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September 7, 2000

Ms. Magalie Roman Salas, Secretary
Federal Communications Commission
The Portals, TW-A325
445 12th Street, S.W.
Washington, DC 20554

Re: ***Ex parte* Notification**
ET Docket No. 98-153
Ultra-Wideband

Dear Ms. Salas:

Transmitted herewith are an original and one copy of a document sent on September 6, 2000, to Mr. John Reed, Senior Engineer of the Technical Rules Branch of the Office of Engineering and Technology.

Should any questions arise concerning this matter, please contact me.

Sincerely,

Kurt E. DeSoto

Kurt E. DeSoto
Counsel for Time Domain Corporation

cc: John Reed

Enclosure

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Time Domain Corporation

7057 Old Madison Pike
Huntsville, AL 35806
256-922-9229

August 29, 2000

Mr. Steve Jones
Office of Spectrum Management
National Telecommunications and Information Administration
Room 6725 HCHB
1401 Constitution Avenue, NW
Washington, DC 20230

Re: Comments on NTIA GPS/UWB Measurement Plan

Dear Mr. Jones:

Time Domain Corporation respectfully submits the attached comments on the Measurement Plan To Determine The Potential Interference Impact To Global Positioning System Receivers From UltraWideBand Transmission Systems, August 8, 2000 (the "test plan"), in response to the invitation extended in the Public Notice of August 14, 2000, 65 FR 49544. The attached comments were prepared by members of the technical staff at Time Domain. We appreciate the opportunity of being able to provide feedback to NTIA on this important undertaking.

Sincerely,
Time Domain Corporation

/s/ transmitted electronically

Paul Withington
Vice-President for Standards & Testing

Attachments

Comments on NTIA GPS/UWB Measurement Plan

Prepared by Members of the Technical Staff
Time Domain Corporation
Huntsville, Alabama

I.

II. Executive Summary

The evaluation of GPS receiver susceptibility to UWB signals is an extremely demanding and difficult endeavor. While the impact of Gaussian white noise on GPS receivers is well understood, the impact of ultra-wideband (UWB) emissions is a new area of research. The complexity is compounded by the fact that very few understand the nature of UWB signals and fewer still understand the characteristics of both UWB and GPS systems.

Time Domain Corporation, as a leading UWB technology developer, has a tremendous depth of knowledge of UWB emissions in general and especially of its proprietary time modulated ultra-wideband (TM-UWB) signals. Moreover, because we have had projects that required the integration of TM-UWB transmitters with GPS receivers we have developed some practical expertise in quantifying GPS susceptibility.

We appreciate the hard work that has gone into the preparation of the test plan, particularly given the time constraints that the agency has faced. At the same time, we are concerned that the testing be completed by October 30. It is critical that the FCC be provided with quality data in a timely fashion from which it can make its rules.

The quality of the results will depend on how closely the assumptions that undergird the testing reflect real world conditions. For this reason, the test plan should be revised to include radiated testing that will consider the effects of both multipath propagation and ambient noise, as well as the effects of UWB transmit and GPS receive antennas.

The strengths of the test plan are:

> **An open process.** The process appears to be open. By soliciting input from the UWB industry and others, the agency is starting down the right path.
>
> **Identification of critical issues.** The test plan identifies the sensitive parameters and seeks advice of critical thresholds, *e.g.,* requesting advice on determination of interference thresholds.

The key issues we have identified are:

> **Use of a white noise source.** The test plan states that its purpose is to evaluate the impact of UWB on GPS receivers. The use of a white noise source will mask the impact of UWB. Moreover, the ITU-R document that is an integral part of

these measurement procedures does not delineate the testing methodology and, in any event, does not appear to support the NTIA approach. A more general testing approach would use an UWB signal source without a white noise source. Such an approach would provide UWB interference measurements that can then be used in conjunction with the already well documented impact of white noise to model many possible operational scenarios, and not just one scenario that assumes a significant amount of ambient noise.

Use of a single satellite. One important indicator of GPS receiver performance is accuracy of position determination. A typical GPS terminal receives eight (or more) satellite signals and to determine location and altitude processes at least four of the signals. Significantly more meaningful data will be captured using a measurement technique that contemplates a complete constellation of satellites.

Lack of radiated testing. While Time Domain understands that NTIA plans to conduct radiated testing if funds are made available, the test plan is incomplete without some amount of radiated testing. Radiated testing is necessary to check the laboratory configurations and measurements, and, in particular, to assess the actual impact of ambient signals, antennas, and multipath interference. Without this sort of check on the assumptions inherent in conducted testing and without an assessment of key factors that characterize the actual likely operating environment, the plan will not afford NTIA and the FCC the information needed to reach rational decisions on an appropriate set of regulations for UWB. Radiated testing should also include a comparison of the effects of emissions from Part 15 unintentional and incidental radiators that actually radiate into the GPS bands at the Part 15 limits. Such an effort would address the seminal question of whether there is some characteristic of intentional UWB emitters that causes different interference to GPS than do emissions from digital devices and incidental radiators that fall into the GPS spectrum. By not comparing the GPS interference potential of existing Part 15 devices, a potential "double standard" could be established. New technology would then be subject to a set of standards that incumbent technologies are not even being tested to and may not be able to meet. Regardless of the appropriateness of the current dichotomy in the context of older narrowband technologies, such a double standard would be contrary to NTIA's mission of promoting new technology.

For a number of years, we have worked together with NTIA engineers on susceptibility issues. Our engineers have worked side by side on several occasions at the FCC laboratory. We also recently provided equipment to support the NTIA study process. To provide information that will result in sound implementation decisions, it is critically important that this open process continues and includes all elements of the testing program.

Detailed discussions of each of our three most critical concerns can be found in the section below. Our answers to the NTIA's seven questions (posed in the Federal Register Public Notice) are presented in Appendix A to this document. A detailed section-by-section analysis of the test plan is provided in Appendix B.

III. Discussion of Critical Issues

A. The Test Plan Should Include Separate Characterization of UWB Signal Interference.

The stated goals of the test plan are to:

> "assess the interference potential of UWB signals to GPS receivers."
>
> "promote the establishment of methods for measuring the impact of UWB signals to GPS receivers."[1]

Nevertheless, the test plan contemplates coupling broadband noise and UWB signal sources to inhibit GPS receiver performance. The use of a broadband noise source will likely obscure measurements of the sole impact of UWB. If interference testing is conducted without a broadband noise source, it would be possible to determine the combined impact of both the UWB and white noise sources because the impact of white noise upon GPS receivers is well understood. However, if the testing is carried out as currently proposed, it will be impossible to decouple the impact of the two signal sources. In order to properly quantify the effect of UWB signals on GPS receivers, the UWB signal source should be fed into the GPS receiver without broadband noise. UWB single source data would also permit comparative interference analysis as a function of the existing ambient background interference as it exists at different locations.

With regard to the interference measurement procedure itself, we believe that there may be an inconsistency between the ITU-R M.1477 document cited by NTIA and the NTIA test plan. The ITU document states that the threshold for wideband aggregate interference is -146.5 dBW/MHz, which is equivalent to -103.5 dBm over the 20 MHz GPS bandwidth. Given that thermal noise for the receiver is specified to be -176.6 dBm/Hz, which is equivalent to -103.6 dBm over the 20 MHz wide GPS band, then with no other interference present the thermal noise level, by itself, is within one tenth of a dB of the stated wideband aggregate interference threshold. This means that the allowable noise threshold will be exceeded when any other emitter, including the

[1] Test Plan, Section 2.0, Paragraph 1.

broadband noise or UWB signal sources that NTIA is proposing to use, is added to that environment.

An oft-cited rationale for using a broadband noise source is that it represents, among other things, the impact of Mobile Satellite System Mobile Earth Terminals (MSS MET). However, it remains unclear whether MSS MET signals are equivalent to broadband noise sources. In addition, the assumption that there will always be a MSS MET satellite signals in the area is not consistent with MSS system operating protocols. MSS MET units are multi-mode devices that seek to use terrestrial cellular systems first and only use the satellite links when there is no cellular link available.[2] Because of this, it is not accurate to expect that interfering signals from MSS satellite transmissions will always be present and at the specified levels. This needs to be taken into account during the testing in order to collect a more comprehensive set of data and related test points.

The structure of the NTIA test plan, with the incorporation of a white noise source, follows a procedure advocated by some GPS advocates. *See* Potential Interference to GPS from UWB transmitters, Test Plan - Version 4.5, cited by Department of Transportation, June 22, 2000 Request for Comments Public Notice, 65 FR 38874 (the "Stanford Plan"). At best, it will be extremely difficult to extrapolate from these results to a broad range of scenarios. A goal of this test should be to provide a baseline set of measurements to allow for the broadest application of the results.

B. The Test Plan Should Base Measurements On A Proper Constellation Of Satellites.

We strongly recommend that the testing also include measurements made with a proper constellation of satellites.[3] NTIA has stated that it is unclear which performance

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[2] According to the Globalstar web page, "Globalstar satellite telephone service is delivered through special multi-mode phones, which work just like traditional cellular phones when you are in an area with cellular coverage. When you need to communicate from outside the area covered by ground-based systems, the phones easily switch to Globalstar satellite mode. Satellite and cellular communications are both at your fingertips." *See* Globalstar Products and Services Web Page, available at <http://www.globalstar.com/pages/products.html>. Not many cities in the US, or the world for that matter, are currently without cellular service.

[3] It is nonetheless appropriate to include single channel measurements because a GPS receiver processes each channel independently, and due to spectral features in both the

(Continued...)

metrics should be used in studying the possible interference from UWB to GPS. One such metric, position determination, happens to be paramount for both civilian and survey applications, and the impact on position determination requires at least 4 satellites and cannot be determined from a single satellite. Capturing this additional data should not require much more work as the GPS signal simulator that NTIA will likely be using can easily produce a full constellation.

C. The Test Plan Should Include Radiated Testing.

The test plan should include radiated testing to address antenna effects, the impact of multipath interference and that of ambient noise. The radiated section should include tests to validate the predictions of the conducted test data, *i.e.,* the testing needs a "control" for comparative purposes. The GPS receivers should be taken outside to, at a minimum, validate their performance in the laboratory with the real world, with and without UWB signals present.

Conducted tests provide repeatable results and are necessary for confidence in the data. However, "over the air" real-world testing is necessary to provide context for the laboratory data because there are three major factors left out of the conducted setup: multipath interference, ambient noise, and UWB transmit and GPS receive antennas. Performing radiated tests helps to validate models that must be done as part of the laboratory data analysis. This approach will provide useful data to analysts who need to understand the impact of these three major factors.

The environment is a major factor in determining GPS performance. There are many sources of interference, such as incidental and unintentional radiators, plus licensed transmitters with spurious emissions in the GPS bands. In addition, in many environments the dominant source of interference is multipath propagation of the GPS signal (*i.e.* self-interference). This fact has been stated by numerous GPS experts and was recently reiterated at an open RTCA meeting where an expert in GPS stated his opposition to radiated testing because multipath propagation of the GPS signal might obscure the impact of UWB on GPS receiver performance. Thus, any test that does not include real-world factors will likely misrepresent the significance of UWB signals.

(...Continued)
UWB transmission and the GPS code structure, each channel will respond slightly differently to the UWB energy and it is important to measure those differences.

D. Conclusion

In sum, we truly appreciate the hard work of the NTIA engineers in their efforts to analyze the interference impact of a technology such as UWB. At the same time, incorporation of the changes suggested in these comments is critical if the testing is to provide meaningful information for NTIA and the FCC to use in the UWB rule making.

Appendix A

IV. Responses to Questions for Public Comment

1. Are the candidate GPS receivers identified in the measurement plan representative of the different technologies and user applications?

Having gone through the process of establishing a thorough measurement plan ourselves, we can appreciate the difficulties in choosing a set of GPS receivers that are representative of the different applications and technologies, yet at the same time keep the total number of receivers to a manageable number. The receivers proposed seem like good candidates to us and overlap in many cases the receivers being utilized in the ARL:UT GPS Test Program.

2. Are the UWB transmission system parameters identified in the measurement plan representative of the parameters for UWB transmission systems envisioned for use by the public?

We have no problems with the proposed pulse width, PRF ranges, and modulation types. It would be appropriate to have a 10 MHz PRF, but we understand the time crunch and it isn't 100% necessary.

On the other hand, we do not think that the gating % proposed represents what the UWB community is necessarily doing or proposing. Certainly, NTIA should test 100%, which is worst case. However, at a PRF of 5 MHz, the 20% gating works out to be 200 microseconds out of a millisecond. This is not typical of the gating numbers that we would use; we typically use on/off times in the single digit milliseconds. A good example is our RadarVision1000, which has a PRF of 5 MHz, dithered modulation, and 50% gating with on=off=4 milliseconds. In light of this, we recommend that NTIA either set a fixed on/off time regardless of PRF, or increase the number of pulses per on cycle to at least 10,000.

3. Is pseudo-range error a performance metric for aviation GPS receivers that operate in accordance with Technical Standard Order (TSO) C-129a? If so what is the limit on pseudo-range error?

It seems like pseudo-range error is the appropriate criteria based upon some RTCA documents, such as DO-253, which states that the pseudo-range accuracy standard deviation is 15 cm for airborne accuracy designator B versus the GPS receiver input power of -136 dBm in the presence of a background thermal noise density of -176.6 dBm/Hz. This power level is based on the requirements of a GPS receiver without an external preamp. The receivers shall have the capability of tracking GPS satellites with a maximum power of -116 dBm at the receiver port. *See* Minimum Operational Performance Standards for GPS Local Area Augmentation System Airborne Equipment, Jan. 11, 2000 (RTCA DO-253). The 15 cm standard deviation error is only applicable at -136 dBm with no interference present. So, while we have no recommendation as to the pseudo-range error, we caution that the 15 cm limit is applicable only when the GPS signal power is set to -136 dBm and the broadband noise is at -176.6 dBm/Hz.

4. If pseudo-range error is not an applicable performance metric for GPS receivers that operate in accordance with TSO-C129a, what performance metric should be used? What is associated performance criteria?

An additional metric that may be of value is the impact upon position determination. This is from more of a user perspective – "how has my position readout changed due to the presence of UWB energy."

5. Is a performance metric of time to reacquire a satellite applicable to GPS receivers used for terrestrial applications (e.g., public safety)? If so what is the associated performance criteria?

The applicability of a reacquisition time metric seems to be application dependent. It seems plausible that certain uses of GPS may not rely upon reacquisition time while

other uses may. A reacquisition time metric does appear to address the overall system integrity question.

We have been researching this issue for some time now and have not had success finding any technical documents that list what the performance criteria should be for reacquisition times. Clearly, choosing an arbitrary value does not seem rational or scientific. A better approach would be to evaluate the actual reacquisition time (not just the stated manufacturer specification) of the GPS receiver in operation - without UWB generated interference - and determine what additional time, if any, the operational scenario can withstand for reacquisition when such interfering signals are added.

6. A reacquisition time of 1 second has been proposed by at least one GPS receiver manufacturer for terrestrial applications. Due to the latency inherent in the GPS receiver can a 1 second reacquisition time be accurately measured?

From our experience in working with several GPS receivers over the last year, many receivers, not in the presence of any interfering signals, would fail this proposed criterion. The second paragraph in our response to question 5 also speaks to this issue. We agree with NTIA's concern that the inherent latency may be problematic in actually determining short reacquisition times.

7. What are the performance metrics and associated criteria for GPS receivers used for surveying, maritime, and recreational applications?

We strongly believe that the appropriate performance metric for surveying, maritime, and recreational GPS applications is to examine the impact upon position determination, *i.e.*, from the user perspective: "how has my position readout changed due to the presence of UWB energy". The associated criteria would be dependent on the normal error associated with that specific application (*e.g.*, surveying applications may require centimeter accuracy, and recreational application may require meters).

Appendix B

V. Detailed Comments on NTIA GPS/UWB Measurement Plan

a) Section 1.0 – Introduction

In the second paragraph of this section, UWB is set apart from other systems because of its intentional emissions in certain restricted frequency bands, even though these other systems unintentionally emit, or even intentionally radiate, into these same bands at equal or sometimes even greater power levels. The wording of this section is odd in that it implies that some UWB systems do not radiate into any restricted bands. If that were the case, those systems would not have an issue regarding authorization under the current Part 15 general limits. Also, spurious emissions have been permitted in excess of the Part 15 limits and have not caused problems. We believe that any emissions below 50 μW have little or no potential for interfering with GPS. The issue here is that the very nature of being ultra-wide-band cannot avoid the restricted bands at some level.

The following statement is made in the third paragraph: "As it can be seen, both aviation and non-aviation users would incur adverse impact if there was degradation to GPS signal reception." This is not necessarily a true statement. The term degradation is often used but is rarely precisely defined. For example, it could mean a decrease in received signal strength from a satellite with no apparent loss of performance of the GPS receiver or perhaps the signal loss from one satellite in a constellation of several satellites that will in reality have no impact on system accuracy. Thus, a minor change to GPS operation does not necessarily imply harmful interference or overall decrease in system performance.

We agree with NTIA's discussion about the promise that UWB technology holds, and the importance for protecting GPS. In many ways UWB is very similar to GPS, in that they are both enabling technologies that allow for a variety of very diverse applications.

We would like to have access to the results from the "[p]reliminary measurements utilizing live GPS satellites" that provided "inconclusive results" as to the potential for interference from UWB signals, which is mentioned in the last paragraph of Section 1.0. Can NTIA make public these test results?

b) Section 2.0 - Objective and Approach

In the second and third paragraphs of this Section, the objective of the test plan is made very clear - that these measurements are to define "the maximum level of UWB emissions that can be tolerated at the antenna output (*sic*) of each GPS receiver considered" and to be input for "a separate process that will consider the operational scenarios that might place UWB and GPS equipment in proximity." We are in support of this objective, which is the most rationale approach to providing useful feedback to the FCC's NPRM. This is also the approach that ARL:UT is taking, with one major exception - ARL:UT is not developing the operational scenarios themselves, but providing the data as input for all communities to analyze based on their own specific circumstances. However, care must be taken to properly define the max level of UWB emissions that can be tolerated by GPS receivers in the lab setting so that the data will have the greatest possibility for usefulness. Our recommendations throughout this document are based on our collective attempt to help provide the best data possible.

An additional and critical objective must be to document the difference, if any, between intentional and unintentional UWB emissions in the GPS bands.

This test plan clearly identifies the tasks involved with the first phase of this effort, obtaining the measurement data; however, it does not identify the steps or process for developing the operational scenarios and associated link budgets. We would urge NTIA to clarify how this process is going to unfold. Will NTIA release a separate document, to be published in the Federal Register for comment, on draft operational scenarios? At a recent NTIA briefing with several members of the UWB industry, suggestions were made that there may be future meetings with both the UWB and GPS communities to formulate these scenarios. If so, could NTIA provide a schedule for these meetings and include draft scenarios? In general, we would like NTIA to provide some guidance on how it expects this analysis effort to operate. The data is of little direct use without looking at how both GPS and UWB operate in the "real world".

VI. Section 3.0 - Other Measurement Efforts

Before NTIA considers using any of the other test plans listed in this section, we strongly urge NTIA to look at the comments that Time Domain filed publicly on each effort. We are confident that our comments will improve the plans when they are heeded and integrated.

With regard to the ITS UWB Measurement Effort, we identified a few areas of concern, but noted, in general, that the plan was short on details. One concern we had

is how monitoring the IF filter output of receivers necessarily determines the susceptibility of the receiver to UWB interference. Additionally, it is unclear to us how this current NTIA GPS testing effort will use the results of the APDs from the ITS UWB Measurement Effort, since NTIA will already possess test data on how UWB energy directly affects GPS receivers.

Time Domain also filed comments on the DOT/SU Measurement Effort. We expressed several serious concerns with their test plan, and recognize that there are several similarities between their test plan and this proposed test plan. Also, from the last paragraph of section 4.1, we see that NTIA is planning on taking the data and results of the DOT/SU effort for MOPS-compliant aviation receivers. This seems unsuitable because the stated goal of the DOT/SU data is different from that of the stated goal of this effort. The DOT test plan is not looking necessarily for direct interference; rather they are determining some correction factor of how different the UWB impact is from that of white noise. After determining the correction factor, they plan to use a standard RTCA link budget (based on white noise) along with the correction factor to determine the required separation distance or allowable energy from a UWB source. This is different from the stated goal of the NTIA GPS test plan. Section 2 of this plan states, "the measurements will define the maximum level of UWB emissions that can be tolerated at the antenna output of each GPS receiver considered . . . These thresholds will be used in a link budget analysis for each specific UWB-to-GPS scenario identified..." From our reading of this test plan, it is not NTIA's goal to measure the difference in impact from a UWB signal to white noise and come up with a correction factor. Also, the DOT/SU plan states that they will be testing a land-based receiver. Is NTIA planning on taking the results of this test as well, since the receiver is not an aviation grade receiver? Time Domain recommends that NTIA carefully consider how the DOT/SU data will be taken and used (*i.e.*, not for direct interference determination) before directly applying that data to the operational scenarios, which are yet to be developed by NTIA.

In section 3.3, we recommend that NTIA note that ARL:UT plans to perform aggregate testing as well, and some radiated testing to help verify the models needed to assess the conducted data. This test program is also testing aviation and survey grade receivers. Moreover, the ARL:UT testing is also measuring precision aviation GPS receivers. We recommend that NTIA consider using the data from these tests, in particular the radiated tests taken in an operating environment, in addition to the other test results.

VII. Section 4.0 – Measurement Plan

In one version of the plan (handed out at a recent NTIA briefing for the UWB industry), the tasks listed total seven, where task 6) is "the development of procedures to determine UWB radiated signal effects when received by a GPS antenna" and task 7) is "data recording and reporting methods". The version on the website just has six tasks listed, where the task 6) above is deleted and task 7) above is task 6 on the website version. This task 6), which is intended to account for radiated measurements, is a critical testing and analysis step and NTIA must make sure that it is part of the working version of its GPS test plan.[4] As stated vociferously in our main comments, radiated testing is a vital step in understanding the data from the conducted setup.

An overall comment on the measurement plan concerns the *use* of the conducted data and the *possibility* of radiated data. Time Domain strongly urges that NTIA perform both conducted and radiated testing. Based on the discussion in the preceding paragraph, it appears that NTIA is considering using radiated tests. Proper radiated testing will allow validation of the techniques used to measure and analyze the conducted data, since several key system and environmental parameters are very difficult to model via solely conducted testing. Moreover, radiated testing is required for evaluating the impact of unintentional UWB emissions. (It should be noted that computer manufacturers are using time-dithered clock signals to reduce their peak emissions so that they can comply with Part 15 unintentional limits.)

In the second paragraph of this section the statement is made, "Any modifications to this measurement plan will be coordinated between OSM and ITS." We would like to know whether these modifications will be recorded for future revisions and whether they will be made publicly available.

4.1 Identification of GPS Receivers to be Measured

We appreciate the difficulty in trying to determine which GPS receivers and technologies to test against. There are two different tracks that NTIA could take here: it can use the same or similar receivers being used in the other test efforts in order to compare the data, or it can consider totally different receivers and technologies in order to get a wider experimentation base and use the data from all the efforts to provide a larger database of information. Both approaches have their pros and cons. It is,

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[4] From this point forward, we will attempt to make clear which version of the test plan we are referring to where they differ.

however, important that NTIA work closely with GPS equipment manufacturers to make sure the NTIA can gain access to all the necessary performance parameters that they would like to track. Many receivers will not provide all of that data like those used for "supplementary navigation aids". Additionally, the term "aviation grade GPS receivers" does not mean that all aviation grade GPS receivers are equal.

Moreover, NTIA should explain how they plan to compensate for GPS receivers that use active antenna (*i.e.*, antennas that include an amplifier in the antenna housing). When performing conducted testing, the antenna is not used, so the receiver will not have the usual benefit of the amplifier. This is a loss both in gain and noise figure. There are a few approaches to this: (1) try to find receivers that do not use active antennas or are not intended to be used with preamps; (2) use receivers that would normally have active antennas and try to find a matching preamp to add to the measurement configuration; or (3) use receivers with or without active antennas, and with no preamp in the measurement setup and perform a normalization routine which sets the output power of the simulator to different values depending on the receiver (*see* UT:ARL test plan for more info on this third approach).

With regard to future versions of the test plan, and the final report, we would like to know when the technical specifications, including the sensitivities, of the Candidate GPS Test Receivers will be independently verified and made available. This will aid in deciding on which receivers would be most appropriate to test with, and will also help in understanding the measurement data and analysis.

4.2 Identification of UWB Signal Parameters

We have no major issues with the proposed pulse width, PRF ranges, and modulation types. We are also encouraged to see that NTIA will look at all the different permutations. It would be appropriate to have a 10 MHz PRF, but we understand the time crunch and it isn't 100% necessary. However, we do not believe that the gating (%) being proposed represents what the UWB community is necessarily doing. Certainly, it is important to test 100%, which is worst case. However, at a PRF of 5 MHz, the 20% gating (with 1000 pulses per on cycle) works out to be 200 microseconds out of a millisecond. This is not typical of the gating numbers that we would use – we are usually looking at on/off time in the single digit milliseconds. Consider, for example, our RadarVision1000, which has a PRF of 5 MHz, dithered modulation, and 50% gating with on=off=4 milliseconds. We recommend that NTIA either set a fixed on/off time regardless of PRF (on the order of a few milliseconds), or increase the number of pulses per on cycle to at least 10,000. Overall, it would be useful to see another gating percentage, such as 50%.

The plan proposes to measure the power from the UWB signal sources and the broadband noise source in a 20 MHz bandwidth using a filter and a power meter. The filter characteristics are not shown and they will be important in accurately determining the power. If the 20 MHz bandpass filter is not steep enough on the edges the power meter will sum up the additional energy outside of the 20 MHz filter and present an erroneous error reading. Time Domain requests that NTIA provide the filter characteristics in their next version of the test plan, and the final report. With regard to measuring the power from the UWB sources over this 20 MHz, we would like to know whether the emissions are flat across the band. If the emissions are not flat, we would like NTIA to explain how it plans to handle this situation.

4.3 Development of the GPS/UWB Measurement Methodology

In the second paragraph of this section, NTIA states that there "are no established performance metrics or criteria for GPS." A more appropriate statement would be that there is no consensus on performance metrics and criteria for GPS across the varying applications and uses. The different communities have different demands and applications for GPS and therefore have different criterion. For example, the aviation community, through RTCA, has documented their metrics and thresholds. The performance metrics can range from error in pseudo-range to position determination depending on the application of GPS. This is all the more reason to use operational scenarios for analysis of the data along with a verification of the lab setup and results.

The proposal for reacquisition time as a performance metric was raised in the fourth paragraph. The proposed criterion is to monitor whether the receiver acquires within the manufacturer's stated time. This is not a good criterion. Many manufacturer specs are either (i) very conservative, or (ii) overly optimistic. If the concern about GPS is centered on safety of life applications, then there is (or probably should be) a government or technical body specification for such a requirement. If not, the criterion should be based upon what the particular application of GPS will deem minimally necessary. Secondly, the reacquisition time should be determined without ANY interfering sources. The receiver should be able to successfully acquire within the stated reacquisition time criterion on numerous occasions, in order to build statistical confidence that the manufacturer specification or other time criterion is correct.

The test plan proposes to monitor C/No and use this as one of the metrics. We have no direct disagreement with the notion of using C/No in this way, but caution that often the values reported by the receiver can be erroneous or dependent upon the algorithm chosen by the manufacturer to calculate C/No. If NTIA plans to monitor C/No or use it in the follow-on analysis work, we strongly recommend calibrating the receiver to measure the accuracy of the GPS receiver's reported C/No relative to a known C/No.

In the fourth paragraph, NTIA introduces the notion of combining the UWB signals with a broadband noise source in the test setup. This is troublesome and seems counter to the goal of this measurement effort. The stated goal of the NTIA test plan (from section 2), "the measurements will define the maximum level of UWB emissions that can be tolerated at the antenna output (*sic*) of each GPS receiver considered...These thresholds will be used in a link budget analysis for each specific UWB-to-GPS scenario identified..." Based on our reading of this test plan, it is not NTIA's goal to measure the difference in impact from a UWB signal to white noise and come up with a correction factor. This is a similar approach to the DOT/SU plan. However, the DOT/SU plan is using this technique to determine a equivalency factor between UWB and white noise.

In order to evaluate the affect of UWB on GPS receivers UWB should be injected into the GPS receiver *without* broadband noise. Even the ITU-R M.1477 analysis in paragraph 3.2 considers the GPS co-channel self-interference separately from other noise sources. It is a questionable to assume that the interference in the GPS band will have the properties of broadband noise. By combining UWB with broadband noise other spurious effects can be created that enhance or de-emphasize the interference affects of UWB. Moreover, the broadband noise source may cover up some of the effects of the UWB signal when the UWB signal is less than (or equal to) the broadband noise source.

The plan continues to describe the power level chosen for the broadband noise source and the rationale behind that. However, the rationale seems to be stacking the deck against UWB. In essence what is being said is, "We are going to use the minimum guaranteed signal from the satellite and then we are going to assume that we have the minimum C/N ratio to barely acquire a single satellite and then solve for what the noise would have to be. We then are going to assume that this is the noise level found in the ambient and then we will add UWB energy." A similar analogy to this approach follows: Fill a glass to the brim with water and then determine how much apple juice can be added before the glass overflows. Any drop of apple juice will overflow the glass due to the already existing level of water. This does not answer the question that NTIA is seeking, which is how much apple juice is required to overflow the glass.

If in the process of defining operational scenarios, the testing group decides that the glass is already mostly full then that information along with the data can make the complete determination. After all, the stated objective is to use these measurements to determine how much UWB energy is needed to degrade the receiver to a stated level (2 dB below break-lock) and then use these measurements in an operational scenario analysis. The operational scenario analysis will necessarily include other emitters; trying to emulate other interference on the lab bench in determining the impact of UWB emissions on GPS receivers is not good practice.

Moreover, in reading through the stated ITU-R document we have seen that the stated threshold for receiver wideband aggregate interference is -146.5 dBW/MHz = -116.5 dBm/MHz = -103.5 dBm/20 MHz. Note that the thermal noise for the receiver is -176.6 dBm/Hz = -116.6 dBm/MHz = -103.6 dBm/20 MHz. Thus, with no other emitter even present, thermal noise by itself is at the stated receiver wideband aggregate interference threshold. This means that when any other emitter is added to that environment, the threshold will be exceeded; this includes the broadband noise source that NTIA is proposing to use.

Our recommendation is for NTIA to measure just UWB emissions alone against the GPS receivers. We still like the normalization routine with the broadband noise alone that establishes a baseline of the receiver performance. However, we strongly disagree with the measurement philosophy of judging the impact of UWB signals from a composite of UWB and broadband noise.

Additionally, we would like to know the type of 20 MHz bandpass filter that NTIA plans to use in the testing.

Also, the sixth sentence in the fourth paragraph states that , "if there is a significant deviation in the one-sigma ..." We would like to know how NTIA plans to determine what a significant deviation is (*e.g.*, 1 dB, 3 dB, 10 dB, 30 dB)?

Finally, we have a minor editorial comment in this section: The fourth sentence states "the broadband noise and the composite signal power will each be incremented... ." This is different from what is outlined in section 4.4.2 where the broadband noise is kept constant and only the UWB power changes. This discrepancy could be fixed by using "or" rather than "and".

4.4 Development of Single Source UWB Interference Measurement Procedures

The second paragraph of this section describes the measurement procedure as using only a single satellite or channel. While it is appropriate to consider the impact of a single marginal signal, it is also necessary to account for the other GPS signals available to the receiver. While a UWB signal has the potential to reduce the C/No of a given satellite signal, there will likely be seven other GPS signals to choose from and each channel will be impacted differently depending on its spectral features. We strongly recommend that a full (or at a minimum a partial) constellation of satellites be utilized.

Furthermore, NTIA has stated that it is unclear which performance metrics should be used in studying the possible interference from UWB to GPS. One such metric, which happens to be paramount for both civilian and survey uses is the actual impact in the position determination. This requires at least 4 satellites to determine. From the data that is currently being proposed, this will be impossible to conclude. In terms of additional work required, it really isn't that much more work. The GPS simulator can easily produce a full constellation, and NTIA is already planning to automate the system, which only need be slightly modified to record the data from several satellite channels. **We strongly urge that NTIA consider multiple satellite channels in its GPS testing.**

Moreover, there is no information about the single channel GPS simulator. We are concerned about the frequency stability, offset carrier phase noise, intermod, etc. Any one of these affects could combine with the UWB and change the interference impact. At a minimum NTIA should state which channel is being tracked so analysts can consider the code spectral features.

We also have several detailed questions pertaining to the specifics of the test procedure. The NTIA test plan does not indicate how many minutes of data, sampling interval, and number of samples of pseudo-range will be collected for each attenuation level change. Can this be detailed or outlined in the next version of the test plan and the final report? As an example, the UT:ARL test plan calls for gathering data for 600 seconds per attenuation setting for a certain statistical certainty of 95%. The NTIA test plan seems to indicate that the data is only gathered for the 1 sigma certainty. Once again, how long is the data to be gathered? Also in step 8 of 4.4.1, how long will the GPS receiver be allowed to track until the noise is reintroduced? In step 10, a 50 meter step in simulated pseudo-range will be introduced - is this done using the GPS simulator? If not, please explain how the 50 meter step is introduced. As a general comment, if an LNA is used care then care must be taken not to saturate the LNA due to the peak level of the pulses. In step 12, the receiver is being required to reacquire with an 80% or greater success rate. What is the significance of this value? Should it not be 100%? If the receiver does not reacquire (without the UWB signal present) 100% of the time to the stated spec then is not either the receiver or the spec invalid for the test? We recommend that NTIA take the time to seriously consider these technical questions and that the next version of the test plan include these details.

4.5 Development of Measurement Procedures for Assessing Aggregate UWB Interference

The following statement is made in the second paragraph of this section: "In order to develop procedures that will provide consistent, repeatable results, the aggregate interference measurements should be made using a GPS simulator and closed-system measurements." Obtaining repeatable results are required to have confidence in any testing data. Yet, with regard to UWB, it is critically important to have test results that model real-world operational scenarios. In this respect, there are three major factors present in the radiated test environment that are not part of the conducted setup – multipath interference, ambient noise, and the impact of transmit and receive antennas. Proper radiated testing is needed to validate the conducted testing model. Such testing will allow, at a minimum, critical information regarding the three major "radiated-environment" factors listed above to be fed back for compensation in the conducted tests.

In table 4, we want to know what is meant by "combined power level range." Is that measurement at the output of the UWB generator combiner or the output of the combiner of the UWB and broadband noise generator? Table 4 states that the level should be set to -94, but the step by step says the broadband noise is at -91 and the combined UWB signal will initially be at -97 and then will be increased up to the break-lock point. This procedure is very unclear. We strongly urge NTIA to clarify this procedure, both in terms of power levels and in terms of noting the location where the power is measured.

We would like to see more combinations from the aggregate testing, specifically we would like to see a dithered modulation with a gating of 20 % (*i.e.*, an amount less than 100%). This represents the scenario that Time Domain is hoping to deploy if allowed commercial approval. We are not aware of any application that uses simultaneous synchronized UWB transmissions. For example, Time Domain's through-wall sensing radars transmit in bursts for signal processing reasons. In addition, wireless local area networks are packet radios that essentially transmit in bursts. To the extent that the test configuration may be used to synchronize the transmissions from multiple UWB sources, such a configuration is unrealistic.

In the case of measurement IV, when the multiple sources are on, we would like to know whether they are all increased the same amount at the same time, or whether one or two are set to a constant power level and the other source(s) increased? We would appreciate NTIA providing more details on this point. This measurement can be accomplished a number of ways depending on what scenario one is trying to reproduce (*e.g.*, three device at an equal distance from the receiver moving towards it at the same rate, different rates, or some are moving and some stationary).

Time Domain has 20 UWB signal generators that were built to support the ARL:UT aggregate testing. NTIA/ITS is welcome to borrow them for testing, assuming that use

of the generators by NTIA can be coordinated with the ARL:UT effort. Use of these devices would allow NTIA to build a better aggregate model with additional data points.

4.6 Radiated Tests (from hardcopy of test plan provided at recent NTIA briefing)

The purpose of the radiated testing should be to validate the predictions of the conducted test data. The conducted data provides repeatable reliable results, however, the use here is unclear. The radiated testing proposed in this section – which appears only in the handout from the recent NTIA briefing – is performed in a somewhat uncontrolled environment. As a result, it will be difficult to have repeatable data. Nevertheless, these tests can provide some amount of a validation or "sanity check" on the analysis effort utilizing the conducted data. In the conducted testing, (i) the antennas (and possibly front-end filters and LNAs) are bypassed, (ii) there is no true ambient noise, and (iii) there is no multipath interference. These are all critical performance parameters for determining the actual interference potential of UWB signals. Unfortunately, the radiated section in the "handout" version of the NTIA GPS test plan appears to only study antenna impacts. The radiated section does not include many details about characterizing the receiving antenna, LNA, downstream filters that would occur in an actual receiver, etc. All of these factors will affect what the GPS receiver front end is presented with from an interference perspective.

Along with the proposed radiated antenna testing, the GPS receivers should be taken outdoors to, at a minimum, validate their performance from the simulator to the real world, with and without a UWB source present. This can either be done in a relatively clean, clear, and quiet environment in an attempt to verify that the simulated conducted tests are match the outdoor tests. The testing can also be performed in a manner that matches one of the operational scenarios, in order to validate the conducted data along with the associated analytical model for determining interference within a specified operational scenario.

Time Domain firmly urges that radiated testing be made an integral part of the test effort, and that the radiated tests be used to validate the conducted measurements and that the analyses developed to predict interference in an operational scenario. Moreover, radiated testing should be used to determine if there is some characteristic of intentional UWB emissions that makes it significantly different from Part 15 unintentional emissions in the GPS bands.

Time Domain further urges that the NTIA keep the process for revising this plan an open process as we move forward. We hope that additional briefings are provided by NTIA to discuss status of this test plan and of the test process.

4.6 Data Recording and Reporting (from website)

4.7 Data Recording and Reporting (from hardcopy of test plan provided at recent NTIA briefing)

We request that the reporting of data also include the final measurement procedures, including block diagrams of setups, equipment parameters, etc – the info that is required to allow someone to repeat the testing. This helps others in understanding how to use the data and relate it to the particular equipment setup. Additionally, assuming that testing is conducted with a proper constellation of satellites, we would like to know whether NTIA plans to record any information from the GPS system simulator, such as the satellite channel number, GPS time and date, etc., in order to determine satellite location for proper analysis. Finally, we would like to know the format and process that the NTIA plans to use to distribute the information it gathers from the GPS receivers and simulator. Because of the limited timeframe and because software programs may need to be written to process this information, it would be helpful to know beforehand what data format the NTIA plans to use in recording the data.

VIII. Appendix A.0 – Calibration Procedures

In general, this section is straightforward and we have no concerns regarding the proposed calibration procedures. However, we recommend that the output of the GPS simulator be shown to meet the requirements of an FAA or GPS JPO certified simulator. Lastly, we recommend calibrating the receiver to measure the accuracy of the GPS receiver's reported C/No relative to a known C/No.