SECTION 4.0
SUMMARY/CONCLUSIONS

4.1 SUMMARY OF MEASUREMENT FINDINGS

In the measurement component of this assessment, 32 UWB signal permutations were identified for examination with respect to the interference potential to GPS receivers. For each of four pulse repetition frequencies (PRFs);100 kHz, 1 MHz, 5 MHz, and 20 MHz, eight distinct UWB waveforms were generated by combining four modulation types (constant PRF, On-Off Keying (OOK), 2% relative dither, and 50% absolute dither) and two states of gating (100% and 20%). Each of these UWB parameters are described in the paragraphs below.

The PRF defines the number of pulses transmitted per unit time (seconds). The PRF governs both the magnitude and spacing of the spectral lines in an unmodulated UWB signal. For example, a 5 MHz PRF signal produces spectral lines that are spaced every 5 MHz in the frequency domain. As the PRF is increased, the spectral lines become spaced further apart, but the energy contained in each spectral line is increased. Within the context of this report, "constant PRF" refers to an unmodulated UWB signal.

Gating refers to the process of distributing pulses in bursts by employing a programmed set of periods where the UWB transmitter is turned on or off for a period of pulses. For the measurements performed in this study, the gated UWB signal utilized a scheme where a burst of pulses lasting 4 ms was followed by a 16 ms period when no pulses were transmitted. This is referred to as 20% gating, because the UWB pulses are transmitted 20% of the time. The signal permutations depicted within this report as 100% gating, define a signal where pulses are transmitted 100% of the time.

OOK refers to the process of selectively turning off or eliminating individual pulses to represent data bits. With OOK modulation, the energy in the spectrum is equally divided between the spectral line components and the noise continuum component.

Dithering refers to the random or pseudo-random spacing of the pulses. Two forms of dithered UWB signals were considered in this effort. These are an absolute referenced dither, where the pulse period is varied in relation to the absolute clock, and a relative referenced dither, where the pulse spacing is varied relative to the previous pulse. The PRF of a relative dithered pulse train is equal to the reciprocal of the mean pulse period. The PRF of an absolute dithered pulse train is equal to the frequency of the clock. Dithering of the pulses in the time domain spreads the spectral line content of a UWB signal in the frequency domain making the signal appear more noise-like.

For illustration, Figure 4-1 shows the spectral content for a 1 MHz PRF UWB signal as measured in a 24 MHz bandpass filter when: unmodulated, OOK modulated, 50% absolute reference dithered, and 2% relative referenced dithered.

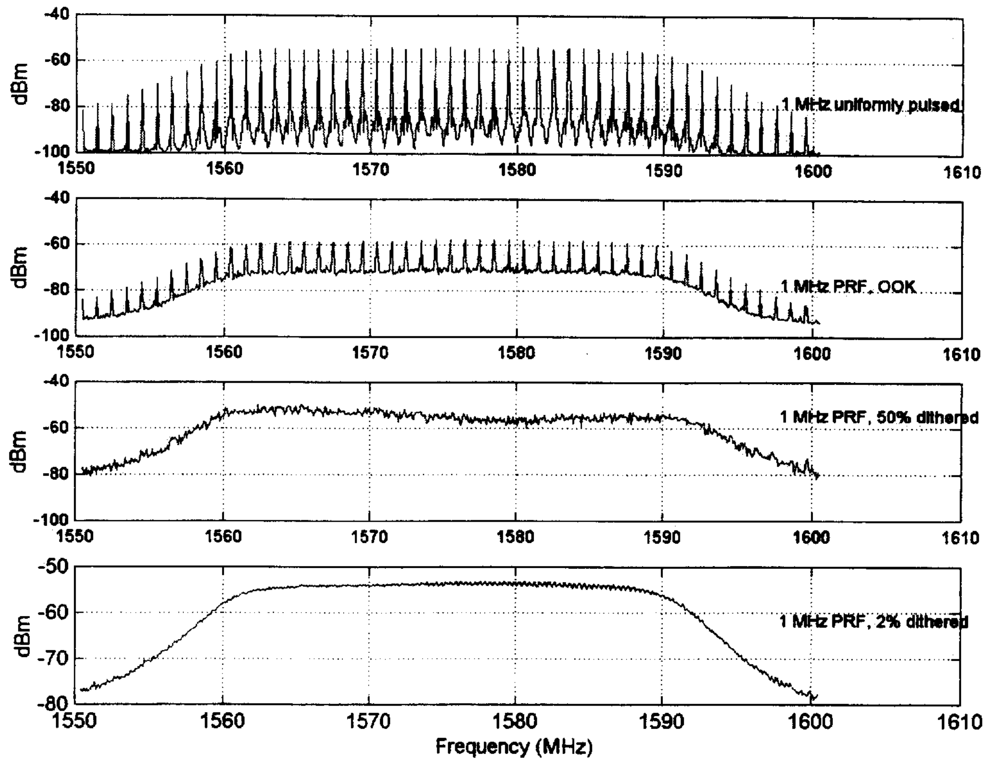

Figure 4-1. Illustration of Modulation Effects on a UWB Signal as Measured in a 24 MHz Bandpass Filter

The results of this measurement effort were found to be UWB signal-dependent and are strongly related to the PRF examined. Thus, in this section, the summary of the measurement results, and the conclusions drawn from them, will be grouped by UWB signal PRF for each of the GPS receivers measured.

4.2 ANALYSIS OF C/A-CODE GPS RECEIVER INTERFERENCE SUSCEPTIBILITY DATA

Previous work in quantifying interference to GPS receivers has been performed in RTCA and ITU-R technical working groups. Much of this work has focused on the effect of different interference signal types upon C/A-code receivers, since these represent the predominant receiver architecture in the civilian marketplace. This work has determined that GPS C/A-code receivers are most susceptible to CW-like interference. This is due to the potential for interfering spectral lines to become aligned with the 1 kHz spaced spectral lines of the GPS C/A-code, produced as a result of the relatively short, periodic nature of the Gold codes used to generate the pseudo-random sequences necessary for code division multiple access (CDMA) operation. RTCA and ITU-R have documented an interference protection level -150.5 dBW, at the input of the GPS receiver, as necessary to protect GPS receivers from this type of interfering signal. GPS C/A-code receivers are also susceptible to broadband noise-like interference where the documented protection level, at the input of the GPS receiver is -140.5 dBW/MHz. Both of the above protection levels are based on a GPS signal level of -134.5 dBm at the input to the GPS receiver.

RTCA has also determined that GPS C/A-code receivers are less sensitive to low duty cycle pulse-like interfering signals. The interference protection level documented for this type of interference is +20 dBm (peak pulse power), at the input to the receiver, for duty cycles less than 10%.

In the analysis of measurements 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 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 collected under this addendum report effort were for a GPS receiver employing a narrowly spaced correlator and a TSO-C129a (aviation) compliant GPS receiver. The C/A-code GPS receiver that was the subject of the NTIA Report 01-45 is referred as 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 was analyzed by determining the median along with the range of data for each receiver and the results are shown Table 4-1. 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 across the three receivers that process the L1 C/A code signal. The noise-like susceptibility values are similarly consistent across the three GPS receivers.

TABLE 4-1. Median and Range of Data Values for the Interference Thresholds

Data Set	Interference Threshold Values		
	C/A Code	Narrowly-Spaced Correlator	TSO-C129a Compliant
Median for CW-Like Interference (Break-Lock)	-145 dBW	-145.9 dBW	-140.8 dBW
Range of Data	-143.7 to -146.5 dBW	-139.9 to -147 dBW	-138.2 to -147.8 dBW
Median for Noise-Like Interference (Break-Lock)	-129 dBW/MHz	-131.6 dBW/MHz	-134.4 dBW/MHz
Range of Data	-127.8 to -130.9 dBW/MHz	-127 to -132.7 dBW/MHz	-131.6 to -135 dBW/MHz
Median for Noise-Like Interference (Reacquisition)	-133 dBW/MHz	No Measured Data	-134.9 dBW/MHz
Range of Data	-129.8 to -133.9 dBW/MHz		-131.6 to -136 dBW/MHz

Table 4-2 shows the overall median and range for the combined data for the three receivers. This 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 the three receivers. The data in Table 4-2 was used to compare the NTIA data with GPS/UWB measurement data collected by other entities.

TABLE 4-2. Overall Median and Range of Data Values for the Interference Thresholds

Data Set	Interference Threshold Values (Data Combined for the Three Receivers)
Median for CW-Like Interference (Break-Lock)	-144.5 dBW
Range of Data	-138.2 to -147.8 dBW
Median for Noise-Like Interference (Break-Lock)	-133.2 dBW/MHz
Range of Data	-127 to -135 dBW/MHz
Median for Noise-Like Interference (Reacquisition)	-134.6 dBW/MHz
Range of Data	-129.8 to -136 dBW/MHz

In order to make a comparison between the NTIA and SU data, data sets had to be identified where similar measurement procedures, interference criteria, and UWB signal characteristics are used. Where measurement procedures, interference criteria, and UWB signal characteristics were similar, appropriate comparisons were made. The comparison of the NTIA and SU data is presented in Table 4-3.

As indicated in Table 4-3, the SU GPS/UWB interference measurement program considered two types of GPS receivers. These are referred to as a high-grade GPS aviation receiver and a low-cost Original Equipment Manufacturer (OEM) receiver. Several interference criteria were also used including break-lock and pseudo-range accuracy. The interference effects for the SU data examined in this analysis can be characterized as noise-like or CW-like. The SU measured interference threshold data is reported in units of dBm (average power) as measured in a 24 MHz bandwidth filter. For comparison purposes the SU data was adjusted to units of dBW/MHz for noise-like interference cases and referenced to a GPS signal level of -130 dBm. Similarly, the CW-like cases were adjusted to determine power in a single spectral line in dBW and referenced to a GPS signal level of -130 dBm. Both SU measured CW-like interference cases in Table 4-3 used a UWB signal that resulted in only one line within the 24 MHz measurement filter. The NTIA data is primarily for the break-lock condition either for CW-like or noise-like interference effects and is compared to the SU CW-like and noise-like data as appropriate. For the SU test that used pseudo-range accuracy as the interference criterion, the NTIA median interference threshold value for reacquisition was used for comparison. Table 4-3 also contains the range of data associated with each NTIA median threshold level.

A review of the Table 4-3 information indicates that the SU data is consistent (comparing the adjusted threshold level columns) with the NTIA measured receiver input threshold data. The high-grade aviation receiver is slightly more robust than the receivers tested by NTIA under break-lock conditions. However, 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 OEM 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 JSC was also compared to the NTIA data. Again, because of differences in the measurement approach and the interference threshold criteria, only a subset of the ARL:UT data could be used in this comparison. These differences in measurement approach are explained in the JSC Report. The comparison of NTIA data with ARL:UT data is shown in Table 4-4. 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 cases shown in Table 4-4 are consistent with the NTIA data particularly if one compares the ARL:UT data to the range associated with the NTIA median value. A possible exception to this consistency is observed in the data for Receiver Number One with UWB interference and a loss of one SV (-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 consistent with the ARL:UT test results for these two cases.

TABLE 4-3. Comparison of SU and NTIA Interference Threshold Levels

SU Receiver Type	Interference Criteria	Category of Interfering Signal Effect	SU Report Threshold Level	SU Adjusted Threshold Level	Comparable NTIA Adjusted Threshold Overall Median Level	Range of Data Associated with NTIA Median Levels
Aviation	Break-Lock	Noise-like	-83.8 dBm/24 MHz	-126.3 dBW/MHz	-133.2 dBW/MHz	-127 to -135 dBW/MHz
	Break-Lock	CW-like	-101.27 dBm/24 MHz	-136.5 dBW	-144.5 dBW	-138.2 to -147.8 dBW
	15 cm Pseudo-Range Error	Noise-like	-89.7 dBm/24 MHz	-132.2 dBW/MHz	-134.6 dBW/MHz	-129.8 to -136 dBW/MHz
OEM	Break-Lock	Noise-like	-87.8 dBm/24 MHz	-130.3 dBW/MHz	-133.2 dBW/MHz	-127 to -135 dBW/MHz
	Break-Lock	CW-like	-104.27 dBm/24 MHz (4 dB backoff)	-139.5 dBW	-144.5 dBW	-138.2 to -147.8 dBW

TABLE 4-4. Comparison of ARL:UT and NTIA Interference Threshold Levels

ARL:UT Receiver	Interference Effects*	ARL:UT Interference Signals and Threshold Interference Levels			Comparable NTIA Median Threshold Levels with Associated Range of Data
		White Noise (dBW/MHz)	UWB Mode 7 (dBW/MHz)	UWB Mode 13 (dBW/MHz)	
1	Loss of 1 SV	-126.8	-142.3	-142.7	-133.2 dBW/MHz Median Break-Lock Level for Noise-Like Interference
	Loss of Multiple SVs	-124.8	-131.3	-133.7	
2	Loss of 1 SV	-126.2	-129.7	-131.1	
	Loss of Multiple SVs	-126.2	-127.7	-129.1	-127 to -135 dBW/MHz Range of Data Associated with Median
3	Loss of 1/Multiple SVs	-127.9	-127.4	-128.8	
4	Loss of 1 SV	-129.9	-129.4	-133.8	
	Loss of Multiple SVs	-127.9	-129.4	-133.8	

* The ARL:UT data shows, among many other performance measures, the interference power level at the input of the GPS at which the signal from one and/or more than one GPS SV cannot be tracked. This performance measure compares with the break-lock measure used by NTIA.

Finally, if one subtracts 4.5 dB from the median values of Table 4-2 to correct the GPS reference signal from -130 dBm to -134.5 dBm, the NTIA data can be compared to the existing RTCA and ITU GPS interference limits. The adjusted median value for CW-like interference would be -149 dBW and for noise-like interference for reacquisition would be -139.1 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.

In summary, the GPS receiver interference threshold data is consistent across the three receivers tested in the NTIA measurement program. These receivers are those that process the C/A code L1 signal. The NTIA data was shown to be comparable to the SU and ARL:UT test results. Admittedly, these comparisons can only be made for a subset of the SU and ARL:UT data because of differences in the UWB characteristics considered and the measurement procedures used. 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 analysis to determine the interference impact of GPS/UWB operations in various scenarios.

4.3 SUMMARY OF ANALYSIS FINDINGS

There are literally hundreds of applications of GPS, with additional applications being defined on a seemingly daily basis. To attempt to define a unique operational scenario for each of these applications would be a massive, if not impossible undertaking. Therefore, within the context of this assessment, an effort was made to define a set of operational scenarios, in conjunction with the GPS user and UWB communities, that could be used to bound the possible GPS applications.

The two main parameters needed to perform the analyses, which are defined by the operational scenarios, are the likely separation distance between a GPS receiver and UWB transmitter, and the likely orientation of the antennas with respect to one another. The likely separation distance is used to assess the propagation path loss, to formulate an assumption as to the likelihood of multiple UWB devices in view of the GPS receiver, and to determine the interference allotment for UWB devices within the constraints defined by the application. The likely antenna orientation is used to estimate the antenna gain realized by the GPS antenna in the direction of the UWB devices.

In the public meetings that were held, a set of operational scenarios were defined that NTIA accepts as bounding the parameters of interest. For example, the terrestrial scenarios involving the public safety use of GPS, define a minimum separation distance of 2 meters. The en-route aviation operational scenario defines a minimum separation distance of 1000 feet (approximately 300 meters). These two cases bound the minimum distance separation of the remaining operational scenarios. Furthermore, it appears reasonable that these two scenarios will also bound operational scenarios not specifically considered within this effort, with respect to the minimum distance separation. Additionally, it is reasonable to assume that there will be a limited number of UWB devices operating at a distance of 2 meters from a GPS receiver, as defined by the terrestrial operational scenario discussed in Section 3. However, when the en-route aviation scenario is considered, a larger number of UWB devices can be in view from an aircraft at an altitude of 1000 feet. Therefore, it is believed that the operational scenarios considered also bound the GPS applications with respect to the potential aggregation of UWB devices.

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 4-5 through 4-8. 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 the Tables 4-5 through 4-8 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.

Tables 4-5 through 4-8 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 4-5 summarizes the analysis results for UWB devices that operate with a PRF of 100 kHz. For the narrowly-spaced correlator receiver architecture, when the operational scenario includes either a single UWB device or a small number of UWB devices operating with a PRF of 100 kHz, the interference effect was categorized as being pulse-like. The computed values of maximum allowable EIRP range from -70.8 to -39.3 dBW/MHz depending upon the operational scenario under consideration.

In the aviation non-precision approach operational scenario the TSO-C129a compliant C/A code receiver architecture was considered. For the TSO-C129a compliant C/A code receiver architecture, when the operational scenario includes a small number of UWB devices operating with a PRF of 100 kHz, the interference effect was categorized as being pulse-like. As shown in Table 4-5, the computed maximum allowable EIRP is -58.2 dBW/MHz. In the aviation en-route navigation operational scenarios, it is assumed that there is a large number of UWB devices present such that, independent of the individual UWB signal parameters, the interference effect can be characterized as being noise-like (i.e., central limit theorem). The computed values of maximum allowable EIRP are -75.9 dBW/MHz when all of the UWB devices were assumed to be operating inside of a building and -84.9 dBW/MHz when all of the UWB devices were assumed to be operating outside of a building.

Table 4-6 summarizes the analysis results for UWB devices that operate with a PRF of 1 MHz. For the narrowly-spaced correlator receiver architecture, when the operational scenario includes either a single UWB device or a small number of UWB devices operating with a PRF of 1 MHz, the interference effect was characterized as being CW-like, pulse-like, or noise-like. This characterization depends on the modulation and gating percentage employed. When the operational scenario considered a single UWB device employing 100% gating and no modulation, the interference effect was characterized as being CW-like. For all other signal permutations, the single entry UWB device interaction interference effect was characterized as being pulse-like. For the single UWB device operational scenario, the interference effect was characterized as being pulse-like and the values of maximum allowable EIRP range from -66.5 to -49 dBW/MHz. When the interference effect was characterized as being CW-like, the computed values of maximum allowable EIRP range from -104.7 to -87.2 dBW, depending on the operational scenario under consideration. In the operational scenarios where multiple UWB device interactions were considered, the interference effect for 1 MHz, 100% gating, was still CW-like. The values of maximum allowable EIRP range from -93.8 to -73.2 dBW. For all other 1 MHz UWB signal permutations, the interference effect was characterized as being noise-like. When the multiple UWB device interaction interference effect was characterized as being noise-like, the computed values of maximum allowable EIRP range from -87.9 to -67.3 dBW/MHz, depending upon the operational scenario under consideration.

In the aviation non-precision approach operational scenario, where the TSO-C129a compliant C/A code receiver architecture was analyzed, the interference effect was characterized as being either CW-like or noise-like. As shown in Table 4-6, the values of computed maximum allowable EIRP are -87 dBW (CW-like) and -88.3 dBW/MHz (noise-like). In the aviation en-route navigation operational scenarios, there were a large number of UWB devices assumed to be present, therefore the interfering signal was characterized as being noise-like. The computed values of maximum allowable EIRP are -75.9 dBW/MHz when all of the UWB devices were assumed to be operating inside of a building and -84.9 dBW/MHz when all of the UWB devices were assumed to operating outside of a building.

Table 4-7 summarizes the analysis results for UWB devices that operate with a PRF of 5 MHz. In the terrestrial and surveying operational scenarios where a single UWB device is operating with a PRF of 5 MHz, the interference effect was characterized as being CW-like, pulse-like, or noise-like. This characterization depends on the type of modulation and gating percentage that was employed. As shown in Table 4-7, the range of the computed values of maximum allowable EIRP for the different interfering signal characterizations were: -107.3 to -89.8 dBW (CW-like), -49.1 to -31.6 dBW/MHz (pulse-like), and -88.3 to -70.8 dBW/MHz (noise-like). In the operational scenarios where a small number of UWB devices with a PRF of 5 MHz were operating, the interference effect was characterized as being either CW-like or noise-like. This characterization depends on the type of modulation and gating percentage that was employed. When the interference effect was characterized as being CW-like, the values of maximum allowable EIRP range from -96.4 to -75.8 dBW, depending on the operational scenario under consideration. When the interference effect was characterized as being noise-like, the values of maximum allowable EIRP range from -87.9 to -67.3 dBW/MHz, depending on the operational scenario under consideration.

In the aviation non-precision approach operational scenarios, where the TSO-C129a compliant C/A code receiver architecture was considered, the interference effect was characterized as being CW-like or noise-like depending on the type of modulation and gating percentage that was employed. As shown in Table 4-7, the values of computed maximum allowable EIRP were -83.6 dBW (CW-like) and -89.3 dBW/MHz (noise-like) In the aviation en-route navigation operational scenarios, there were a large number of UWB devices assumed to be present, therefore the interfering signal was characterized as being noise-like. The computed values of maximum allowable EIRP are -75.9 dBW/MHz when all of the UWB devices were assumed to be operating inside of a building and -84.9 dBW/MHz when all of the UWB devices were assumed to be operating outside of a building.

Table 4-8 summarizes the analysis results for UWB devices that operate with a PRF of 20 MHz. In the terrestrial and surveying operational scenarios where a single UWB device is operating with a PRF of 20 MHz, the interference effect was characterized as being CW-like, pulse-like, or noise-like. This characterization depends on the type of modulation and gating percentage that was employed. As shown in Table 4-8, the range of the computed values of maximum allowable EIRP for the different interfering signal characterizations were: -107.5 to -90 dBW (CW-like), -82.8 to -65.3 dBW/MHz (pulse-like), and -96.1 to -78.6 dBW/MHz (noise-like). In the operational scenarios where a small number of UWB devices with a PRF of 20 MHz are operating, the interference effect was characterized as being either CW-like or noise-like. This characterization depends on the type of modulation and gating percentage that was employed. When the interference effect was characterized as being CW-like, the values of maximum allowable EIRP range from -96.6 dBW to -76 dBW, depending on the operational scenario under consideration. When the interference effect was characterized as being noise-like, the values of maximum allowable EIRP range from -91.2 to -70.6 dBW/MHz, depending on the operational scenario under consideration.

In the aviation non-precision approach operational scenario, where the TSO-C129a compliant C/A code receiver architecture was considered, the interference effect was characterized as being either CW-like or noise-like. As shown in Table 4-8, the values of computed maximum allowable EIRP were -88.1 dBW (CW-like) and -87.3 dBW/MHz (noise-like). In the aviation en-route navigation operational scenarios, there are a large number of UWB devices assumed to be present, and the interference effect was characterized as being noise-like. The computed values of maximum allowable EIRP are -75.9 dBW/MHz when all of the UWB devices were assumed to be operating inside of a building and -84.9 dBW/MHz when all of the UWB devices were assumed to be operating outside of a building.

TABLE 4-5. 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 4-6. 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 4-7. 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 4-8. 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 4-5 through 4-8. 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 allowable EIRP is less than the current Part 15 level.

An examination of Table 4-5 (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, as being fairly robust to low-duty cycle pulsed interference. The worst-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 is likely to 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 4-6 through 4-8 (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 remain 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 4-5 through 4-8, the results of the analysis indicate that the values of maximum allowable EIRP that are necessary to preclude interference to GPS receivers are 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 4-2 through 4-5 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 maximum allowable EIRP levels determined from an analysis of each UWB signal permutation in potential interactions with the narrowly-spaced correlator receiver architecture that were defined by all of the operational scenarios considered in the study.

For the operational scenarios considered for single and multiple UWB devices, Figures 4-2 and 4-3 displays the range of maximum allowable EIRP for the UWB signal that were classified in this study as causing pulse-like interference effects in the GPS receiver. Figure 4-4 displays the range of maximum allowable EIRP levels for those UWB signals that were classified in this study as causing noise-like interference effects in the GPS receiver. Figure 4-5 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 in the GPS narrowly-spaced correlator receiver. The labels on the y-axis in Figures 4-2 through 4-5 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.

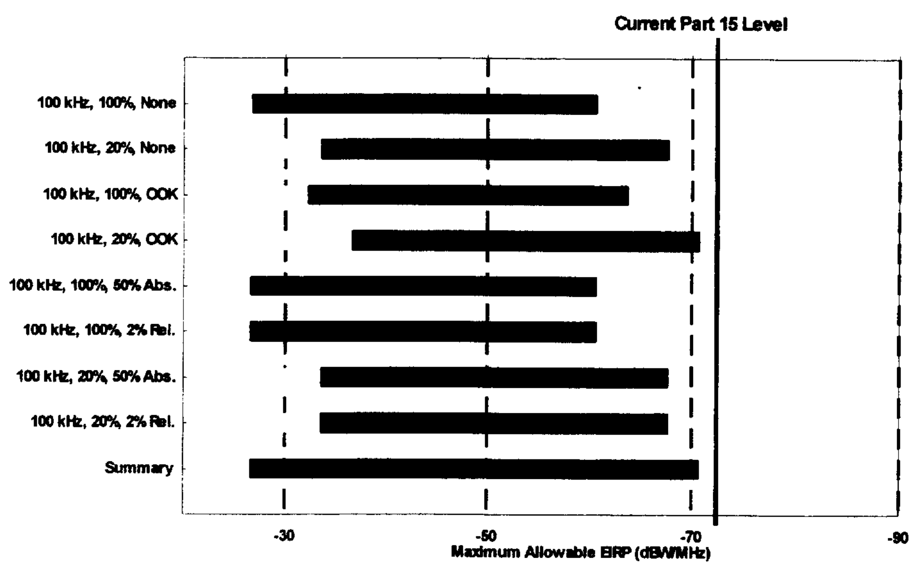

Figure 4-2. Range of Maximum Allowable EIRP for Pulse-Like UWB Signal for the Narrowly-Spaced Correlator Receiver Architecture (Single and Multiple UWB Device Operational Scenario)

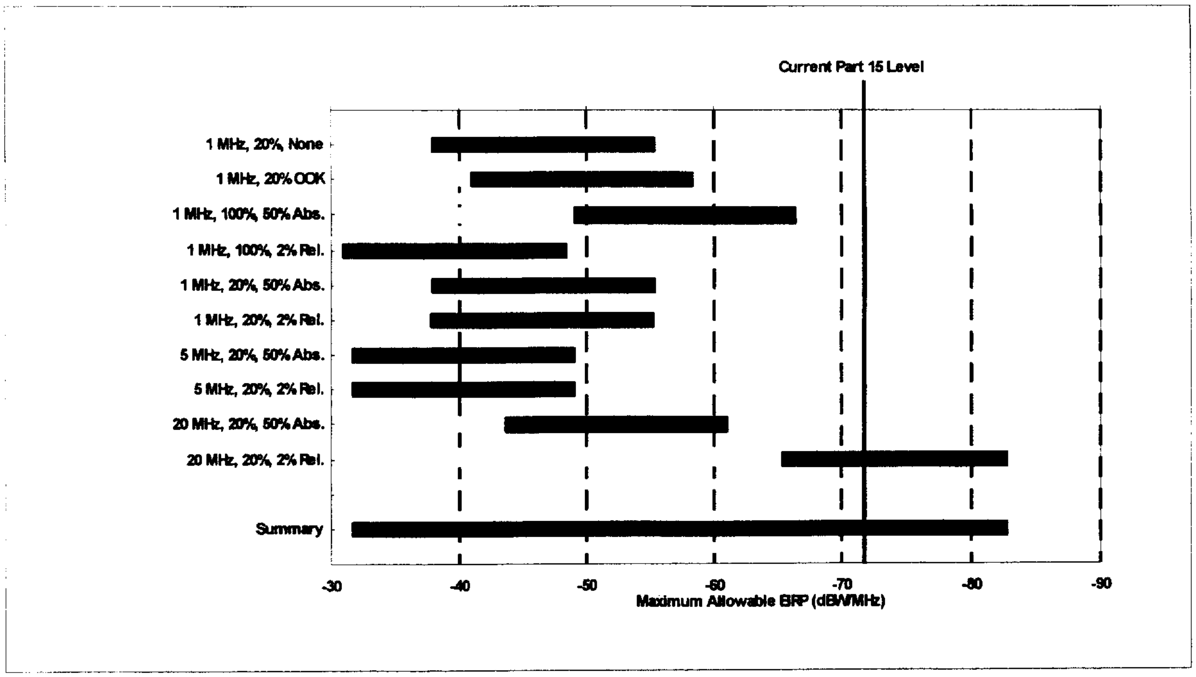

Figure 4-3. Range of Maximum Allowable EIRP for Pulse-Like UWB Signal for the Narrowly- Spaced Correlator Receiver Architecture (Single UWB Device Operational Scenario)

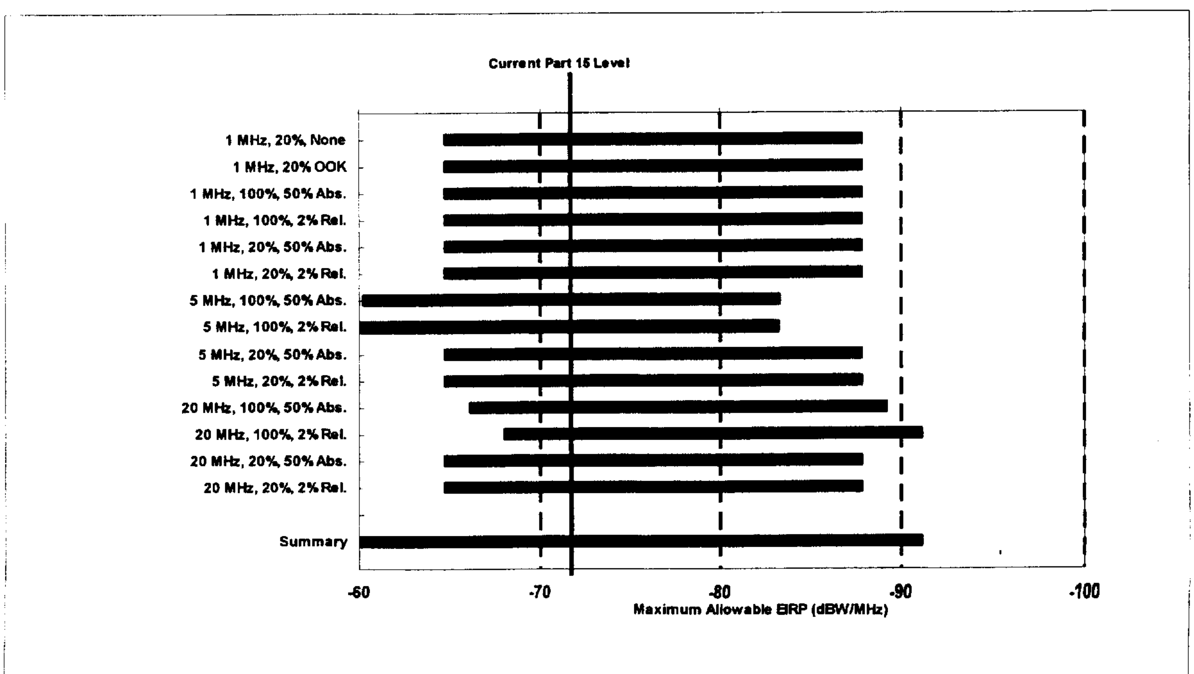

Figure 4-4. Range of Maximum Allowable EIRP for Noise-Like UWB Signals for Narrowly-Spaced Correlator Receiver Architecture (Single and Multiple UWB Device Scenarios)

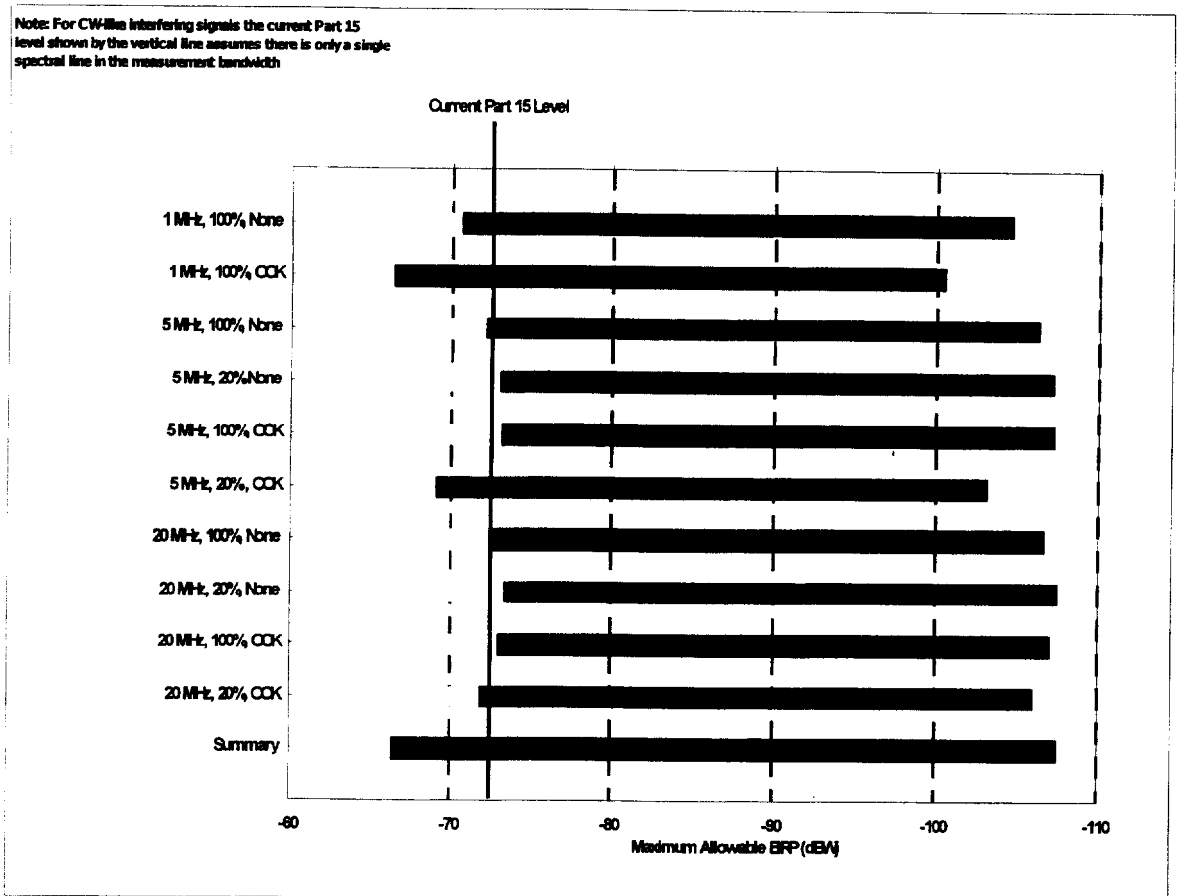

Figure 4-5. Range of Maximum Allowable EIRP for CW-Like UWB Signals for the Narrowly-Spaced Correlator Receiver Architecture (Single and Multiple UWB Device Operational Scenarios)

An examination of Figures 4-2 through 4-5 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 4-2 shows the maximum allowable EIRP levels corresponding to those UWB signal permutations with a PRF of 100 kHz. For the UWB signal permutations represented in Figure 4-2, 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 4-2 for these 100 kHz PRF UWB waveforms. From Figure 4-2, 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 4-3 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 4-4 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 4-5 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 4-6 through 4-8 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 study. 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 were classified as pulse-like, noise-like, or CW-like.

Figure 4-6 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 4-7 presents the maximum allowable EIRP levels or the 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 4-7, 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 scenarios.

Figure 4-8 shows the maximum allowable EIRP levels for the PRFs of 1 MHz, 5 MHz, and 20 MHz, when the UWB signal permutations were classified as causing CW-like interference effects to the TSO-C129a compliant receiver. As shown in Figure 4-8, 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 in the applicable operational scenarios.

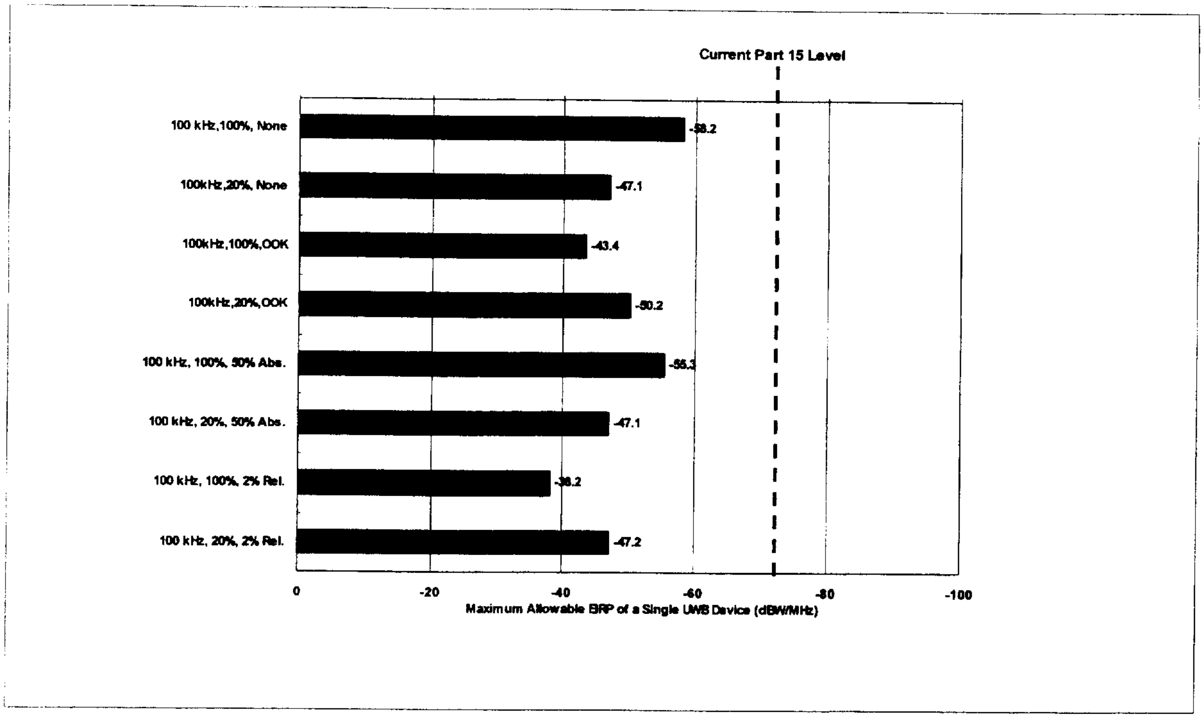

Figure 4-6. Maximum Allowable EIRP as a Function of UWB Signal Structure for the TSO-C129a Compliant C/A Code Receiver Architecture (Pulse-Like UWB Signals)

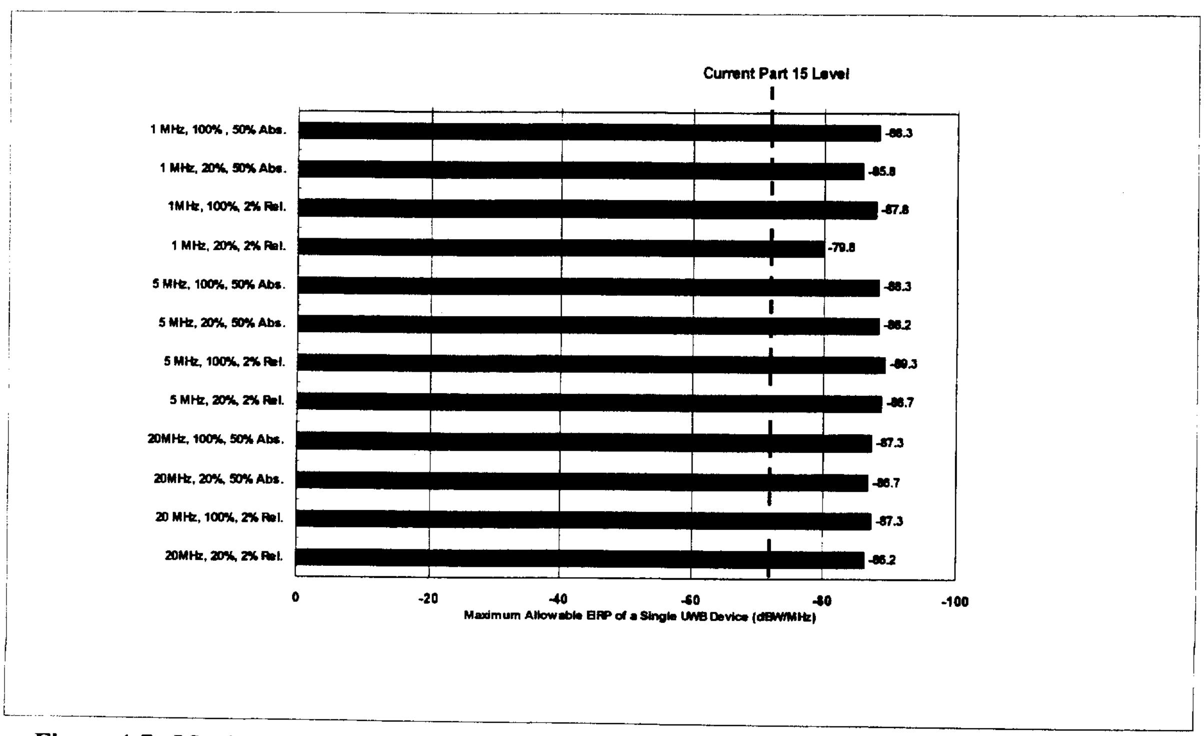

Figure 4-7. Maximum Allowable EIRP as a Function of UWB Signal Structure for the TSO-C129a Compliant C/A Code Receiver Architecture (Noise-Like UWB Signals)

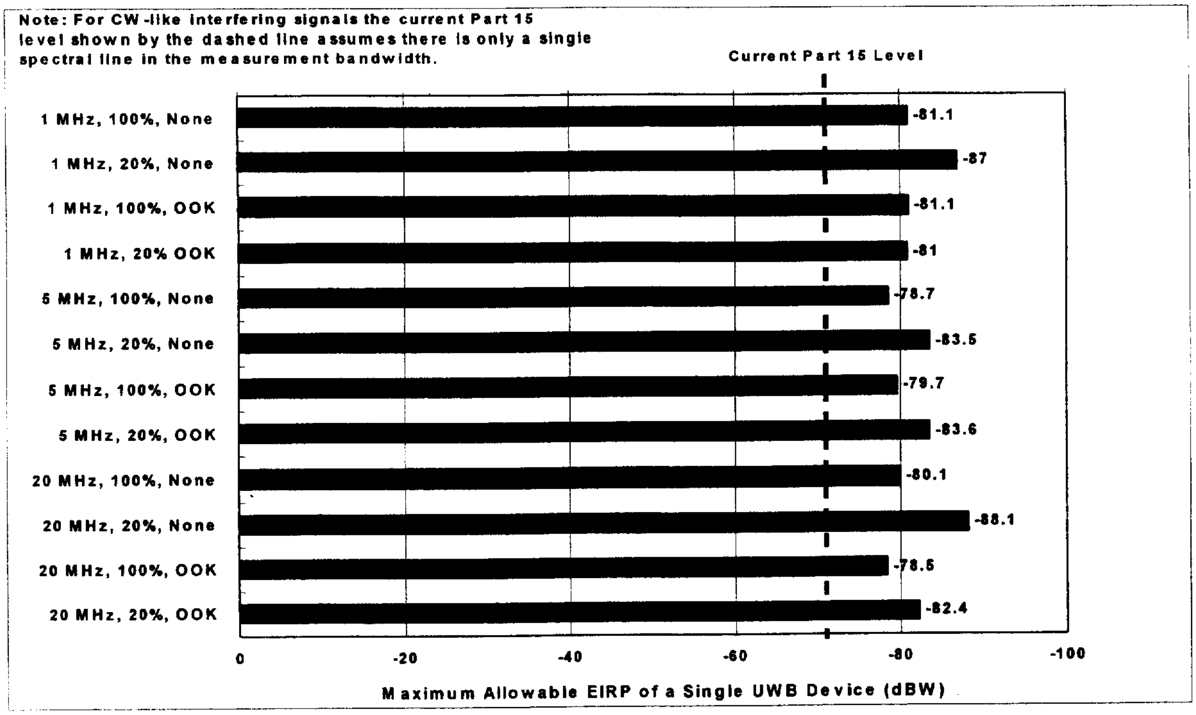

Figure 4-8. Maximum Allowable EIRP as a Function of UWB Signal Structure for the TSO-C129a Compliant C/A Code Receiver Architecture (CW-Like UWB Signals)

Table 4-9 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 4-10 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 4-9 and 4-10 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 4-9. Comparison of EIRP Levels for C/A Code and Narrowly-Spaced Correlator Receiver Architectures

Operational Scenario	Interference Effects	C/A Code	Narrowly-Spaced Correlator
		EIRP Range	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 4-10. 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 4-11 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 4-12 presents an overview of the analysis results for the TSO-C129a compliant receiver. Table 4-13 presents an overview of the distance separation analysis results for the C/A code receiver architecture for multiple-entry UWB device interactions.

TABLE 4-11. Overview of Single-Entry Analysis Results for the C/A Code, Semi-Codeless, and Narrowly-Space Correlator Receiver Architectures

UWB PRF (MHz)	Distance Separation (m)*								
	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 is the GPS antenna receive antenna gain									

TABLE 4-12. 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 4-13. 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 (m)*		
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 is the GPS antenna receive antenna gain

4.4 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 report 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 strong 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 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).