 (E911), and network synchronization
Airport Surveillance Radar (ASR-9) (2700-2900 MHz)	0.653	Monitors location of civil and military aircraft in and around airports to a range of 110 km
Next Generation Weather Radar (NEXRAD) (2700-2900 MHz)	0.55	Provides quantitative and automated real-time information on storms, precipitation, hurricanes, tornadoes, and a host of other important weather information
Maritime Radionavigation Radar (2900-3100 MHz)	4 - 20	Maritime radionavigation radars provide a safety service function that assists vessel commanders in safe navigation of waterways. The marine radar provides information on surface craft locations, obstructions, buoy markers, and navigation marks (shore-based racons, radar beacons) to assist in navigation and collision avoidance
Aircraft Altimeter (Pulsed) (4200-4400 MHz)	30	Radar altimeters determine and display aircraft height to pilots. They are used in commercial and private aviation as well as military aircraft
Microwave Landing System (MLS) (5030-5091 MHz)	0.15	Used for precision approach and landing of aircraft
Terminal Doppler Weather Radar (TDWR) (5600-5650 MHz)	0.91	Provides quantitative measurements of gust fronts, wind shear, micro bursts, and other weather hazards for improving the safety of operations at major airports

TABLE 2.
Federal Systems Not Considered in NTIA UWB Compatibility Assessment

System (Operating Frequency Range)	Receiver IF Bandwidth (MHz)	Function
Traffic advisory and Collision Avoidance System (TCAS) (1030 MHz and 1090 MHz)	9	TCAS provides proximity warnings and resolution advisories to aircraft equipped with Mode S transponders or ATCRBS transponders.
Mode-S Data Link (1030 MHz and 1090 MHz)	8	Mode S is a discrete-address beacon system that selectively interrogates aircraft.
Air Route Surveillance Radar (ARSR-1/2) (1280-1350 MHz)	1	Used by the FAA to monitor aircraft during en-route flight to distances of beyond 370 km (200 nm).
Air Route Surveillance Radar (ARSR-3) (1250-1350 MHz)	0.4	Used by the FAA to monitor aircraft during en-route flight to distances of beyond 370 km (200 nm)
Airport Surveillance Radar (ASR-7) (2700-2900 MHz)	2.4/5.5	Monitors location of civil aircraft in and around airports to a range of 110 km
Airport Surveillance Radar (ASR-8) (2700-2900 MHz)	1.2/5	Monitors location of civil aircraft in and around airports to a range of 110 km.

[23] The bandwidth for GPS receivers will vary depending upon the receiver architecture employed. Bandwidths of 1 to 2 MHz are common for coarse acquisition receiver architectures, 12 MHz for narrowly-spaced correlator receiver architectures, and 20 MHz for semi-codeless receiver architectures

WSR-74 (2700-2900 MHz)	2	Meteorological radar used in the vicinity of an airport
WSR-88 (2700-2900 MHz)	2 4	Meteorological radar used in the vicinity of an airport

Table 3.
Summary of Appendix A Analysis Results

System	Required Distance Separation	
	Proposed Definition of Part 15 Peak Power	Current Definition of Part 15 Peak Power
ASR-7/8	1.6 km	200 m
Maritime Radar	1 9 km	460 m

As discussed in Appendix A, the analysis did not consider an extensive range of receiver signal processing capabilities. As discussed earlier, the effect of pulsed interference on receiver processing is difficult to quantify and is strongly dependent on the characteristics (pulse width, PRF, duty cycle) of the signal. In general, there are numerous signal processing features of radars that can be expected to help suppress low duty cycle pulsed interference, especially from a few isolated sources. A pulsed duty cycle, defined in the radar receiver bandwidth, of less than 1% that is asynchronous with the desired signal will have minimal impact on radar receiver performance.

In addition to the federal systems identified in Tables 1 and 2, the Commission has recently allocated spectrum in the 4940-4990 MHz band ("4.9 GHz Band") to be used to accommodate a variety of broadband applications to support public safety agencies in performing their missions regarding homeland security and protection of life and property.[24] The frequency utilization plan for the 4 9 GHz Band will consist of ten 1 MHz channels and eight 5 MHz channels that can be combined to a maximum of 20 MHz.[25] The Commission permits federal government entities to enter into sharing agreements with public safety licensees

[24] *In the Matter of The 4 9 GHz Band Transferred from Federal Government Use*, Memorandum Opinion and Order and Third Report and Order, WT Docket No 00-32 (released May 2, 2003).

[25] *Id* at ¶ 39

to use this spectrum.[26] As noted by the Commission, both federal government and non-government public safety entities are potential participants in incident-scene emergency operations, and could benefit from the same broadband communications technologies contemplated for this band.[27] Appendix B provides an assessment of the potential impact of the proposed definition of peak power measured in a 1 MHz resolution bandwidth on these wideband (e.g., 20 MHz) public safety communication systems. As shown in Appendix B, the proposed definition of peak power for wideband Part 15 devices could increase the distance separation required for compatible operation by a factor of 20 compared to the current definition of peak power

In a separate study, NTIA has examined the effects of pulsed interfering signals on a wideband (e.g., 20 MHz) digital receiver that employed error correction capabilities and bit interleaving, which were not considered in the Appendix B analysis.[28] The measurements examined the susceptibility of the receiver to pulsed interfering signals as a function of pulse characteristics that included pulse width, pulse repetition rate, and peak amplitude. The measurements indicated that the receiver was relatively robust in the presence of low duty cycle interference When the duty cycle was less than 0.005 (a half percent), interference thresholds exceeded 10 dB above the desired signal level (e.g., signal-to-interference (S/I) = -10 dB). However, interference thresholds converge rapidly to a continuous wave (CW) level of an S/I = 8 dB when the duty cycle exceeds 1% The results were almost identical for all cases, regardless of absolute pulse repetition rate or pulse width, when the interference exceeds 5%. In that case, the interference threshold is nearly that of a CW signal. In effect, the receiver performance was

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[26] *Id* at ¶ 25

[27] *Id*

[28] NTIA Report 02-393, *Measurements of Pulsed Co-Channel Interference in a 4-GHz Digital Earth Station Receiver*, National Telecommunications and Information Administration (May 2002)

severely affected if 5% or more of the symbols were deleted from the data stream.[29] This report only examined one error correction and bit-interleaving implementation, thus the results could be different for other implementations.[30] The measurement results are consistent with impact of pulsed interference on GPS receivers. In a GPS receiver, pulsed interference will corrupt data bits causing "holes" in the received signal As long as these "holes" are relatively short (e.g., do not corrupt a large number of data bits) and occur infrequently (e.g., low duty cycle), the pulsed interference will not severely degrade GPS receiver performance.

The analysis performed by NTIA indicates that the distance separations required for compatible operation between federal systems and Part 15 devices meeting the proposed peak power definition are greater than those for Part 15 devices meeting the current peak power definition. However, NTIA believes that if a duty cycle limit of 1% in the victim receiver bandwidth is established, compatible operation of Part 15 devices with federal systems is possible.[31] Since this proposal pertains to the general category of Part 15 devices, adequate measurement procedures would need to be developed to certify compliance with the allowable duty cycles.

V. NTIA HAS DEVELOPED A PROPOSED COMPLIANCE MEASUREMENT PROCEDURE FOR 24 GHZ VEHICULAR RADAR SYSTEMS EMPLOYING PULSED FREQUENCY HOPPING MODULATION.

The Commission is proposing to permit pulsed frequency hopping (FH) systems to operate under the provisions for UWB vehicular radar systems.[32] The Commission requests comment on the measurement procedures to be used for demonstrating compliance with the emission limits, including whether a general measurement procedure can be developed that is

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[29] *Id* at 19

[30] In receivers where error correction and bit-interleaving techniques are not implemented, it is expected that the interference impact could be more pronounced

[31] For an impulsive signal the maximum allowable PRF would be 1% of the receiver bandwidth.

[32] MO&O/FNPRM at ¶ 160

applicable for a full range of system parameters and whether various system parameters need to be limited to specific ranges of values for the measurements to be meaningful.[33]

The rules adopted in the First R&O permit UWB vehicular radars that operate in the 22-29 GHz frequency range.[34] The 23.6-24 GHz frequency band is a restricted band allocated to passive radio services such as the Radio Astronomy (RA) Service, the Earth Exploration-Satellite Service (EESS), and the Space Research (SR) Service. The rules adopted in the First R&O establish an emission mask to facilitate compatibility with passive sensors used in the EESS.[35] All of the analyses performed to develop the emission limits for UWB vehicular radars were based on impulsive signals.[36] Furthermore, NTIA did not consider pulsed FH systems in developing the compliance measurement procedures adopted for UWB devices in the First R&O.

NTIA believes that the emission spectrum characteristics of a pulsed FH transmitter can vary depending on the following system parameters: pulse width, PRF, frequency hopping bandwidth, frequency hopping pattern, number of frequency hopping channels, hopping channel frequency separation, and the time length of the hopping sequence. Furthermore, unlike impulsive signals, the peak-to-average ratio of a pulsed FH system can vary over a wide range depending on the system parameters. NTIA performed measurements as documented in Appendix C examining the impact that various combinations of the pulsed FH system parameters have on the compliance measurements. The objective of these measurements was to gain further insight into the proper techniques for measuring the emissions of devices employing pulsed FH modulation. Based on the results of these measurements NTIA developed the measurement procedure described in Appendix D, that can be used to demonstrate compliance

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[33] *Id* at ¶ 161

[34] *See* 47 C F R §15 515

[35] *See* 47 C F R §15 515(d) and (c)

[36] Typical pulse widths used by UWB devices currently are on the order of 0 1 to 2 nanoseconds, or less, in width

with the peak and average power emission limits for 24 GHz vehicular radars that employ pulsed FH modulation. Recommendations regarding the system parameters to be provided by the applicant for device certification are also included in Appendix D.

In the measurement procedures for the average power using a root-mean-square (RMS) detector, an averaging time must be specified. In the FNPRM, the Commission proposed to allow a maximum 10 millisecond (msec) averaging time to accommodate compliance testing for frequency hopping vehicular radar systems.[37] Several commenters are concerned that the proposed 10 msec averaging time for the compliance measurements would produce results that underestimate the amount of interference that pulsed FH signals employed by vehicular radars could cause to EESS sensors.[38] For example, the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Conical Scanning Microwave Imager/Sounder (CMIS) sensor operating in the 23.6 - 24 GHz band has an integration time of 1.2 msec, which is almost an order of magnitude shorter than the 10 msec measurement averaging time proposed by the Commission.[39] The National Academy of Sciences' Committee on Radio Frequencies indicates that future EESS sensors that will operate in this band will have an integration time on the order of 0.1 msec to achieve high-resolution imaging.[40]

NTIA believes in order to have compliance measurements of a pulsed FH signal that are meaningful in assessing potential interference to EESS sensors, a proper balance must be established between: the integration time of the EESS sensor; the frame time period of the pulsed FH signal; and the averaging time for the RMS average power compliance measurement. For example, if the averaging time of the compliance measurement is too long compared to the

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[37] MO&O/FNPRM at ¶ 160

[38] National Academy of Sciences' Committee on Radio Frequencies Comments, ET Docket 98-153 (July 16, 2003) at 4 ("CORF Comments"), Northrop Gruman Corporation and Ratheheon Company Reply Comments, ET Docket No 98-153 (August 20, 2003) at 6.

[39] CORF Comments at 6

[40] *Id* EESS sensor integration times are defined by the angular resolution and scan geometry

EESS sensor integration time, this could underestimate the received interference power level seen by the EESS sensor. On the other hand, if the averaging time of the compliance measurement is too short compared to the frame period of the pulsed FH signal, there will not be a sufficient number of pulses available to compute a meaningful RMS level of the average power. In the compliance measurement procedures described in Appendix D, NTIA has proposed an averaging time for the RMS measurement of 1 msec within the 23.6-24 GHz EESS band and 10 msec outside of the EESS band. NTIA believes that the 1 msec averaging time for the compliance measurement withing the 23.6-24 GHz EESS frequency band is necessary to ensure not only the protection of existing EESS sensor operations, but also to allow EESS sensing technology to develop and produce the higher quality of sensing data that is expected from such technology developments.

VI. THE INTERFERENCE IMPACT TO EESS SENSOR RECEIVERS FROM PULSED FREQUENCY HOPPING VEHICULAR RADARS IS COMPARABLE TO THAT OF THE IMPULSE VEHICULAR RADARS PERMITTED BY THE COMMISSION'S UWB RULES.

The Commission is requesting comment on whether the higher instantaneous power delivered by a pulsed frequency hopping system would cause harmful interference to existing systems.[41] Comments are requested on any interference concerns that arise from this new modulation type or its method of measurement.[42] Comments are also requested on the adequacy of the measurement results for the purpose of quantifying the impact to systems that could receive interference from pulsed frequency hopping vehicular radar systems.[43]

In developing the emission limits adopted in the First R&O for UWB vehicular radars, NTIA performed an analysis to assess the potential impact to passive EESS sensors operating in

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[41] MO&O/FNPRM at ¶ 159

[42] *Id* at ¶ 161

[43] *Id*

the 23.6-24 GHz frequency range[44] This analysis only addressed the potential impact of impulse UWB signals to EESS sensors. The adopted average power limits for impulsive signals, are to be measured in a 1 msec time interval. At the PRFs proposed for the impulse vehicular radars, the average power is fully defined in a 1 msec time interval. To assess the potential interference impact of allowing pulsed FH vehicular radars to operate under the requirements of the rules adopted in the First R&O, the comparative analysis in Appendix E was performed. The analysis computed the interference level in the EESS receiver from several impulse and pulsed FH signals. Certain parameters that are common (e.g., propagation loss, antenna gains) to all the interference cases considered were not included in the computations. The exclusion of these common parameters does not change the comparative results The comparative analysis was between representative waveforms of several impulse waveforms with different characteristics and pulsed FH signals with characteristics that were considered representative. The comparative analysis considered eight signal types: two impulse non-dithered signals, an impulse dithered signal, and five variations of pulsed FH signals The characteristics of the pulsed FH signals are specified in terms of hopping frequency range, pulse width, hopping sequence, number of hop channels, and PRF. The comparative interference power at the output of the EESS receiver filter and whether or not the signal is limited by the peak or average power are summarized in Table 4. The analysis assumes that the measured average power is fully defined in a time interval that does not exceed the integration time of the EESS sensor (e.g., on the order of 1 to 2 msec).

Table 4.
Summary of Comparative Analysis

Signal Type	Average or Peak Power Limited	Comparative Interference Power (dBm/400 MHz)
10 MHz PRF Non-Dithered Impulse	Average Power Limited	-25 3
1 MHz PRF Non-Dithered Impulse	Average Power Limited	-15.3

[44] Letter from William T Hatch, Associate Administrator, Office of Spectrum Management, National Telecommunications and Information Administrator, to Mr Edmond J Thomas, Chief, Office of Engineering and Technology, Federal Communications Commission (February 13, 2002) at Attachment 2 ("Hatch Letter").