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

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Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
The Portals
445 Twelfth Street, S.W.
Room TW-A325
Washington, D.C. 20554

Re: Revision of Part 15 of the Commission's Rules Regarding Ultrawideband Transmission Systems, ET Docket No. 98-153

Dear Ms. Salas:

Enclosed please find an original and two (2) copies of the letter and accompanying reports from Michael D. Gallagher, Deputy Assistant Secretary for Communications and Information, Department of Commerce, to Chairman Michael K. Powell in the above-referenced proceeding. A copy of the letter and accompanying reports were also hand-delivered to Chairman Powell, each of the Commissioners, and Bruce A. Franca, Acting Chief, Office of Engineering and Technology.

Please direct any questions you may have regarding this letter to the undersigned. Thank you for your cooperation.

Respectfully submitted,

Kathy D. Smith
Chief Counsel

Enclosures

cc: The Honorable Michael K. Powell
The Honorable Kathleen Q. Abernathy
The Honorable Michael J. Copps
The Honorable Kevin J. Martin
Bruce A. Franca, Acting Chief
Office Engineering and Technology

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

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The Honorable Michael K. Powell
Chairman
Federal Communications Commission
The Portals
445 12th Street, S.W.
Washington, D.C. 20554

Re: Revisions of Part 15 of the Commission's Rules Regarding Ultrawideband Transmission Systems, ET Docket No. 98-153

Dear Chairman Powell:

The National Telecommunications and Information Administration (NTIA) has completed measurement and analysis reports (enclosed) on the effects of Ultrawideband (UWB) signals on Global Positioning System (GPS) receivers that use a C/A-code tracking receiver employing multiple, narrowly-spaced correlators, and a Technical Standard Order (TSO)-C129a compliant aviation, C/A-code tracking receiver, which is used in en-route and non-precision approach applications. The two reports document measurements made by NTIA's Institute for Telecommunication Sciences on the effects of several types of UWB signals on the two GPS receivers measured and an analysis by NTIA's Office of Spectrum Management applying those results to several operational scenarios involving both GPS receiver and UWB devices developed at a series of open public meetings. The results of these reports augment and confirm conclusions in previous NTIA GPS measurements and analysis reports submitted to you on March 9, 2001.

Sincerely,

Michael D. Gallagher
Deputy Assistant Secretary
for Communications and Information

Two Enclosures
NTIA Report 01-389, Addendum to NTIA Report 01-384
Measurement to Determine Potential Interference
to GPS Receivers from Ultrawideband Transmission Systems

NTIA Special Publication 01-47, An Assessment of
Compatibility Between Ultrawideband Devices
and GPS Receivers (Report Addendum)

NTIA SPECIAL PUBLICATION 01-47

ASSESSMENT OF COMPATIBILITY BETWEEN ULTRAWIDEBAND (UWB) SYSTEMS AND GLOBAL POSITIONING SYSTEM (GPS) RECEIVERS (REPORT ADDENDUM)

SPECIAL PUBLICATION

U.S. DEPARTMENT OF COMMERCE ● National Telecommunications and Information Administration

NTIA SPECIAL PUBLICATION 01-47

ASSESSMENT OF COMPATIBILITY BETWEEN ULTRAWIDEBAND (UWB) SYSTEMS AND GLOBAL POSITIONING SYSTEM (GPS) RECEIVERS (REPORT ADDENDUM)

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U.S. DEPARTMENT OF COMMERCE
Donald L. Evans, Secretary

Michael D. Gallagher, Deputy Assistant Secretary
for Communications and Information

November 2001

ACKNOWLEDGMENTS

The authors wish to thank the many organizations and persons who contributed to the completion of this report. In particular we wish to thank the Federal agency representatives on the Interdepartment Radio Advisory Committee and the Interagency GPS Executive Board for providing vital comments, information, and review of this report.

We wish to thank the NTIA's Institute for Telecommunication Sciences for their support and work in the measurement process that is fundamental to this report. We also wish to thank the contributing NTIA employees: Paul Roosa and Mike Doolan.

EXECUTIVE SUMMARY

BACKGROUND

The study described in this report was undertaken by the National Telecommunications and Information Administration (NTIA) in response to a Federal Communications Commission (FCC) Notice of Proposed Rule Making (NPRM) concerning the operation of a new class of spectrum-dependent devices, designated as ultrawideband (UWB) devices under the FCC's rules and regulations in Part 15 of Title 47 of the Code of Federal Regulations (CFR).[1] This NPRM raises a number of questions and concerns regarding the electromagnetic compatibility (EMC) of the proposed UWB transmitting devices with those spectrum-dependent systems currently in operation. The NTIA, as the Executive Branch agency principally responsible for developing and articulating domestic and international telecommunications policy affecting Federal Government spectrum users, is particularly interested in the potential for interference to telecommunications infrastructure utilizing Federal Government spectrum for critical and/or safety-of-life functions, many of which operate in spectrum designated as the restricted frequency bands for that reason. Before UWB devices can operate in restricted frequency bands used by critical Federal Government radiocommunication systems, NTIA must examine the potential interference introduced from their proposed operations. The Global Positioning System (GPS) is an example of a critical radionavigation system that operates in several of the restricted frequency bands.

In February of 2001, NTIA released Special Publication 01-45, *Assessment of Compatibility Between Ultrawideband (UWB) Systems and Global Positioning System (GPS) Receivers*. This document reported on measurements and analysis results obtained for the C/A code tracking and semi-codeless GPS receiver architectures, and indicated ongoing efforts to measure and analyze the interference susceptibility for a C/A code tracking receiver employing multiple narrowly spaced correlators and a Technical Standard Order (TSO) C-129a compliant aviation receiver. This report serves as an addendum to NTIA Report 01-45, and details the results obtained for the remaining two receivers, and also provides a comparison to other data sets that are on the public record.

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[1] The UWB emissions considered in this report are limited to those using a burst of a series of impulse-like signals. However, there are several ways of defining UWB signals, one being an emission that has an instantaneous bandwidth of at least 25% of the center frequency of the device. There are also several ways of generating very wide signals, including the use of spread spectrum and frequency hopping techniques.

OBJECTIVE

The primary objective of this study is to define maximum allowable UWB equivalent isotropically radiated power (EIRP)[2] levels that can be tolerated by GPS receivers, when used within various operational applications, without causing degradation to GPS operations. NTIA then compared these EIRP levels to the emission levels derived from the limits specified for intentional radiators in C.F.R., Title 47, Part 15.209 to assess the applicability of the Part 15 limits to UWB devices.[3]

GPS SYSTEM DESCRIPTION

The GPS is a space-based radionavigation satellite system providing precise position, velocity, and time information on a continuous, worldwide basis. The GPS space segment consists of a 24-satellite constellation with the satellites distributed in six orbital planes at an approximate altitude of 20,000 km. With the current configuration of the GPS constellation, there are typically from 6 to 11 satellites simultaneously visible from any point on the surface of the Earth. However, within a metropolitan area, the number of visible satellites is often reduced due to blockage from buildings or other man-made structures. GPS satellites currently transmit a spread spectrum signal using a multiple access capability known as code division multiple access (CDMA) on two microwave frequencies: Link 1 (L1) on 1575.42 MHz, and Link 2 (L2) on 1227.60 MHz. A civil coarse/acquisition (C/A) code and a quadrature-phase precision (P) code are multiplexed on the GPS L1 frequency while only the P-code is modulated on the L2 carrier. The C/A signal supports the standard positioning service and the P signal supports the precise positioning service.

A modernization effort is currently ongoing that will add two new civil signals to the GPS system. A C/A-like signal has been proposed for addition on L2, and a new signal structure has been defined for broadcast in a recently allocated Radionavigation-Satellite Service frequency band (1164-1188 MHz) and will be designated Link 5 (L5).

GPS APPLICATIONS

GPS is becoming the cornerstone for air navigation for all phases of flight (en-route, precision and non-precision approach) and is the preferred navigation system for maritime operations. In order to meet the exacting standards required from a safety-of-life system, the U.S. Government has either developed, or is developing augmentations to the basic GPS system for aviation, maritime, and land use. The Wide Area Augmentation System (WAAS) and the

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[2] The computation of EIRP is in terms of the average power of the UWB signal for all cases considered in this report. This average power is based on root-mean-square (RMS) voltage.

[3] The existing Part 15 measurement procedure uses an average logarithm detector process and is not equivalent to measurements using an RMS detector process.

building or other obstacle in the satellite-to-receiver path, causing a temporary loss-of-lock between the GPS receiver and the satellite of interest. As the vehicle clears the obstacle and again becomes visible, the GPS receiver must be able to reacquire the lost satellite signal in the presence of UWB energy in a time consistent with that associated with no UWB energy present.

Measurements Performed. ITS performed closed system (conducted) measurements to assess the potential impact to each of the GPS receivers from a single UWB transmitter (one-on-one) interaction. The complete measurement data sets for the narrowly-spaced correlator and TSO-C129a compliant receivers are presented in a separate report published by ITS.

Analysis Component

The data collected from the measurements were used in a subsequent analysis effort performed by NTIA's OSM to calculate the maximum allowable EIRP that can be emitted from a UWB transmitter without exceeding the measured interference susceptibility level. A source-path-receiver analysis was performed to calculate these maximum allowable EIRP levels for both a single UWB transmitter-to-GPS receiver interaction and for the case of an aggregate of UWB transmitters-to-GPS receiver interaction. In performing these analyses, related parameters were determined from operational scenarios, which define the conditions under which proposed UWB devices may be in proximity to GPS receivers in operational applications. These operational scenarios were developed in open, public meetings with participation from UWB and GPS manufacturers and users. The specific proposals for operational scenarios to be considered in the NTIA study included GPS receivers used in the following applications: terrestrial[5] (e.g., public safety applications such as cellular phone embedded E-911 and emergency response vehicle navigation, geographic information systems, precision machine control, and general operations), maritime navigation (in constricted waterways, harbors, docking, and lock operations); railway operations (positive train control), surveying, and aviation (en-route navigation and non-precision approach). These scenarios do not represent all possible applications of GPS, however, they do represent a reasonable bound on the parameters necessary to perform the broadly based analyses. For example, the separation distances represented in these scenarios range from a minimum of 2 meters for the embedded E-911 scenario, to a maximum of approximately 300 meters (1000 feet) for the en-route aviation scenario.[6]

An analysis was also performed to determine the distance separations that are required to preclude interference to the different GPS receiver architectures, if the UWB device is operating at the current Part 15 level of -71.3 dBW/MHz. The measured UWB interference thresholds for both single-entry and multiple-entry UWB device interactions were considered.

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[5] Within the context of this report, terrestrial refers to land-based operations.

[6] Enhanced sensitivity GPS receivers using base station augmentation/aiding for E911 applications are not represented in this report.

RESULTS

This report documents the results of the measurement and analysis program conducted by NTIA. Policy recommendations and/or guidance with respect to proposed UWB operations are not included within the scope of this effort. The following paragraphs discuss the findings of this program.

Analysis of Susceptibility Data

In the analysis of measurement results reported in this addendum report and in NTIA Report 01-45, it was found that the interference effects on GPS C/A-code receivers from each of the UWB signals considered could be classified as either continuous wave (CW)-like, noise-like, or pulse-like interference. In each case where the interference effect was classified as CW- or noise-like, a specific interference threshold value could be determined from the measured data. The susceptibility threshold values that were analyzed for CW-like interference effects were the UWB power in a single spectrum line (in dBW) that caused the GPS receiver to break-lock. For noise-like interference effects, a set of susceptibility threshold values were analyzed where the GPS receiver was caused to break-lock and a separate set of values where the GPS receiver reacquisition time was increased due to interference. For both data sets, the susceptibility values were the power spectral density (in dBW/MHz) of the UWB signal that resulted in the interference effect.

The data presented in this addendum report were for a GPS receiver employing narrowly-spaced correlators and a TSO-C129a (aviation) compliant GPS receiver. The GPS receiver employing the C/A code receiver architecture that was included in NTIA Report 01-45 is referred in this report as the C/A code receiver.

The susceptibility values for each of the three receivers and for each interference effect/criterion (i.e., CW-like/break-lock, noise-like/break-lock, and noise-like/reacquisition) were examined to gain insight into the variability, reliability and accuracy of the measured data. The susceptibility data analyzed herein was referenced to a desired signal level of -130 dBm and for the noise-like interference effects the power of the UWB signal was added to the -93 dBm/20 MHz noise signal that was also input to the GPS receiver as required in the test plan. These data conversions were used to facilitate the comparison of measured data resulting from this program and from other GPS interference measurement efforts.

The susceptibility data collected in the NTIA measurement effort was analyzed by determining the median along with the range of data for each receiver. The median for the CW-like interference effects might indicate that performance of the TSO-C129a compliant receiver is more robust (can withstand a higher interference level before a break-lock condition is realized) than the other receivers. However, examination of the range of data for CW-like effects would indicate the data is consistent. The noise-like susceptibility values are within the bounds of measurement accuracy including variations associated with slightly differing test set-ups.

The overall median and range of data for the combined data for the three receivers shows the range of the data varies over a fairly small range relative to the median values. This again is an indication of data consistency across all receivers. This data was used in the comparison with GPS/UWB measurements performed by the Stanford University (SU) and the Applied Research Laboratories University of Texas (ARL:UT).

In order to make a comparison between the NTIA and SU susceptibility data, data sets had to be identified where similar measurement procedures, interference criteria, and UWB signal characteristics are used. Because of the differences in measurement procedures, interference criteria, and UWB signal characteristics, not all the SU and NTIA data can be compared, only a subset of the data supports a comparison. In addition to break-lock and pseudo-range error measurements, SU carried out reacquisition tests, however, the procedures and criteria were different than those used in the NTIA tests. The SU data was found to be comparable to the NTIA receiver input threshold data. The high-grade aviation receiver is slightly more robust than the receivers tested by NTIA under break-lock conditions; the SU break-lock thresholds are within 2 dB of the range of the NTIA data. For the aviation receiver pseudo-range measurement and both the Original Equipment Manufacturer receiver measurements, the SU data is within the range of the NTIA data.

The interference threshold data reported in the ARL:UT report as analyzed by the Joint Spectrum Center (JSC) was also compared to the NTIA receiver susceptibility data. Again, because of differences in the UWB signal characteristics, the measurement approach, and the interference threshold criteria, only a subset of the ARL:UT data could be used in this comparison. The interference threshold for the ARL:UT results are the values shown in the JSC Report with an appropriate correction (-43 dB) to convert from dBm/20 MHz to dBW/MHz for comparison purposes. Most of the ARL:UT data examined are comparable to the NTIA data particularly if one compares the ARL:UT data to the range associated with the NTIA median value. The possible exception to this comparability is for Receiver 1 with UWB interference and a performance metric of a loss of one satellite (-142.3 dBW/MHz for UWB Mode 7 and -142.7 dBW/MHz for UWB Mode 13). For these conditions, the receiver seems to be more susceptible to UWB interference. As discussed in the JSC Report, there is evidence for possible CW-like interference effects having occurred during the ARL:UT tests for these conditions. As shown in many of the GPS interference tests, GPS receivers are more susceptible to CW-like interference than noise-like interference. The NTIA data shows a median value of -144.5 dBW for CW-like interference for a break-lock condition. This is comparable to the ARL:UT test results for these two cases.

The NTIA susceptibility data was also compared to the existing RTCA and International Telecommunication Union GPS interference limits. The corrected median value for CW-like interference would be -149.5 dBW and for noise-like interference for reacquisition would be -139.5 dBW/MHz. These values can be compared to the existing protection limits for GPS receivers of -150.5 dBW for CW-like interference and -140.5 dBW/MHz for noise-like interference.

The GPS receiver interference susceptibility data resulting from the NTIA measurement program was examined and found to be consistent across the three receivers that process the C/A code L1 signal. The NTIA susceptibility data was shown to be comparable to the SU and ARL:UT test results. These comparisons can only be made for a subset of the SU and ARL:UT data because of differences in the UWB characteristics, the measurement procedures, and the interference criteria. Finally, the NTIA data was compared favorably to existing interference protection limits for GPS. For the parameter sets tested, this data defines the limit of the power level of the UWB signal that can be tolerated at the GPS receiver input to protect the desired performance. This body of susceptibility data can be used in source-path-receiver analyses to determine the interference impact of GPS/UWB operations in various operational scenarios.

Analysis Results

In this analysis, NTIA determined the maximum allowable EIRP for the different UWB signal permutations, using the operational scenarios proposed in the public meetings. The results of the analysis are summarized in Tables 1 through 4. Each table corresponds to a UWB PRF examined in the analysis. The tables provide a description of the: operational scenario; UWB signal characteristics; GPS receiver architecture; interfering signal characterization; interference threshold; and the computed values of maximum allowable EIRP. The values of maximum allowable EIRP shown in Tables 1 through 4 are for a single UWB device, and represent the highest EIRP at which UWB devices can operate and still provide protection to the GPS receiver architecture under consideration for the conditions specified in the operational scenarios. In a multiple UWB device interaction, the maximum allowable EIRP level of a single-entry UWB device as shown in the tables was determined by partitioning the total interference allotment in accordance with the multiple (aggregate) UWB device factor as discussed in Section 3.1.4.

Tables 1 through 4 also include a comparison of the computed values of maximum allowable EIRP with the current Part 15 level of -71.3 dBW/MHz. When the interference effects are classified as being pulse-like or noise-like, the values of maximum allowable EIRP can be directly compared to the current Part 15 level. When the interference effect is classified as being CW-like, the maximum allowable EIRP can be compared to the Part 15 level, if it is assumed that there is only a single spectral line in the measurement bandwidth. If the difference between the current Part 15 level and the computed maximum allowable EIRP is negative, no additional attenuation below the current Part 15 level is necessary to protect the GPS receiver architecture under consideration. If the difference is positive, this value specifies the additional attenuation below the current Part 15 level that is necessary to protect the GPS receiver architecture under consideration.

Table 1. Summary of Analysis Results (PRF = 100 kHz)

Operational Scenario Description					UWB Signal Characteristics		GPS Receiver	Characterization of Interfering Signal	Maximum Interference Threshold (dBW/MHz)	Maximum Allowable EIRP (dBW/MHz)	Comparison with the Current Part 15 Level (dB)
Application	UWB Single	UWB Multiple	UWB Indoor	UWB Outdoor	Gating %	Mod.					
Terrestrial	X			X	20	OOK	Narrow Correlator	Pulse-Like	-110.2	-70.8	-0.5
Terrestrial		X	X		20	OOK	Narrow Correlator	Pulse-Like	-110.2	-55.2	-16.1
Terrestrial		X		X	20	OOK	Narrow Correlator	Pulse-Like	-110.2	-59.9	-11.4
Maritime		X	X		20	OOK	Narrow Correlator	Pulse-Like	-110.2	-39.3	-32
Maritime		X		X	20	OOK	Narrow Correlator	Pulse-Like	-110.2	-45.7	-25.6
Railway		X	X		20	OOK	Narrow Correlator	Pulse-Like	-110.2	-53.9	-17.4
Railway		X		X	20	OOK	Narrow Correlator	Pulse-Like	-110.2	-55.4	-15.9
Surveying	X			X	20	OOK	Narrow Correlator	Pulse-Like	-110.2	-53.3	-18
Surveying		X		X	20	OOK	Narrow Correlator	Pulse-Like	-110.2	-53.4	-17.9
Aviation-NPA		X		X	100	None	TSO C-129a	Pulse-Like	-117.9	-58.2	-13.1
Aviation-ER		X	X		Note 1	Note 1	TSO C-129a	Noise-Like	-136	-75.9[2]	4.6
Aviation-ER		X		X	Note 1	Note 1	TSO C-129a	Noise-Like	-136	-84.9[2]	13.6

Notes:
1. In this operational scenario, it is assumed that there is a large enough number of UWB devices such that independent of the individual UWB signal parameters, the aggregate effect causes noise-like interference.
2. This maximum allowable EIRP is based on a density of 200 active UWB devices per square kilometer.

Table 2. Summary of Analysis Results (PRF = 1 MHz)

Operational Scenario Description					UWB Signal Characteristics		GPS Receiver	Characterization of Interfering Signal	Maximum Interference Threshold[1]	Maximum Allowable EIRP[1]	Comparison with the Current Part 15 Level (dB)
Application	UWB Single	UWB Multiple	UWB Indoor	UWB Outdoor	Gating %	Mod.					
Terrestrial	X			X	100	None	Narrow Correlator	CW-Like	-144.1	-104.7	33.4
Terrestrial	X			X	100	50% Abs.	Narrow Correlator	Pulse-Like	-105.9	-66.5	-4.8
Terrestrial		X	X		100	None	Narrow Correlator	CW-Like	-144.1	-89.1	17.8
Terrestrial		X	X		20 & 100	Multiple	Narrow Correlator	Noise-Like	-132.2	-83.2	11.9
Terrestrial		X		X	100	None	Narrow Correlator	CW-Like	-144.1	-93.8	22.5
Terrestrial		X		X	20 & 100	Multiple	Narrow Correlator	Noise-Like	-132.2	-87.9	16.6
Maritime		X	X		100	None	Narrow Correlator	CW-Like	-144.1	-73.2	1.9
Maritime		X	X		20 & 100	Multiple	Narrow Correlator	Noise-Like	-132.2	-67.3	-4
Maritime		X		X	100	None	Narrow Correlator	CW-Like	-144.1	-79.6	8.3
Maritime		X		X	20 & 100	Multiple	Narrow Correlator	Noise-Like	-132.2	-73.7	2.4
Railway		X	X		100	None	Narrow Correlator	CW-Like	-144.1	-87.8	16.5
Railway		X	X		20 & 100	Multiple	Narrow Correlator	Noise-Like	-132.2	-80.7	9.4
Railway		X		X	100	None	Narrow Correlator	CW-Like	-144.1	-89.3	18
Railway		X		X	20 & 100	Multiple	Narrow Correlator	Noise-Like	-132.2	-82.2	10.9
Surveying	X			X	100	None	Narrow Correlator	CW-Like	-144.1	-87.2	15.9
Surveying	X			X	100	50% Abs.	Narrow Correlator	Pulse-Like	-105.9	-49	-22.3
Surveying		X		X	100	None	Narrow Correlator	CW-Like	-144.1	-87.3	16
Surveying		X		X	20 & 100	Multiple	Narrow Correlator	Noise-Like	-132.2	-75.4	4.1
Aviation-NPA		X		X	20	None	TSO C-129a	CW-Like	-146.7	-87	15.7
Aviation-NPA		X		X	100	50% Abs.	TSO C-129a	Noise-Like	-142	-88.3	17
Aviation-ER		X	X		Note 2	Note 2	TSO C-129a	Noise-Like	-136	-75.9[3]	4.6
Aviation-ER		X		X	Note 2	Note 2	TSO C-129a	Noise-Like	-136	-84.9[3]	13.6

Notes:
1. When the interference effect has been characterized as being pulse-like or noise-like, the value is expressed in units of dBW/MHz. The value is expressed in units of dBW when the interference effect has been characterized as being CW-like.
2. In this operational scenario, it is assumed that there is a large enough number of UWB devices, such that independent of the individual UWB signal parameters the aggregate effect causes noise-like interference.
3. This maximum allowable EIRP is based on a density of 200 active UWB devices per square kilometer.

Table 3. Summary of Analysis Results (PRF = 5 MHz)

Operational Scenario Description					UWB Signal Characteristics		GPS Receiver	Characterization of Interfering Signal	Maximum Interference Threshold[1]	Maximum Allowable EIRP[1]	Comparison with the Current Part 15 Level (dB)
Application	UWB Single	UWB Multiple	UWB Indoor	UWB Outdoor	Gating %	Mod.					
Terrestrial	X			X	100	OOK	Narrow Correlator	CW-Like	-146.7	-107.3	36
Terrestrial	X			X	20	Multiple	Narrow Correlator	Pulse-Like	-88.5	-49.1	-22.2
Terrestrial	X			X	100	50% Abs.	Narrow Correlator	Noise-Like	-127.7	-88.3	17
Terrestrial		X	X		100	OOK	Narrow Correlator	CW-Like	-146.7	-91.7	20.4
Terrestrial		X	X		20	Multiple	Narrow Correlator	Noise-Like	-132.2	-83.2	11.9
Terrestrial		X		X	100	OOK	Narrow Correlator	CW-Like	-146.7	-96.4	25.1
Terrestrial		X		X	20	Multiple	Narrow Correlator	Noise-Like	-132.2	-87.9	16.6
Maritime		X	X		100	OOK	Narrow Correlator	CW-Like	-146.7	-75.8	4.5
Maritime		X	X		20	Multiple	Narrow Correlator	Noise-Like	-132.2	-67.3	-4
Maritime		X		X	100	OOK	Narrow Correlator	CW-Like	-146.7	-82.2	10.9
Maritime		X		X	20	Multiple	Narrow Correlator	Noise-Like	-132.2	-73.7	2.4
Railway		X	X		100	OOK	Narrow Correlator	CW-Like	-146.7	-90.4	19.1
Railway		X	X		20	Multiple	Narrow Correlator	Noise-Like	-132.2	-80.7	9.4
Railway		X		X	100	OOK	Narrow Correlator	CW-Like	-146.7	-91.9	20.6
Railway		X		X	20	Multiple	Narrow Correlator	Noise-Like	-132.2	-82.2	10.9
Surveying	X			X	100	OOK	Narrow Correlator	CW-Like	-146.7	-89.8	18.5
Surveying	X			X	20	Multiple	Narrow Correlator	Pulse-like	-88.5	-31.6	-39.7
Surveying	X			X	100	50% Abs.	Narrow Correlator	Noise-Like	-127.7	-70.8	-0.5
Surveying		X		X	100	OOK	Narrow Correlator	CW-Like	-146.7	-89.9	18.6
Surveying		X		X	20	Multiple	Narrow Correlator	Noise-Like	-132.2	-75.4	4.1
Aviation-NPA		X		X	20	OOK	TSO C-129a	CW-Like	-143.3	-83.6	12.3
Aviation-NPA		X		X	100	2% Rel.	TSO C-129a	Noise-Like	-143	-89.3	18
Aviation-ER		X	X		Note 2	Note 2	TSO C-129a	Noise-Like	-136	-75.9[3]	4.6
Aviation-ER		X		X	Note 2	Note 2	TSO C-129a	Noise-Like	-136	-84.9[3]	13.6

Notes:
1. When the interference effect has been characterized as being pulse-like or noise-like, the value is expressed in units of dBW/MHz. The value is expressed in units of dBW when the interference effect has been characterized as being CW-like.
2. In this operational scenario, it is assumed that there is a large enough number of UWB devices, such that independent of the individual UWB signal parameters the aggregate effect causes noise-like interference.
3. This maximum allowable EIRP is based on a density of 200 active UWB devices per square kilometer.

Table 4. Summary of Analysis Results (PRF = 20 MHz)

Operational Scenario Description					UWB Signal Characteristics		GPS Receiver	Characterization of Interfering Signal	Maximum Interference Threshold[1]	Maximum Allowable EIRP[1]	Comparison with the Current Part 15 Level (dB)
Application	UWB Single	UWB Multiple	UWB Indoor	UWB Outdoor	Gating %	Mod.					
Terrestrial	X			X	20	None	Narrow Correlator	CW-Like	-146.9	-107.5	36.2
Terrestrial	X			X	20	2% Rel.	Narrow Correlator	Pulse-Like	-122.2	-82.8	11.5
Terrestrial	X			X	100	2% Rel.	Narrow Correlator	Noise-Like	-135.5	-96.1	24.8
Terrestrial		X	X		20	None	Narrow Correlator	CW-Like	-146.9	-91.9	20.6
Terrestrial		X	X		100	2% Rel.	Narrow Correlator	Noise-Like	-135.5	-86.5	15.2
Terrestrial		X		X	20	None	Narrow Correlator	CW-Like	-146.9	-96.6	25.3
Terrestrial		X		X	100	2% Rel.	Narrow Correlator	Noise-Like	-135.5	-91.2	19.9
Maritime		X	X		20	None	Narrow Correlator	CW-Like	-146.9	-76	4.7
Maritime		X	X		100	2% Rel.	Narrow Correlator	Noise-Like	-135.5	-70.6	-0.7
Maritime		X		X	20	None	Narrow Correlator	CW-Like	-146.9	-82.4	11.1
Maritime		X		X	100	2% Rel.	Narrow Correlator	Noise-Like	-135.5	-77	5.7
Railway		X	X		20	None	Narrow Correlator	CW-Like	-146.9	-90.6	19.3
Railway		X	X		100	2% Rel.	Narrow Correlator	Noise-Like	-135.5	-84	12.7
Railway		X		X	20	None	Narrow Correlator	CW-Like	-146.9	-92.1	20.8
Railway		X		X	100	2% Rel.	Narrow Correlator	Noise-Like	-135.5	-85.5	14.2
Surveying	X			X	20	None	Narrow Correlator	CW-Like	-146.9	-90	18.7
Surveying	X			X	20	2% Rel.	Narrow Correlator	Pulse-Like	-122.2	-65.3	-6
Surveying	X			X	100	2% Rel.	Narrow Correlator	Noise-Like	-135.5	-78.6	7.3
Surveying		X		X	20	None	Narrow Correlator	CW-Like	-146.9	-90.1	18.8
Surveying		X		X	100	2% Rel.	Narrow Correlator	Noise-Like	-135.5	-78.7	7.4
Aviation-NPA		X		X	20	None	TSO C-129a	CW-Like	-147.8	-88.1	16.8
Aviation-NPA		X		X	100	Multiple	TSO C-129a	Noise-Like	-141	-87.3	18
Aviation-ER		X	X		Note 2	Note 2	TSO C-129a	Noise-Like	-136	-75.9[3]	4.6
Aviation-ER		X		X	Note 2	Note 2	TSO C-129a	Noise-Like	-136	-84.9[3]	13.6

Notes:
1. When the interference effect has been characterized as being pulse-like or noise-like, the value is expressed in units of dBW/MHz. The value is expressed in units of dBW when the interference effect has been characterized as being CW-like.
2. In this operational scenario, it is assumed that there is a large enough number of UWB devices, such that independent of the individual UWB signal parameters the aggregate effect causes noise-like interference.
3. This maximum allowable EIRP is based on a density of 200 active UWB devices per square kilometer.

Certain observations were made based on a review of the last column in Tables 1 through 4. This column lists the difference between the current Part 15 level of -71.3 dBW/MHz (considered as an average power limit) and the computed maximum allowable EIRP values. As stated earlier, a positive number in the last column indicates that the computed level of maximum allowable EIRP is less than the current Part 15 level.

An examination of Table 1 (PRF = 100 kHz) shows the effect of the C/A code signal process, used by both the narrowly-spaced correlator and the TSO-C129a compliant receivers, being fairly robust to low-duty cycle pulsed interference. The worse-case comparison to the current Part 15 level is the aviation en-route navigation operational scenario with UWB devices operating outdoors (13.6 dB below the Part 15 level). This is based on a density of active UWB devices of 200/km^2. If one considers the use of 100 kHz PRF could be of interest in only UWB device applications such as ground penetrating radars and through-the-wall imaging radars, the projected density of UWB devices may not be as high as assumed. If, for example, the density of UWB devices operating at 100 kHz is 20/km^2, the maximum allowable EIRP would increase by 10 dB.

Tables 2 through 4 (UWB waveforms with PRFs of 1, 5, and 20 MHz) show that the maximum allowable EIRP level necessary to satisfy the measured GPS performance criteria must be below the current Part 15 level for most of the operational scenarios considered. Those interactions that involve operational scenario/UWB signal parameter combinations that require an attenuation of 20 dB or more below the Part 15 level were selected for closer examination. This examination indicates that in most of these cases, the interactions involve: 1) UWB waveforms that were deemed CW-like in their interference effect to the GPS receivers, for which the measurements indicate a greater interference susceptibility or 2) operational scenarios in which the UWB transmitter is considered to be operating at a close distance (within several meters) to the GPS receivers. This data suggests that if the spectral line content of the UWB waveforms could be removed from consideration, perhaps through regulation, there still remains several interactions involving noise-like UWB waveforms at these PRFs for which the EIRP levels would still have a potential to cause interference at levels 18 to 20 dB below the current Part 15 level.

As shown in Tables 1 through 4, the results of the analysis indicate that the values of maximum allowable EIRP that are necessary to preclude interference to GPS receivers is highly dependent on the parameters of the UWB signal. This is consistent with the findings from the measurement effort where the performance of the GPS receiver in the presence of a UWB signal was also found to be highly dependent on the UWB signal structure.

Figures 1 through 4 display computed maximum allowable EIRP levels for those UWB signal permutations that were classified within this study as pulse-like, noise-like, and CW-like with respect to their interference effects on the GPS narrowly-spaced correlator receiver architecture. The values reported in these charts represent the range of maximum allowable UWB EIRP levels. The values were determined from an analysis of each UWB signal permutation in potential interactions with the narrowly-spaced correlator receiver architecture. The analysis included all of the operational scenarios considered in the study.

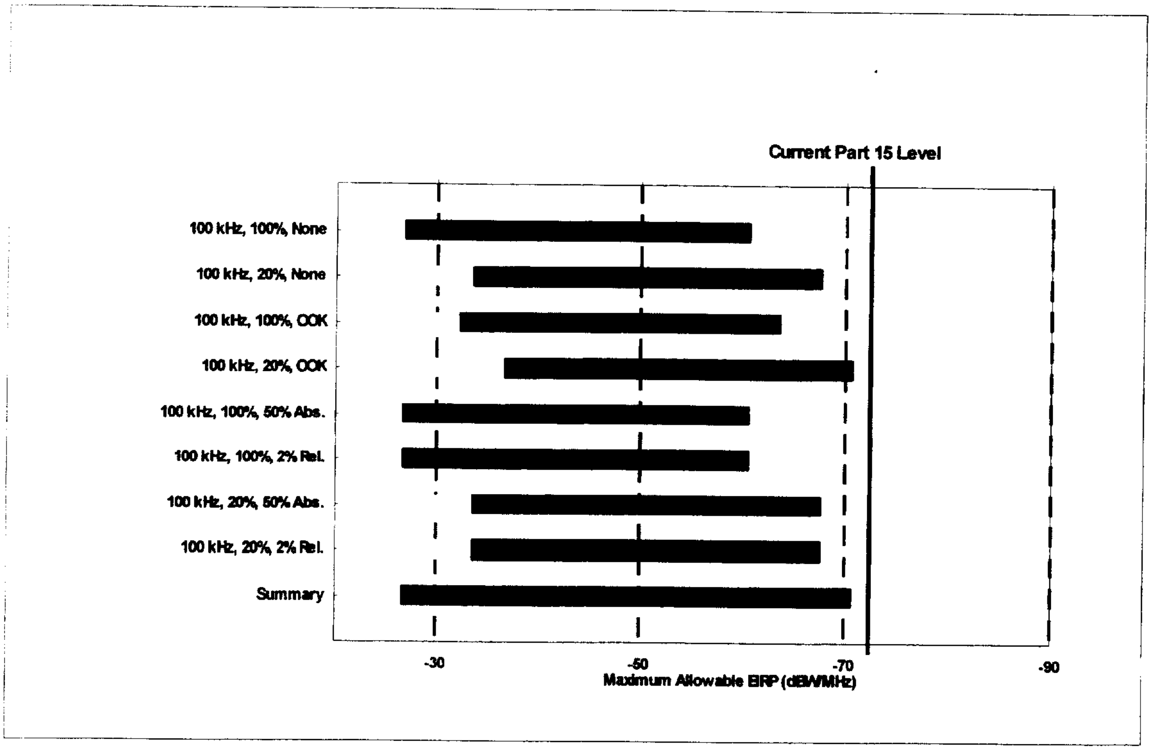

Figure 1. Range of Maximum Allowable EIRP for Pulse-Like UWB Signal for the Narrowly-Spaced Correlator Receiver Architecture (Single and Multiple UWB Device Operational Scenario)

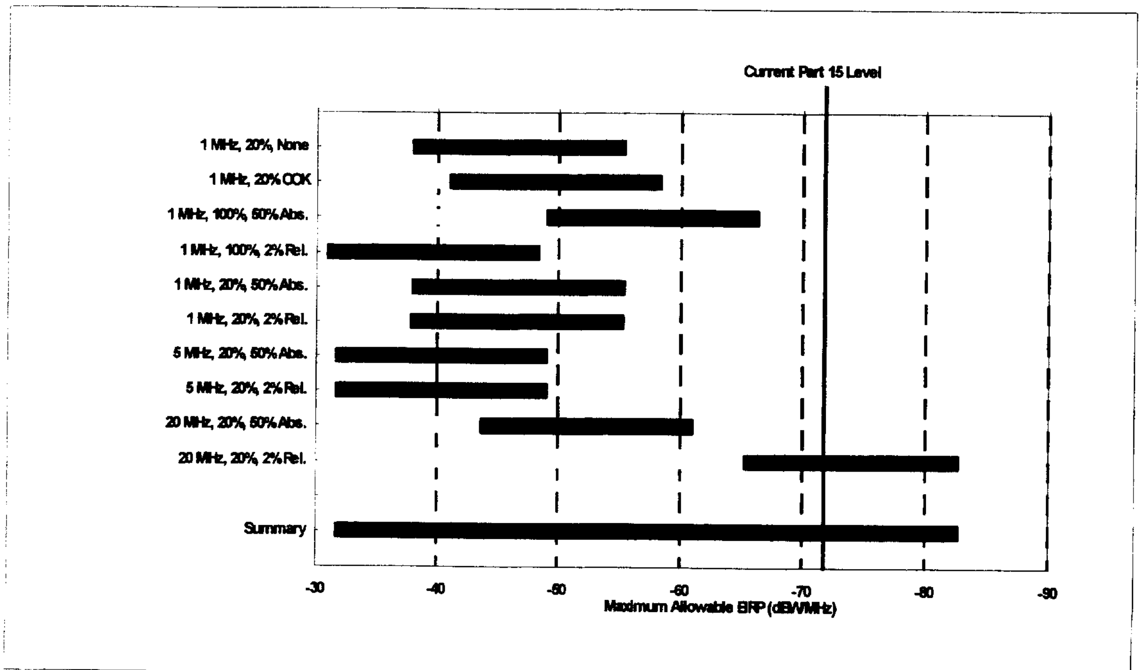

Figure 2. Range of Maximum Allowable EIRP for Pulse-Like UWB Signal for the Narrowly-Spaced Correlator Receiver Architecture (Single UWB Device Operational Scenario)

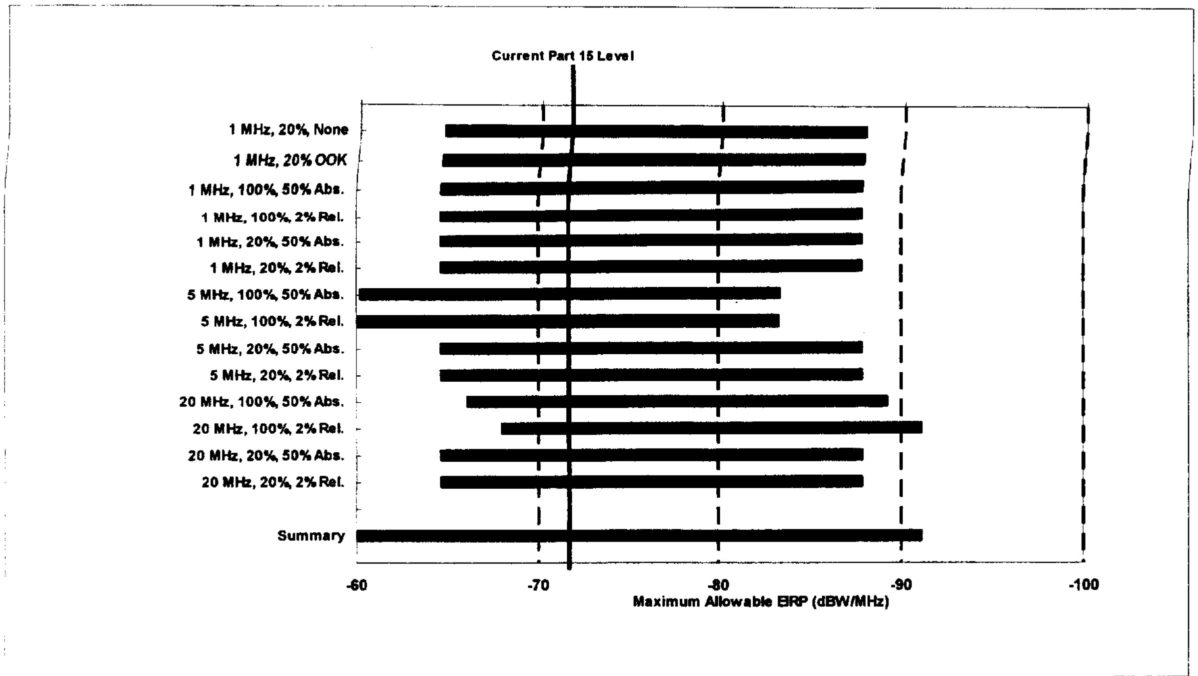

Figure 3. Range of Maximum Allowable EIRP for Noise-Like UWB Signals for Narrowly-Spaced Correlator Receiver Architecture (Single and Multiple UWB Device Scenarios)

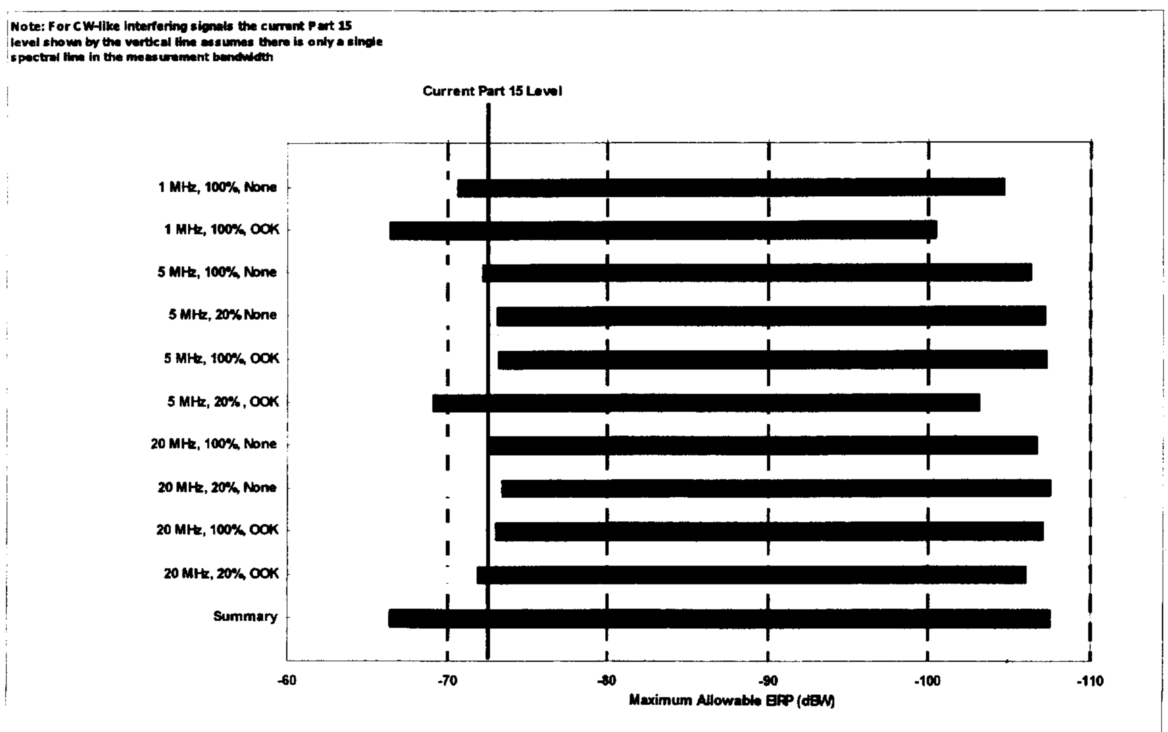

Figure 4. Range of Maximum Allowable EIRP for CW-Like UWB Signals for the Narrowly-Spaced Correlator Receiver Architecture (Single and Multiple UWB Device Operational Scenarios)

For the operational scenarios considered for single and multiple UWB devices, Figures 1 and 2 display the range of maximum allowable EIRP for the UWB signals that were classified in this study as being pulse-like. Figure 3 displays the range of maximum allowable EIRP levels for those UWB signals that were classified in this study as being noise-like. Figure 4 displays the range of maximum allowable EIRP levels for those UWB signals that were classified in this study as being CW-like in their interference effects on the GPS narrowly-spaced correlator receiver. The labels on the y-axis in Figures 1 through 4 identify the various UWB signal structures in terms of PRF, percent gating, and the type of modulation. For example, a UWB signal structure with a PRF of 100 kHz, 100% gating, and no modulation will have a y-axis label of: 100 kHz, 100%, None.

An examination of Figures 1 through 4 clearly indicates that the maximum allowable EIRP required to satisfy the measured performance threshold of the narrowly-spaced correlator GPS receiver, across all of the operational scenarios is a function of the UWB signal structure. Figure 1 shows that the maximum allowable EIRP corresponding to those UWB signal permutations with a PRF of 100 kHz. For the UWB signal permutations represented in Figure 1, neither a break-lock nor a reacquisition could be measured for UWB power levels up to the maximum power available from the UWB signal generator. For these cases, the maximum UWB signal generator power level was used to compute the maximum allowable EIRP level. Thus the reported maximum allowable EIRP level represents a lower limit for these cases. That is, the actual maximum allowable EIRP level may be higher than the level shown in Figure 1 for these 100 kHz PRF UWB waveforms. From Figure 1, it can be observed that the maximum allowable EIRP levels necessary to satisfy the measured performance threshold for the narrowly-spaced correlator GPS receiver over all of the operational scenarios considered in this study range from -70.8 to -26.6 dBW/MHz.

In the operational scenarios where single UWB device interactions are considered, several UWB signal permutations employing PRFs of 1 MHz, 5 MHz, and 20 MHz, caused an effect similar to that of low-duty cycle pulsed interference to the narrowly-spaced correlator receiver. Figure 2 shows that for these UWB signal permutations, the maximum allowable EIRP levels necessary to satisfy the GPS receiver performance thresholds for the operational scenarios considered within this study range from -82.8 to -31.6 dBW/MHz.

Figure 3 shows that the maximum allowable EIRP levels necessary to satisfy the measured performance thresholds over all of the operational scenarios considered in this study range from -91.2 to -60.1 dBW/MHz for those UWB signals employing PRFs of 1 MHz, 5 MHz, and 20 MHz, that are classified as noise-like in their interference effects on the GPS narrowly-spaced correlator receiver.

The data presented in Figure 4 shows that the maximum allowable EIRP levels range from -107.5 to -66.4 dBW over all of the operational scenarios considered for those UWB signals that are classified as CW-like in their interference effects on the GPS narrowly-spaced correlator receiver. These maximum allowable EIRP levels are based on the power in a single spectral line and in order to make a comparison to the Part 15 level, it must be assumed that only a single spectral line appears in the measurement bandwidth.

Figures 5 through 7 present summary plots showing the maximum allowable EIRP calculated for the aviation non-precision approach operational scenario using the TSO-C129a compliant GPS receiver measured as part of this effort. The analysis results are presented as a function of the different UWB signal permutations examined. For the TSO-C129a compliant receiver, the interference effects of the UWB signals examined are classified as pulse-like, noise-like, or CW-like.

Figure 5 shows that for those UWB signals examined with a PRF of 100 kHz, the calculated maximum allowable EIRP level is above the current Part 15 level. Therefore, based on the results of the analysis, no additional attenuation is necessary.

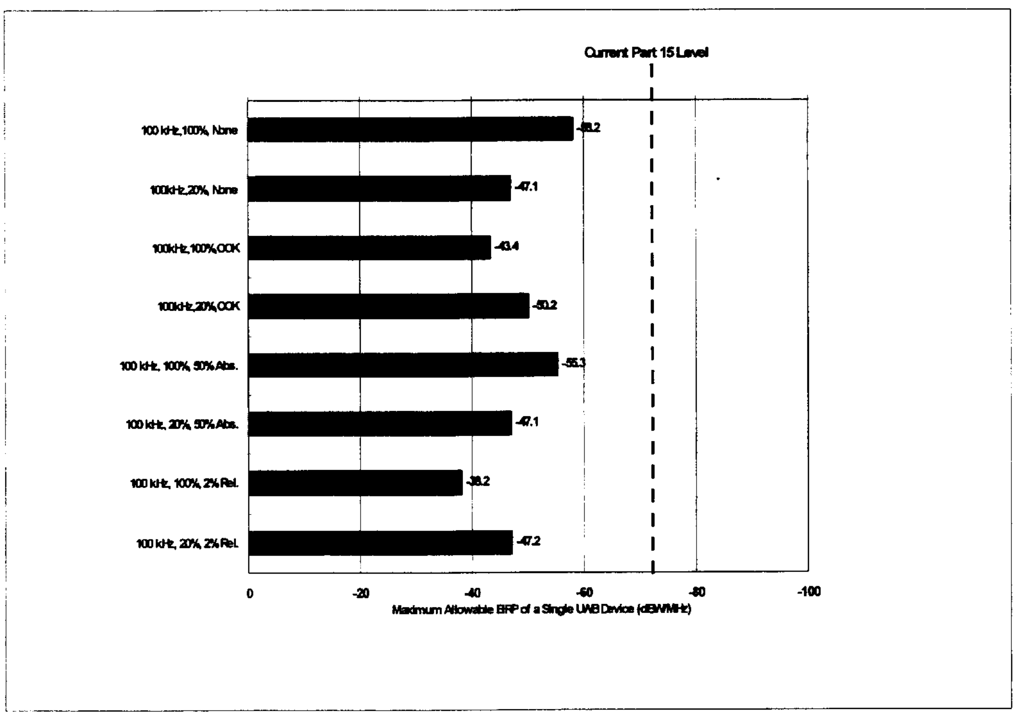

Figure 5. Maximum Allowable EIRP as a Function of UWB Signal Structure for the TSO-C129a Compliant C/A Code Receiver Architecture (Pulse-Like UWB Signals)

Figure 6 shows the maximum allowable EIRP levels for PRFs of 1 MHz, 5 MHz, and 20 MHz, when the UWB signal permutations were classified as causing noise-like interference to the TSO-C129a compliant GPS receiver. As shown in Figure 6, the maximum allowable EIRP must be as much as 18 dB below the current Part 15 level to satisfy the measured performance threshold of the TSO-C129a compliant GPS receiver in the applicable operational scenario.

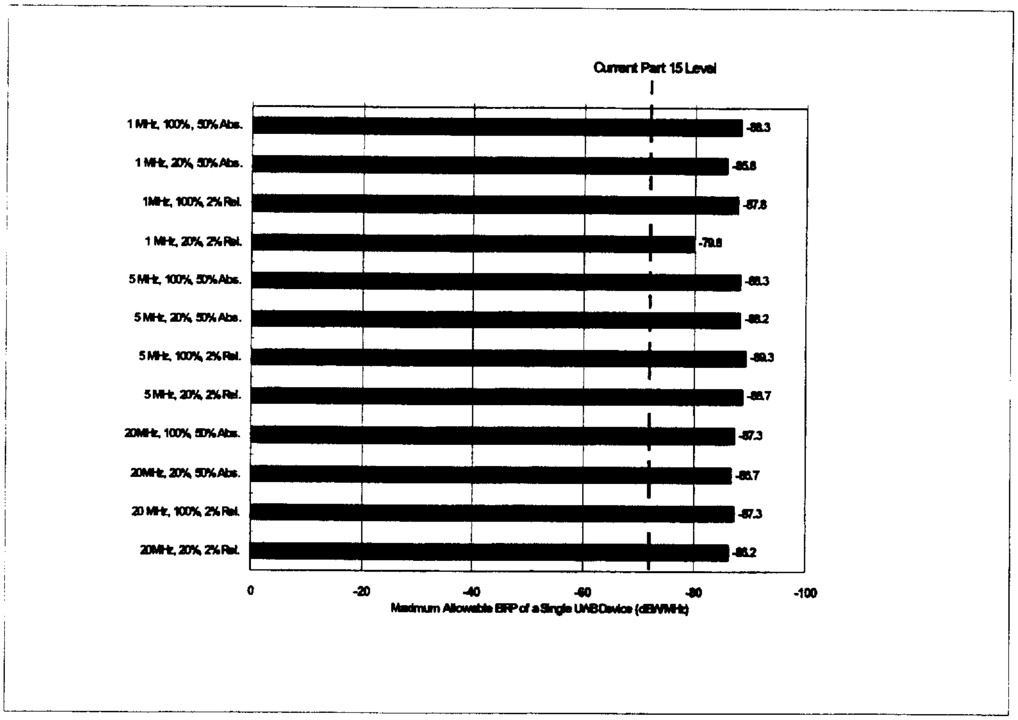

Figure 6. Maximum Allowable EIRP as a Function of UWB Signal Structure for the TSO-C129a Compliant C/A Code Receiver Architecture (Noise-Like UWB Signals)

Figure 7 shows the maximum allowable EIRP levels for the PRFs of 1 MHz, 5 MHz, and 20 MHz, that have been classified as causing CW-like interference to the TSO-C129a compliant receiver. As shown in Figure 7, for those UWB signal permutations, the maximum allowable EIRP must be as much as 17 dB below the current Part 15 level to satisfy the measured performance threshold of the TSO-C129a compliant receiver.

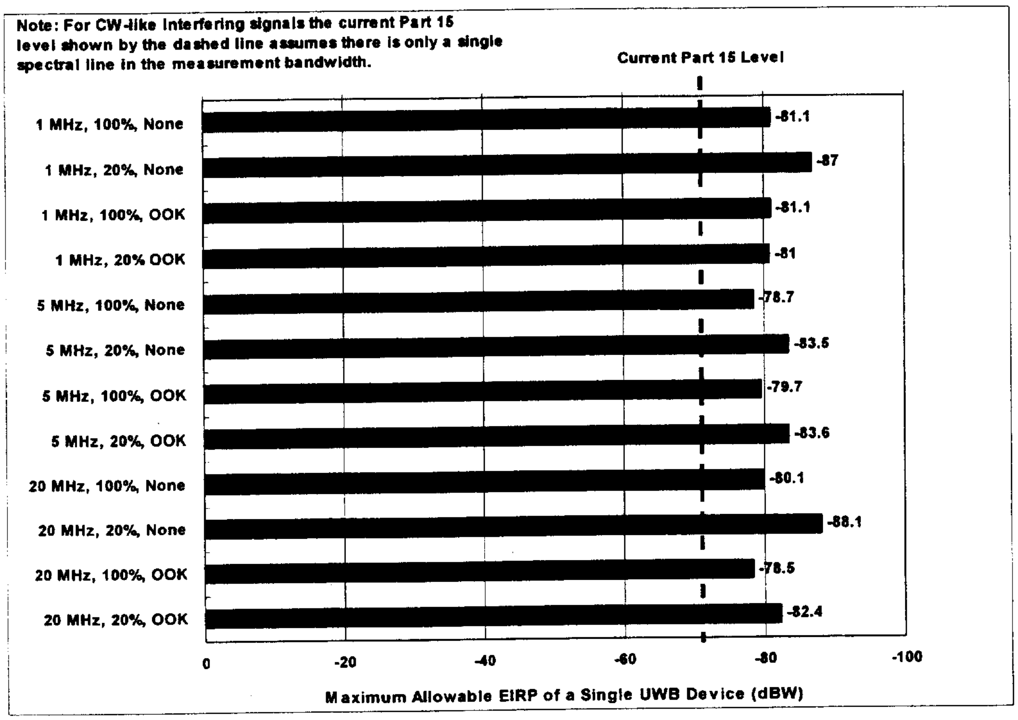

Figure 7. Maximum Allowable EIRP as a Function of UWB Signal Structure for the TSO-C129a Compliant C/A Code Receiver Architecture (CW-Like UWB Signals)

Table 5 provides a comparison of the range of computed EIRP levels for the C/A code receiver architecture considered in NTIA Report 01-45 and the narrowly-spaced correlator receiver architecture considered in this addendum. Table 6 provides a comparison of the computed EIRP levels for the C/A code receiver architecture considered in NTIA Report 01-45 and the TSO-C129a compliant C/A code receiver architecture considered in this addendum. An examination of the computed EIRP levels shown in Tables 5 and 6 indicates that the ranges of computed EIRP levels are consistent among the different GPS receivers under the conditions of the operational scenarios that were analyzed.

Table 5. Comparison of EIRP Levels for C/A Code and Narrowly-Spaced Correlator Receiver Architectures

Operational Scenario	Interference Effects	C/A Code EIRP Range	Narrowly-Spaced Correlator EIRP Range
Terrestrial - Single	Pulse-Like	-95.6 to -49.6 dBW/MHz	-82.8 to -48.4 dBW/MHz
Terrestrial - Multiple (Outdoor)	Pulse-Like	-62.3 to -49.7 dBW/MHz	-59.9 to -49.8 dBW/MHz
Terrestrial - Multiple (Indoor)	Pulse-Like	-57.6 to -45 dBW/MHz	-55.2 to -45.1 dBW/MHz
Terrestrial - Single	Noise-Like	-98.6 to -96.6 dBW/MHz	-96.1 to -88.2 dBW/MHz
Terrestrial - Multiple (Outdoor)	Noise-Like	-93.7 to -90.2 dBW/MHz	-91.2 to -83.3 dBW/MHz
Terrestrial - Multiple (Indoor)	Noise-Like	-89 to -85.5 dBW/MHz	-86.5 to -78.6 dBW/MHz
Terrestrial - Single	CW-Like	-106.9 to -104.3 dBW	-107.5 to -100.5 dBW
Terrestrial -Multiple (Outdoor)	CW-Like	-96 to -93.4 dBW	-96.6 to -89.6 dBW
Terrestrial - Multiple (Indoor)	CW-Like	-91.3 to -88.7 dBW	-91.9 to -84.9 dBW
Maritime (Outdoor)	Pulse-Like	-48.1 to -34.8 dBW/MHz	-45.7 to -34.9 dBW/MHz
Maritime (Indoor)	Pulse-Like	-41.7 to -26.5 dBW/MHz	-39.3 to -26.6 dBW/MHz
Maritime (Outdoor)	Noise-Like	-79.5 to -75.3 dBW/MHz	-77 to -68.4 dBW/MHz
Maritime (Indoor)	Noise-Like	-73.1 to -67 dBW/MHz	-70.6 to -60.1 dBW/MHz
Maritime (Outdoor)	CW-Like	-81.8 to -78.5 dBW	-82.4 to -74.7 dBW
Maritime (Indoor)	CW-Like	-75.4 to -70.2 dBW	-76 to -66.4 dBW
Railway (Outdoor)	Pulse-Like	-57.8 to -45.2 dBW/MHz	-55.4 to -45.3 dBW/MHz
Railway (Indoor)	Pulse-Like	-56.3 to -43.7 dBW/MHz	-53.9 to -43.8 dBW/MHz
Railway (Outdoor)	Noise-Like	-88 to -84.5 dBW/MHz	-85.5 to -77.6 dBW/MHz
Railway (Indoor)	Noise-Like	-86.5 to -83 dBW/MHz	-84 to -76.1 dBW/MHz
Railway (Outdoor)	CW-Like	-91.5 to -88.9 dBW	-92.1 to -85.1 dBW
Railway (Indoor)	CW-Like	-90 to -87.4 dBW	-90.6 to -83.6 dBW

Table 6. Comparison of EIRP Levels for C/A Code and TSO-C129a Complaint C/A Code Receiver Architectures

Operational Scenario	Interference Effects	C/A Code	TSO-C129a Compliant
		EIRP Range	EIRP Range
Aviation - Non-Precision Approach	Pulse-Like	-52.9 to -40.3 dBW/MHz	-58.2 to -38.2 dBW/MHz
Aviation - Non-Precision Approach	Noise-Like	-84.3 to -80.8 dBW/MHz	-89.3 to -79.8 dBW/MHz
Aviation - Non-Precision Approach	CW-Like	-86.6 to -84 dBW	-88.1 to -78.5 dBW
Aviation - En-route (Outdoor)	Noise-Like	-85.6 dBW/MHz	-84.9 dBW/MHz
Aviation - En-route (Indoor)	Noise-Like	-76.6 dBW/MHz	-75.9 dBW/MHz

An analysis was also performed to determine the distance separations that would preclude interference to the different GPS receiver architectures, if the UWB device is operating at the current Part 15 level of -71.3 dBW/MHz. The measured UWB interference thresholds for both single-entry and multiple-entry UWB device interactions were considered.

Table 7 presents an overview of the distance separation analysis results for the C/A code, semi-codeless, and narrowly-spaced correlator receiver architectures for single-entry UWB device interactions. Table 8 presents an overview of the analysis results for the TSO-C129a compliant receiver. Table 9 presents an overview of the distance separation analysis results for the C/A code receiver architecture for multiple-entry UWB device interactions.

Table 7. Overview of Single-Entry Distance Separation Analysis Results for the C/A Code, Semi-Codeless, and Narrowly-Space Correlator Receiver Architectures

UWB PRF (MHz)	Distance Separation (m)* To Preclude Interference								
	Gr = 3 dBi			Gr = 0 dBi			Gr = -4.5 dBi		
	C/A Code	Semi-Codeless	Narrowly-Spaced Correlator	C/A Code	Semi-Codeless	Narrowly-Spaced Correlator	C/A Code	Semi-Codeless	Narrowly-Spaced Correlator
0.1	5	92	4	3.5	65	3	2	39	2
1	178	412	186	126	292	132	75	174	79
5	219	412	251	155	292	178	92	174	106
20	240	347	257	170	246	182	101	146	108

*Note: G_r is the GPS receive antenna gain.

Table 8. Overview of Distance Separation Analysis Results for TSO-C129a Compliant GPS Receiver

UWB PRF (MHz)	Distance Separation (m)
0.1	9
1	251
5	170
20	285

TABLE 9. Calculated Distance Separations to Preclude Interference from Multiple-Entry UWB Device Interactions Based on the Current Part 15 Emission Limit (C/A Code Receiver Architecture)

UWB Parameters				Distance Separation (meters)*		
PRF (MHz)	Gating Percent	Modulation	Number of UWB Signal Generators	Gr = 3 dBi	Gr = 0 dBi	Gr = -4.5 dBi
10	100	Dithering 2% Rel.	6	213	151	90
10	20	Dithering 2% Rel.	6	180	127	76
10 3 3	100 100 20	None None Dithering 2% Rel.	2 1 3	351	248	148
3 3	20 20	None Dithering 2% Rel.	4 2	174	123	73
1	100	Dithering 2% Rel.	1	41	29	17
1	100	Dithering 2% Rel.	2	104	73	44
1	100	Dithering 2% Rel.	3	127	90	54
1	100	Dithering 2% Rel.	4	147	104	62
1	100	Dithering 2% Rel.	5	184	130	78
1	100	Dithering 2% Rel.	6	180	127	76
Note: G_r is the GPS receive antenna gain						

CONCLUSIONS

This addendum was prepared to report on the results of the susceptibility measurements on the two GPS receivers that were not completed in time to be included in the initial NTIA report (NTIA Report 01-45). This addendum also provides the results of the analyses applying this measured data to determine maximum EIRP levels that would protect these GPS receivers within the applications represented by the operational scenarios examined. The measurements reported in this addendum are limited to single-entry interference cases. The aggregate and other ancillary measurements reported in NTIA Report 01-45 were not repeated as a part of this addendum. There were no noteworthy differences in either the receiver susceptibility measurements or the analysis results between the initial report and this addendum.

In addition to reporting the interference susceptibility data from the remaining two receivers tested in the overall NTIA measurement effort, this addendum presents a comparison among the data sets collected within the NTIA measurement program as well as a comparison of the NTIA data with comparable data sets measured in the other UWB-to-GPS measurement efforts conducted by SU and ARL:UT. In performing this comparison, a definite consistency in the total data set that has been made a part of the public record has been noted. This consistency within the measured data has also been noted by other parties to this proceeding.

The data sets acquired from three of the receivers tested in the NTIA measurement program were compared to one another and found to be consistent with respect to the interference susceptibility levels measured and the interference effects that were observed. In addition, the NTIA measured data was compared to similar data sets collected for the GPS receivers examined in the measurement efforts performed by SU and ARL:UT. This comparison also indicates a significant consistency between the measured susceptibility data and the observed interference effects among the GPS receivers considered in the various test programs. Finally, an NTIA comparison between the measured GPS susceptibility data and the existing interference protection criteria developed within RTCA and the ITU-R also indicates a consistency between the measured interference thresholds and the existing GPS interference criteria. This consistency across the data sets, coupled with emergence of consistent trends in the interference effects observed by all of the measurement parties, suggests that a meaningful record of GPS receiver susceptibility data has been compiled in this proceeding.

The previous NTIA report noted a relationship between the interference susceptibility of a GPS receiver, particularly the C/A-code receiver, and the characteristics of the interfering UWB signal (e.g., PRF, dithering, gating, etc). This same relationship is also noted in the results of the additional measurements reported in this addendum; however, another parameter effecting the interference potential to a GPS receiver from UWB emissions was noted - the pre-correlator bandwidth of the GPS receiver. In the supplemental measurement effort, the susceptibility to UWB emissions was examined for two additional GPS receivers. Both of these receivers process the GPS C/A-code signal transmitted on L1 (the narrowly-spaced correlator receiver also has an L2 capability, but it was disabled for these tests). The narrowly-spaced correlator GPS receiver

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ADR	Accumulated Delta-Range
APD	Amplitude Probability Distribution
ARL:UT	Applied Research Laboratories University of Texas
ARNS	Aeronautical Radionavigation Service
BL	Break-Lock
C/A	Coarse/Acquisition
C/N_0	Carrier-to-Noise Power Density Ratio
CDMA	Code Division Multiple Access
CFR	Code of Federal Regulations
CMC	Code Minus Carrier
CW	Continuous Wave
dB	Decibels
dBi	Decibels relative to an isotropic antenna
dBic	Decibels relative to an isotropic circularly polarized antenna
dBm	Decibels relative to one milliwatt (equal to -30 dBW)
dBW	Decibels relative to one watt (equal to 30 dBm)
DGPS	Differential Global Positioning System
DNBL	Did Not Break lock
DoD	Department of Defense
E-911	Enhanced-911
EIRP	Equivalent Isotropically Radiated Power
EMC	Electromagnetic Compatibility
ER	En-Route Navigation
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FTE	Flight Technical Error
GEO	Geostationary Earth Orbiting
GHz	Gigahertz
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
IF	Intermediate Frequency
IGEB	Interagency GPS Executive Board
IRAC	Interdepartment Radio Advisory Committee
ITS	Institute for Telecommunication Sciences
ITU-R	International Telecommunication Union - Radiocommunication Sector
JHU/APL	Johns Hopkins University/Applied Physics Laboratory
JSC	Joint Spectrum Center
kHz	kilohertz
L1	GPS Link 1 (1575.42 MHz)
L2	GPS Link 2 (1227.60 MHz)
L5	GPS Link 5 (1176.45 MHz)

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utilizes an architecture that makes use of multiple correlators, spaced less than one chip apart, to mitigate multipath effects at the receiver. This GPS receiver architecture uses a precorrelator bandwidth of approximately 16 MHz. The second GPS receiver measured in the supplemental effort is an existing aviation-grade (TSO-C129a-compliant) receiver. This receiver is unique in that it provides a Receiver Autonomous Integrity Monitoring (RAIM) capability. The precorrelator bandwidth of this receiver is approximately 2 MHz. The C/A-code receiver for which the measured interference susceptibility data was reported in NTIA Report 01-45, employed a precorrelator bandwidth of approximately 10 MHz. When comparing the susceptibility data collected for each of these receivers, a relationship between the interference effect and the receiver bandwidth was observed. For example, some of the UWB signal permutations (particularly among the 1 MHz PRF signals) that produced pulse-like interference effects in the wider band GPS receivers (the 10 MHz C/A-code receiver and the 16 MHz narrowly-spaced correlator receiver), excited a response characteristic of the more disruptive noise-like or CW-like interference effects in the narrower bandwidth receiver (i.e., the 2 MHz aviation receiver).

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

LAAS	Local Area Augmentation System
LNA	Low Noise Amplifier
LOS	Line-of-Sight
LR	Loss Ratio
MDH	Minimum Descent Height
MHz	Megahertz
ms	millisecond
MSS	Mobile Satellite Service
NASA	National Aeronautics and Space Administration
NBL	Noise Break-Lock
NOI	Notice Of Inquiry
NPA	Non-Precision Approach
NPRM	Notice of Proposed Rulemaking
NSE	Navigation System Error
NTIA	National Telecommunications and Information Administration
OEM	Original Equipment Manufacturer
OOK	On-Off Keying
OSM	Office of Spectrum Management
PDOP	Position Dilution Of Precision
PRF	Pulse Repetition Frequency
PROM	Programmable Read Only Memory
PTC	Positive Train Control
RAIM	Receiver Autonomous Integrity Monitoring
RMS	Root-Mean-Square
RNSS	Radionavigation Satellite Service
ROM	Read Only Memory
RTCA	RTCA, Inc.
RQT	Reacquisition Time
SPS	Standard Positioning Service
SU	Stanford University
SV	Space Vehicle
TSE	Total System Error
TSO	Technical Standard Order
USCG	United States Coast Guard
UWB	Ultrawideband
WAAS	Wide Area Augmentation System