determined following completion of testing is whether "blanket" authorization of classes of UWB devices is to be permitted (and, if so, for what non-restricted bands this would be feasible), or whether, instead, each type of UWB waveform or even each emitter within one or more classes of UWB waveform are required to be licensed on an individual bases.

The structural approach contemplated in the *NPRM* has a number of shortcomings. For example, it is inappropriate for the Commission to distinguish between and among UWB devices and applications based on such qualitative criteria as how the devices are to be marketed or even on such putatively quantitative criteria as whether they are to be high power, low power or very low power.[36] Distinguishing UWB systems based on such characteristics establishes nothing about their potential to interfere with GPS and other safety services, which should be the paramount criterion. The approach called for by the Council overcomes these flaws, and will enable an orderly and rational regime for the regulation of UWB devices to be established.

1. With Appropriate Regulatory And Operational Safeguards, Certain UWB Radar Devices May Be Compatible With GPS, Although The Precise Frequency Bands Of Operation Remain Under Study.

The most appropriate starting point in developing rules to protect GPS and other restricted systems would be to look at UWB devices with specifically licensed UWB waveforms. As stated above, UWB emitters can be divided into two broad classes: a subclass of UWB radars (comprised exclusively of GPRs and WIDs); and all other UWB devices (including radars that operate in free space and UWB communications devices, which are potentially networked).[37] The former category involves the use of single emitters, the latter category often involves licensing of networks. Although, non-networked, non-free-space radar UWB devices contribute to the noise floor, these

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[36] *See id.* at 8 (¶ 18).

[37] The low-PRF/low duty-cycle characteristics of certain GPRs and WIDs devices facilitate the prediction and isolation of the interference that may be caused to GPS receivers. Thus steps may be taken to ensure the protection of GPS receivers from those GPRs and WIDs. *Cf. NPRM*, FCC 00-163, at 16 (¶ 36) (considering alternatives to avoid interference to the GPS bands based on the PRF of the UWB signal).

types of devices, when used in isolation and licensed with appropriate regulatory safeguards, may be able to be operated without causing harmful interference to GPS receivers if assigned to a non-overlapping portion of the frequency spectrum above 3 GHz.[38] On the other hand, and in addition to their numerous technical compatibility issues, UWB communications devices which can be networked are problematic from a regulatory standpoint, as it is very difficult to control the peak power in localized areas.

In light of these facts, and in order to ensure that GPS is truly and fully protected, there are a number of conditions that the Commission should nevertheless impose on GPR/WID power and operations in any rules it may adopt. Specifically, the Commission must adopt the following conditions on GPR and WID operations: (i) operation exclusively with a to-be-determined set of technical characteristics from comprehensive testing, for example, including, but not limited to, a PRF/duty cycle/peak power, etc (ii) "kill" switches that shut down the devices if they are not being operated in direct contact with the ground or a wall;[39] (iii) adaptive power control for WIDs that automatically ensures that these devices use only the power necessary for the type of wall material being penetrated; (iv) use must be restricted to situations directly involving public safety and/or protection of life or property in order to avoid proliferation of these devices;[40] and (v) all devices must meet the National Telecommunications and Information Administration ("NTIA") waiver-

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[38] Certain GPRs and WIDs devices having characteristics, such as low-PRF/low duty-cycle, facilitate the prediction and isolation of interference that may be caused to GPS receivers. These devices may be given priority consideration by the Commission as it defines the full set of characteristics necessary to license this class of UWB devices for public safety use.

[39] With this condition, it is clear that collision avoidance radars and other UWB radars not operated exclusively in contact with the ground or a wall would necessarily be excluded from this category of UWB radars.

[40] One of the beneficial side-effects of the avoidance of proliferation of these devices comes in the recognition that this type of UWB equipment is easily subject to "misuse," and thus could be an effective intentional jammer of other radio services. Controlled impulse damped wave transmissions, such as those proposed for use by commercial UWB devices, rely on precise antenna design and management. Intentional or unintentional modification of the antenna can drastically distort the resulting waveform and its interference potential. The magnitude of these effects is more severe than for traditional continuous wave emitters allowable under today's Part 15 rules.

order conditions regarding FCC certifications and lab confirmations.[41] FCC certifications may need to be updated to adequately and accurately assess whether or not UWB time domain devices are in compliance with regulations.

These conditions reinforce but do not impede the intentions expressed by the proponents of UWB GPR and WID devices, and are necessary to ensure full protection of GPS. They should therefore be included in any provisional or permanent rules the Commission may choose to adopt in

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[41] In the UWB Waivers, the Commission imposed a number of specific conditions requested by NTIA. *See UWB Waivers*. The following extract from these conditions should be reflected in any rule provision the Commission may adopt regarding GPRs and WIDs that would operate in their own allocated portion of the frequency band:

1. The use and manufacture of any UWB device must be ceased if the device causes harmful interference to another radio service.

2. Before any UWB device can be placed into operation, the equipment must be certified by the Commission, using the procedures discussed in Sections 2.1031-2.1043 of the Commission's Rules.

   a. The certificate must show that the equipment complies with the FCC conditions concerning UWB devices and does not exceed the emission limits in Section 15.209 of the Commission's Rules.

   b. All certification measurements must be confirmed at the FCC Laboratory in Columbia, MD.

   c. All certification measurements must be made using the procedures given in ANSI C63.4-1992, entitled *Methods of Measurement of Radio-Noise Emissions from Low-Voltage Equipment in the Range 9 kHz to 40 GHz*. The average power measurements must use the video filtering procedures contained in Hewlett-Packard Application Note 150, *Spectrum Analysis: Basics*.

   d. Measurements of the peak levels of the UWB devices be made. Resolution bandwidths of the inverse of the pulse width must be used.

3. The manufacturer must apply for a new grant of certification for equipment modifications that would affect the conformity of the actual radiated levels to the requirements of section 15.209 of the Commission's Rules. In addition to the requirements of section 2.1043 of the Commission's Rules, these changes include variations in center frequency and radiated power, or in other spectrum related characteristics, *e.g.*, pulse width and pulse repetition frequency. Changes in design that would bring a petitioner's system out of conformity with section 15.209 of the Commission's Rules are prohibited.

4. The manufacturer and their authorized sales agents must maintain records of all users to whom they sell, lease or otherwise distribute UWB equipment and make them available to the Commission on request. These records must include the nomenclature used in the FCC's grant of certification, a user point of contact, and the intended area of operation.

See Conditions for Approval of Part 15 Waivers Sought by Petitioners, U.S. Radar Inc., Time Domain Corporation, and Zircom Corporation, attached to letter from William T. Hatch, Acting Associate Administrator, Office of Spectrum Management, National Telecommunications and Information Administration, to Dale Hatfield, Chief, Office of Engineering and Technology, Federal Communications Commission (June 15, 1999) (on file with the Commission) ("NTIA Letter").

this proceeding – subject, of course, to the outcome of ongoing tests and measurements.[42] The Council believes that a new Part of the Commission's Rules must be developed to protect the existing stakeholders in the portion of the frequency spectrum to be allocated to UWB. Any rules should, however, be carefully crafted so as to specify what types of devices are permitted, and to preclude all devices not specifically included.

2. The Commission Should Be Extremely Cautious, In The Course Of The Instant Proceeding, In Authorizing The Use Of Any UWB Devices In Any Restricted Band.

a. The Threat Of Harmful Interference Precludes The Use of Most, If Not All, UWB Devices In Frequency Bands Below 3.0 GHz.

The Council has concluded above that certain types of UWB radar devices, if subjected to proper technical and operational conditions, may be able to be operated compatibly with GPS receivers. The determination of whether these UWB GPRs and WIDs can be operated in frequency bands below 3 GHz, while still fully protecting GPS and other safety services, remains to be made after comprehensive test results are in and analyzed. There can be no doubt, however, even without awaiting test results, that unrestricted GPRs/WIDs, radars used in free-space conditions, and networked UWB communications devices all individually pose intolerable threats to safety services. The operation of these types of devices would introduce noise into the GPS bands and would create the risk of harmful interference to GPS receivers. The vital importance of the safety/restricted bands, the paucity of available data, and the Commission's and scientific community's lack of understanding of either networked UWB communications devices or of the aggregating effect of

[42] In this regard, the Council reserves the right to amend its views above, should the results of ongoing testing and measurement efforts indicate that such devices will cause harmful interference to GPS, even when operated in isolation.

non-networked UWB devices preclude the adoption of any rules that would permit the use of such devices in bands below 3 GHz.[43]

In lending its support for the establishment of conditional UWB waivers last year, NTIA stated that proliferation of UWB systems centered near 2 GHz could cause serious problems to several critical, sensitive services important to both the government and the public.[44] NTIA strongly urged the Commission to require the waiver licensees to take steps to move their operations to portions of the spectrum above 2 GHz.[45] No data whatsoever has been put forward to address, much less alleviate, these concerns. Indeed, all analyses to date have the effect of buttressing the concerns. In recognition of this fact, the Commission proposed in the *NPRM* to allow GPRs to operate in any part of the spectrum, but to establish a cut-off point for other UWB devices at 2 GHz.[46]

The Council believes that the Commission must absolutely preclude all UWB operations from the GPS L1, L2, and L5 bands. Indeed, the Council is of the view that such devices, with their inherently incompatible time-domain approach to the use of the spectrum resource, should be precluded from all restricted bands below about 3 GHz, as the interference considerations pertaining to such bands as 2310-2390 MHz, 2483.5-2500 MHz, and certain uses at 2655-2900 MHz should not be overlooked.[47] As a result, the Commission's proposed cut-off point may need to be reset at

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[43] For clarification, when the Council refers herein to bands available or not available for use by UWB, it is referring to the bands across which UWB energy would be pulsed, rather than the center frequency. Thus, when the Council calls for a preclusion of UWB devices above 3 GHz, it is calling for all bandwidths occupied by the affected UWB device to be above 3 GHz.

[44] *See* NTIA Letter at 3.

[45] *See id.*

[46] *See NPRM*, FCC 00-163, slip op. at 12, 14 (¶¶ 25, 30). The *NPRM* actually contains some ambiguity on this critical point, as the Commission at one juncture appears to leave open the question of whether UWB devices other than appropriately-conditioned GPRs and WIDs could be permitted to operate below about 2 GHz. *See id.* at 18 (¶ 39).

[47] The bands 2200-2300 MHz, 2310-2390 MHz, 2483.5-2500 MHz and 2655-2900 MHz are restricted bands under Section 15.205 of the Commission's Rules. *See* 47 C.F.R. § 15.205(a). In proposing a cut-off at 2.0 GHz, the Commission observed that "most radio services operating above 2 GHz use directional antennas that generally

around 2.9 GHz. Such an approach would be consistent both with the Commission's stated objectives to protect the restricted bands, and with the way in which these bands are being used.

Whether the "line" is ultimately drawn at 2.0 GHz as indicated by NTIA and as seemingly proposed in the *NPRM,* or at 3.0 GHz as would appear to be warranted under the Commission's own rationale and the nature of spectrum uses in restricted bands below 3.0 GHz, the need for preclusion of most, if not all, UWB devices from the GPS bands is undeniable. Communication-type applications of UWB such as the networked emitters in close proximity that would be used in the local-area network ("LAN") concepts apparently being advocated by some of the UWB interests, are of particular concern. Indeed, any UWB application that radiates using omnidirectional or semi-omnidirectional antennas (in contrast with the directional and operationally-conditioned GPR/WID applications described above) will necessarily present GPS receivers with significantly higher levels of interference, and the interfering signals will compete with satellite signals that may already be impeded to some extent by antenna masking due to foliage, terrain, and manmade obstructions.

The Commission has recognized that GPS receivers used in land and marine applications (in addition, of course, to those used in aviation) must be protected. GPS receivers used in many of these applications are extremely sensitive to the type of interference that would be produced by UWB devices. Moreover, as GPS receivers are ubiquitously deployed and virtually synonymous with true mobility, and many UWB applications involve situations where UWB devices would be deployed out of doors, the probability of a UWB transmitter or transmitters being operated in close proximity to a GPS receiver is very high.

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discriminate against reception of undesired signals." *NPRM,* FCC 00-163, slip op. at 13 (¶ 27). Although the Council is focused first and foremost on the GPS bands, it is compelled to note that at least some radio services (e.g., the "Big LEO" mobile-satellite service at 2483.5-2500 MHz and Digital Audio Radio/Satellite service at around 2350 MHz) operate with low power satellite transmissions into earth terminals that use omnidirectional antennas.

Once data are available from reliable tests on UWB radar interference, the interference potential of UWB radar devices should be able to be confirmed, along with the need for a strict preclusion of all UWB devices (other than, perhaps, GPRs and WIDs meeting the conditions described above) from the restricted bands below 3 GHz. In this last regard, the Council observes that the repeated claims from proponents of UWB communications devices as to the infeasibility of utilizing filters that would notch out the GPS bands[48] leaves absolute preclusion as the only possible alternative for the Commission to embrace here. This preclusion should be reflected clearly and unequivocally in the Commission's rules.

b. Potential Regulatory Considerations Pertaining To The Authorization Of UWB Communications Devices, Even In Bands Above 3 GHz, May Have To Be Addressed In Separate Regulatory Proceedings.

The prospect for the use of UWB technology in communications devices, which will inevitably be proliferated in networks and therefore cause high levels of local interference with a devastating impact on GPS and other services operating in restricted bands below 3 GHz, raise a number of additional considerations that have heretofore gone unaddressed in any of the Commission's discussions of UWB technology. In particular, the Commission has yet to discuss whether particular applications of UWB technology may in fact rise to the level of a communications service, and thus require an independent technical and public interest determination in a rulemaking proceeding as well as the establishment of a licensing regime pursuant to which authorizations would be issued.

If a particular type of UWB application has the technical and operational characteristics of a communications service, and would be operated in a manner similar to the manner in which current communications services using traditional technology are operated, it would appear to be inequitable for the Commission to allow the UWB-based "service" to operate on an unlicensed

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48 *See NPRM,* FCC 00-163, slip op. at 11 (¶ 25).

basis if authorizations are required in the services with which the UWB "service" would be competing. For example, if a wireless network operator had to purchase the right to operate in a specific area at auction, a UWB proponent that is contemplating a commercially comparable application should not be allowed to evade this regulatory regime even if its operations are restricted to bands where interference would not be caused to GPS and other safety/restricted services.

As a practical matter, the Council observes that, given the large amounts of spectrum associated with particular communications applications of UWB technology and the large networks that are proposed to be employed, the potential for preclusive effects (i.e., mutual exclusivity) between UWB operators in a particular geographic area would appear to be high. Moreover, UWB communications devices are themselves subject to interference, a fact that raises questions as to the efficacy of the technology.[49] Neither the *NPRM* nor any of the testing/measurement plans now on the table are geared to the generation of data regarding the ability of multiple homogeneous or heterogeneous UWB devices to operate on a co-frequency basis. These considerations are clearly beyond the scope of the instant rulemaking proceeding, but would have to be addressed by the Commission in separate proceedings before any authorizations of UWB technology in communications devices – without regard to the frequency bands in which such devices would operate – could be made.

At the very least, it appears completely inappropriate for communications applications of UWB technology to be regulated under Part 15 of the Commission's rules – even if the provisions covering intentional emitters are employed.[50] These are intentional emitters that experience very high peak power excesses that, even though they are transient, have the ability to disrupt services.

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[49] *See* Attachment A, Technical Appendix.

[50] Clearly, UWB devices do not qualify as unintentional radiators; they are not hair dryers or computer chips, but instead are devices that intentionally are seeking to use the radiofrequency spectrum.

Authorization to operate on a non-interfering basis would not be appropriate in this circumstance; a separate, dedicated regulatory regime for communications applications of UWB technology would appear to be warranted.

c. Irrespective Of Where The Preclusion Line Is Drawn, The Commission's Rules Must Contain A Specific Limitation On Unwanted Emissions Into The GPS Bands From Networks Of UWB Devices.

Any Commission rules adopted in this or subsequent proceedings on UWB technology and its applications must ensure, without regard to where the preclusion line for non-GPR/WID devices ultimately is drawn, that unwanted emissions into the GPS bands are strictly limited. In the *NPRM,* for UWB devices other than GPRs and WIDs of the type discussed above, the Commission proposes to adopt the emission limits in Section 15.209 of its rules for UWB operations, with the caveat that emissions that appear below 2 GHz be further attenuated by at least 12 dB beyond the Section 15.209 levels.[51] Furthermore, this caveat must further include the additional phrase: "for the entire network." With respect to unwanted emissions produced into the GPS bands by non-GPR/WID UWB systems that may operate in bands above 2.9 GHz, this would translate into a limitation on unwanted emissions in the GPS bands of –83.25 dBW/MHz.[52]

The Council believes that the Commission's proposal is a step in the right direction, but that it is insufficient by itself to protect GPS receivers from the unique perils associated with networks of UWB communications transmissions. The key shortcoming stems from the fact that the metrics the Commission traditionally uses for assessing unwanted emissions in a continuous wave environment (i.e., dBW/MHz averaged over 1 second or mV/m at a distance of 3 meters) are not directly applicable in the discontinuous, transient-pulsed environment of UWB transmissions. In

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[51] *See NPRM*, FCC 00-163, slip op. at 18 (¶ 39).

[52] For bands above 960 MHz (i.e., for all of the GPS bands), the emission limitation established in Section 15.209 of the Commission's Rules is 500 mV/m at a measurement distance of 3 meters. *See* 47 C.F.R. § 15.209(a). This figure is the equivalent of –71.25 dBW/MHz. With an additional 12 dB of attenuation, the unwanted emission limit would become –83.25 dBW/MHz.

particular, what is needed to provide an accurate measure of the UWB-produced interference into the GPS band is the peak instantaneous power on a nanosecond basis; the standard metrics rely on a time period that is too long to ensure capture of the interfering signal.[53] This suggested unwanted emissions limit was derived using frequency domain assumptions without specifying the time domain waveform, the measurement technique to be used, and the nature of the network environment. It is impossible to specify a "one size fits all" safe harbor. Further progress on an unwanted emission limit may not be possible without a better understanding of the underlying UWB waveforms and their impact on GPS.

In considering these unwanted emission limitations for the GPS bands, the Council applauds the Commission for recognizing in the *NPRM* in this proceeding that all applications of GPS are to be protected from UWB interference. Given that the vast majority of uses of GPS occur in situations where the receiver is mobile, and that a substantial percentage of UWB applications are also likely to be mobile and/or outdoor, the potential for a significant UWB impact on the GPS noise floor is inevitable. For the Commission to limit its deliberations to scenarios where the only affected GPS receiver considered is one located on a landing aircraft, 100 feet above a single interference source, with the GPS receiver shielded from the interferor by the airframe, does not protect the noise floor for safety-of-life, and undercuts achievement of the Commission's laudable objectives with regard to protecting GPS.

For all of those UWB devices that are not permitted to operate in the GPS bands, the Commission must establish a strict limit on the production of unwanted emissions into the GPS bands. For now, the actual values for this limit, and even the units in which it is to be measured, must await the outcome of comprehensive and rigorous testing activities. The Commission must

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[53] The chipping rate of the GPS receiver is approximately 1 chip per microsecond (1.023 mcps). In each millisecond, the receiver makes a go/no-go decision, but it takes only microseconds of interference to affect the ability of the GPS receiver. The Europeans are considering the deployment of their own RNSS constellation, known as Galileo, which would use even higher chipping rates.

gain a further understanding as to the nature of the UWB waveform, and then determine that it is the obligation of the UWB proponent to use appropriate time domain measurement techniques to assure compliance with the appropriately crafted limit.[54] The Council respectfully reserves the right to provide comments on the appropriate limits of unwanted emissions of UWB devices into the GPS bands in response to test data. It does submit, however, that the limit to be adopted should be a general requirement applicable to any UWB device or network that is operating above 3 GHz, and apply to unwanted emissions into any GPS band (i.e., the bands 1559-1610 MHz, 1160-1215 MHz, and 1215-1240 MHz).

d. The Commission Must Refrain From Granting Or Considering Additional Waiver Requests From UWB Proponents Or Modifications To Existing Waivers Until After The Instant Proceeding Has Been Concluded.

In the *NPRM,* the Commission states that it is willing to consider granting additional waiver requests (beyond the original three waivers) on a case-by-case basis.[55] The Council respectfully submits that the Commission should refrain from granting additional UWB waivers for the time being. There are simply too many unknowns associated with UWB (ranging from a fundamental lack of understanding of the underlying science of the relationship between the UWB waveform and the conventional frequency domain devices, to the bevy of policy issues associated with the overlay of the time-domain based UWB technology onto the frequency domain regime, to the harmful impact of networked UWB emitters on GPS receivers) for the Commission to be able to responsibly issue any kind of authorization other than perhaps a very limited experimental authorization operating in a portion of the frequency spectrum that is not overlapping.[56]

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[54] *See* Section III.D, *infra,* for a discussion of measurement methods and requirements. These comments apply with equal vigor to the assessment of compliance with whatever limit is set on unwanted emissions.

[55] *See NPRM,* FCC 00-163, slip op. at 5 n.21.

[56] The Council's recommendation that the FCC complete the core rulemaking before doing anything else due to the complexity of the issues is consistent with the NTIA demand that additional waivers of Part 15 rules to permit the

Clearly, any waiver request for a communications application of UWB technology must be held in abeyance pending resolution of the underlying issues. The interference dangers presented by such uses are becoming clearer every day. In addition, the Commission should hold any requests for additional GPRs and WIDs in abeyance pending the outcome of this proceeding, as the Commission must ensure that the conditions on their operation necessary to safeguard GPS and other safety-of-life and NII services have been properly implemented and that the prospect of the proliferation of these devices has been nullified.

B. The Commission Must Reverse Its Tentative Conclusion That Only The Closest Transmitter Placing An Emission Into The Frequency Of Concern Is Relevant; Multiple Emitters Have A Profound Interference Effect On GPS Receivers.

In the *NPRM*, the Commission tentatively determined that that only the closest transmitter placing an emission into the frequency of concern would be of importance.[57] The Commission stated that the cumulative impact of multiple, co-located UWB devices appears to be negligible at the power levels and with the modulation types being proposed.[58] It recognized, however, that "the cumulative impact of several UWB devices may be different depending on their individual emission and transmission characteristics."[59] The Commission also appeared to recognize, on a core level, that there is a relationship between the PRF, which is only one of the key UWB waveform characteristics to be specified, and the cumulative impact of UWB devices.[60]

To understand the impact of multiple UWB signals on GPS, it is necessary to achieve an understanding of the UWB signal structure (including the parameters relating to the nature of the

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marketing of UWB devices that emit radio frequency energy in the restricted bands be suspended or severely limited until further analyses and measurements have been completed and a regulatory framework developed. *See* NTIA Letter at 4.

57 *See NPRM*, FCC 00-163, at 22 (¶ 47).

58 *Id.*

59 *Id.*

60 *Id.*

networking), the GPS signal structure, and the interrelationship between the two. The GPS signal structure and receivers are well understood.[61] Knowledge and understanding of the UWB signal structure, particularly as applied to communications use is more of an unknown quantity at this point, as is the interrelationship of that signal with GPS receivers. Nevertheless, enough is known about both the UWB signal structure and the impact UWB transmissions would have on GPS to enable a determination to be made that multiple UWB emitters would have a profound interference impact on a GPS receiver.

If a number of GPRS are operating in the same location as a GPS receiver, the interference will be larger than if only a single GPR would be operating. Importantly, UWB aggregation changes, for example, one of the major UWB technical characteristics: effective PRF. If two UWB signals are received, the effective PRF doubles, unless one of the signals is very weak. If three UWB signals are received, the effective PRF nearly triples. The effective PRF is slightly less than linear in the number of UWB transmitters, because some of the UWB pulses may fall on top of each other.

In the case of aggregate emissions, the effective duty cycle of the combined emission will increase so that two, three or more UWB pulses from different UWB emitters will arrive closely following each other in time at the front-end of a victim receiver. As the front-end response of all receivers has a decay time, and as all receivers have a second-stage response threshold, the result will amplify the possibility of interference. The important point is that this aggregate interference cannot be predicted by testing individual UWB transmitters.

In short, the Commission's tentative determination that only the closest UWB transmitter placing a signal into the frequency of concern matters is not correct – at least with respect to GPS

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[61] Even so, consideration of the characteristics of the GPS receiver is no easy task. There are non-linearities in damped response, for both single and multiple UWB input cases, and the response of a GPS receiver to continuous signals cannot be extrapolated to the effect of damped transient signals such as UWB.

receivers.[62] The composite effect is made up of one plus the effect of two, plus the effect of three, etc. The effect is additive, and the additive factor varies depending on whether the network is synchronous or asynchronous. The synchronous network is decidedly, worse. There is, instead, a strong need to ensure that the cumulative contributions of multiple UWB emitters does not lead to any increase in the noise floor of the GPS receivers – a determination that is severely undercut by the Commission's tentative conclusion. The characteristics of networked UWB communications transmitters, the victim receivers, and the interrelationship between the two, play critical roles. If enough UWB emitters are stacked up in a local area, they will completely jam the electromagnetic spectrum. This is the part of the problem of networked UWB devices that must be addressed specifically in any regulatory scheme.

C. The Commission Has Not Allowed Sufficient Time For Conducting The Necessary Tests And Analyzing And Reconciling The Results To Be Obtained.

1. The Commission Has Not Allowed Sufficient Time For Testing And Experimentation.

The reemergence of UWB technology, with which regulators have little familiarity and the physical science of which is not very well understood, after three quarters of a century of dormancy presents a textbook case for the establishment of a comprehensive and exhaustive testing program as a prerequisite to the grant of any permanent operating authority. To be sure, the Commission's 1998 *UWB NOI* seemed to be moving in that direction, as it asked numerous questions in an effort to gain an understanding of just what challenges were posed to the agency by the waiver proposals it subsequently granted. Indeed, even the present *NPRM* asks numerous fundamental questions

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[62] The Council recognizes that tests and measurements are ongoing within several different organizations at this moment. As it indicated in its recent comments on the NTIA GPS/UWB Measurement Plan late last month, however, the Council is unaware of any test or measurement plan that is capable of accurately ascertaining the effects of multiple UWB emitters on a GPS receiver. *See* NTIA Measurement Plan to Determine the Potential Interference Impact to Global Positioning System Receivers from Ultrawideband Transmission Systems, Docket No. 0006232194-0221-02 (August 14, 2000) ("*NTIA Measurement Plan*"); Comments of the U.S. GPS Industry Council on NTIA GPS/UWB Measurement Plan, at 7 (filed August 29, 2000) ("Council Comments on NTIA Measurement Plan"). This is a significant shortcoming, and may require the Commission to defer action on all UWB authorizations other than carefully-restricted low-PRF devices used in GPRs and WIDs pending the development and execution of a test plan to definitively assess the impact of multiple UWB devices on GPS receivers.

about the nature of UWB technology and its impact on services across the existing frequency domain regime, and expresses understandable uncertainty on such core matters as the definition of UWB, how it can possibly be measured, and what type of regulatory scheme should be established.

In the *NPRM*, the Commission recognizes that there is a need both to ensure that radio services are protected against interference, and a need for further testing and analysis before the potential for interference from UWB – particularly into safety services such as GPS – is understood.[63] The Commission also noted that a number of organizations, including NTIA and the Department of Transportation, are planning testing programs, and stated its plan to allow a reasonable period of time for the submission of test results into the record of this proceeding – including an opportunity "for public comment on the test results before reaching any conclusions."[64]

If this were as far as the Commission went in its *NPRM,* the Council would have no issue. The Council fully supports the responsible idea of conducting tests and experiments in this particular situation, and supports the Commission's pledge to provide an opportunity for public comment on the test results before reaching any conclusions on rules for UWB applications.

Unfortunately, the testing/analysis schedule proposed by the Commission is so aggressive as to undermine the ability to develop a full and complete record on which to base a rational rulemaking decision on the future of UWB technology and its uses.[65] Indeed, the Commission should not have made rulemaking proposals prior to the receipt and analysis of the test results, and

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63 *See NPRM,* FCC 00-163, slip op. at 1 (¶ 1).

64 *Id.* at 4 (¶ 7).

65 In the *NPRM,* the Commission states that test results should be submitted into the record no later than October 30, 2000. *NPRM*, FCC 00-163, slip op. at 14 (¶ 31). The Commission notes that one or two testing efforts are already under way. *See id.* However, the fact is that five and one-half months is nowhere near enough time for a comprehensive test program to be developed, debugged, funded, conducted, and reported. In its own Measurement Plan, NTIA (one of the organizations specifically pointed to by the Commission) stated that it would have to cut corners, forgo analysis, and eliminate any ability to make adjustments based on results, in order to produce a limited set of raw data fully two months after the Commission's October 30 deadline. *See NTIA Measurement Plan* at 22.

it should have provided more than five months for the development and conduct of test programs that are intended in theory to enable a decision or decisions to be made on the compatibility of UWB technology with GPS and numerous other existing and vibrant radio services that drive the U.S. economy.

Because it has done neither of these things, the Commission has seriously jeopardized its ability to reach a rational decision. Moreover, it has seemingly endorsed an improper shifting of the burden of proof from the proponents of new UWB technology to the operators of the various existing radio services that would be devastated by implementation of the new technology. UWB proponents should be made to demonstrate the acceptability of their particular devices from an interference standpoint to any and all victim services; the prospective victims should not be placed in a position of having to show interference in order to avoid the overlay of UWB applications atop their frequency bands. Especially given the historic record of moving away from UWB technology, no one has answered the fundamental question that was NOT answered 75 years ago: how to allocate the frequency spectrum to a wide variety of interests and users in the most efficient, non-interfering manner. The basic science question remains unaddressed.

The Council believes that due to the accelerated and compressed testing schedule, the Commission will not be in a position to make any generalizations in rules it may adopt that would authorize the introduction of UWB technology. Instead, the Commission must be very careful to limit any actions it may take here or hereafter to those that are directly supported by the data and analyses received.

2. The Testing Programs Now Under Way Will Not Yield Comprehensive Conclusions About The Compatibility Of UWB Technology And GPS Receivers.

The Council is aware of three separate testing programs that are aiming to provide data for consideration in the instant proceeding's next phase: one test is being conducted by Stanford

University under contract to the Department of Transportation;[66] a second testing program is under development by NTIA;[67] and the third plan is being conducted on behalf of one UWB waiver holder by the University of Texas's Applied Research Laboratory.[68] The Council has actively reviewed the Stanford University and NTIA programs, and notes that other GPS interests have attempted to provide constructive guidance to the program being carried out by the University of Texas on behalf of one of the principal UWB proponents. The reality is, however, that all three test plans have shortcomings in terms of their scope and objectives, and none is designed to provide definitive conclusions as to the compatibility of UWB technology and GPS receivers. Indeed, it is safe to predict, based on comments publicly filed in response to several of the test programs, that there is likely to be significant disagreement among experts as to the reliability and utility of the data and analyses to be generated.

With respect first to the University of Texas/Time Domain plan, the GPS Joint Program Office ("GPS JPO") provided comments a mere three weeks after the test plan was first presented. The GPS JPO expressed serious concerns about the University of Texas plan, stating that:

> The equipment used, test conditions, and data types collected are inadequate for determining the safe distance between the specific emitters and the representative GPS equipment tested. Neither the conclusions of this test nor any results from the data can properly address the potential for interference from this class of devices into a band that is currently used for safety-of-life operations for the general public in numerous and rapidly expanding applications.[69]

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66 *See supra* note 5.

67 *See NTIA Measurement Plan.*

68 Test Plan for UWB/GPS Compatibility Effects for Ultrawideband Testing Consortium, Time Domain Corporation, Huntsville Alabama (May 5, 2000).

69 The Aerospace Corporation Report to the NAVSTAR GPS Joint Program Office, at 1 (May 18, 2000) ("GPS JPO Report"), *included within the* Comments of GPS JPO to the Time Domain/UT ARL UWB Test Plan (May 23, 2000) (together, "GPS JPO Comments"). A copy of the GPS JPO Comments is attached as Attachment B to these Comments.

After providing detailed comments, the GPS JPO concluded that the tests "cannot be used for making a determination regarding UWB as a whole."[70]

The NTIA Measurement Plan is also incapable of providing data that can be used for making a determination regarding UWB as a whole. The key shortcoming of the NTIA plan is not only the lack of time, but the lack of a basic science framework to direct its measurement test program to effectively characterize the potential harm. A comprehensive basis for rationale rule making must be based on a thorough test strategy derived from a core understanding of the physical science involved if it potentially affects the stability of the nation's information infrastructure. Until the basic science has been done, a measurement test program will be, by its very nature, hit or miss. Even so, the NTIA test plan has the potential to generate some data that will be useful, in particular instances, of showing interference effects into three types of GPS receivers from a single UWB radar application.. Critical tests of multiple communications emitters and networked applications, using appropriate time domain measurement equipment, are not on the NTIA near-term program, and as of the date of these Comments, NTIA had not adjusted its list of data to be generated to include a number of key degradation metrics that will be essential to any compatibility determination regarding GPS receivers.[71]

The Department of Transportation test program being conducted by Stanford University offers the best hope for the production of useful data. This program, in contrast with NTIA's program, had been under development long before the adoption of the *NPRM* in this proceeding, and had been more fully vetted within the scientific community. Even so, it is the Council's understanding that the data runs being performed are relatively limited in scope; that the primary

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[70] GPS JPO Report at 4.

[71] A detailed critique, both of the process that led to the NTIA Measurement Plan and a constructive criticism of the plan itself, are provided in the Council's August 29, 2000 Comments on the NTIA Measurement Plan. A copy of the Council's Comments is attached to these Comments as Attachment C.

focus of the tests are on GPS aviation receivers rather than on land and marine receivers; and that, once again, multiple emitter effects are not being assessed. All of these factors mean that this data too will not be able to be generalized by the Commission in this proceeding.

The assessment of interference caused by UWB systems to GPS receivers is a complicated subject. The interference implications of UWB technology are not fully understood to date; it is not clear where in the spectrum UWB systems can be placed; and the full scope of projected UWB services are not fully defined or understood. For these reasons, the Council believes that the initial data of test results will be insufficient to protect either GPSor the NII.

Because the *NPRM* specifically recognizes that the interference mechanisms of concern will not be provided for suspect classes of receivers until the initial comments are filed, there is a real concern that the ongoing tests will fail to address at least some key requirements, and thus be incomplete. Every step in the testing may lead to more questions. Additional testing will take additional time. Due to the lack of understanding at this point of what the test results may reveal, there is a high likelihood that additional testing will be required to resolve any differences or address shortfalls of the current testing. If a scientific framework is not first established, it is guaranteed that additional questions will be raised at every step of the testing process. Premature adoption of rules does not bode well for ensuring a stable NII. Further, none of the ongoing testing programs seems prepared authoritatively to address the impact of networks of multiple UWB devices on a victim receiver. This last point is important due to the overall impact on the noise floor for GPS or any other communications or information service.

The Commission should not go forward with any final rules before the basic scientific understanding has provided a framework for useful and comprehensive testing. The Commission should refrain from adopting even interim rules. The overarching requirement to ensure the protection of safety-of-life applications of GPS and other services dictates that the Commission

should wait until the interference implication of UWB applications and services are all known and understood. It is not reasonable to expect one single, extremely limited, data set to provide all the information necessary to protect the services the Commission is seeking to protect. The Commission should remain mindful of this fact, and decline the temptation it will be facing to establish rules of broad applicability until further tests and more comprehensive data are generated. The public interest, as personified by the millions of users of GPS technology and the other NII services that are the potential victims of UWB interference, demands no less.

D. The Commission Must Establish Precise And Meaningful Emission Limits And Associated Measurement Procedures That Provide Full Protection To GPS And Other Safety/Restricted Services.

1. The Commission Must Regulate The Total UWB Peak Emissions Per Nanosecond.

In the *NPRM*, the Commission notes that comments provided in response to the *UWB NOI* indicated that peak levels for UWB devices could be up to 60 dB higher than the average levels, leading to a significantly increased risk of interference to certain receivers.[72] Believing that "special consideration" is needed to develop emissions limits for UWB devices, the Commission tentatively concluded that it is necessary to regulate both the peak and average emission levels above 1 GHz and quasi-peak emissions below 1 GHz from UWB transmitters, just as it regulates these emission levels for most other types of Part 15 transmission systems.[73]

The Commission is correct to recognize that there is a need, particularly in bands above 1 GHz, to regulate both the peak and average emission levels. There is a substantial difference

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[72] *See NPRM*, FCC 00-163, slip op. at 16 (¶ 35). The Commission noted that if the PRF of the UWB signal is much greater than the bandwidth of a receiver, the emission may appear to be random noise, the effect of which is proportional to the average power in the UW signal within the receiver's bandwidth. It went on to note, however, that if the PRF is less than the receiver's bandwidth, the UWB signal within the receiver's bandwidth may appear to the receiver as impulsive noise, the effect of which would be proportional to the peak power of the UWB signal. The Commission also noted that UWB devices spread their emissions over a wide bandwidth as compared to most current Part 15 devices. As a result, receivers that use wide bandwidths are likely to receive more total energy from UWB devices than from most other Part 15 devices. *Id.*

[73] *See NPRM*, FCC 00-163, slip op. at 16 (¶¶ 35- 36).

between the two where UWB is concerned. This difference can be effectively highlighted by reference to an analogy drawn from the field of ultrashort pulse spectroscopy. The field of ultrashort pulse spectroscopy first developed in the 1960s, and has since achieved a measure of maturity within the scientific community. It is dependent on the production of very short light pulses. Although ultrashort light pulses are much shorter than ultrashort radiofrequency radiation (i.e., UWB) pulses, the same relationship between peak and average power applies, along with the same relationship between the resultant interference effects.

A recent article on ultrashort-pulse lasers reports that:

> Although the average power from the laser may be quite moderate and the total energy within a pulse small, the extremely short duration of each pulse guarantees that the peak instantaneous power is large. In a typical system the interval between pulses is 100,000 times longer than the pulses themselves, and so the peak power is about 100,000 times the average power. For example, a 100-femtosecond pulse with a moderate energy of three microjoules (not enough energy to heat a drop of water by a millionth of a degree Celsius) delivers a peak power of 30 megawatts. When focused on a tiny spot, such high powers ablate many materials . . . .[74]

The same logic and arithmetic applies to UWB pulses. If the Commission were to require that the average power of a particular emitter be limited to 1 milliwatt, and the emitter of concern transmits conventional, continuous-wave signals, the peak power is also 1 milliwatt. However, if the emitter of concern transmits UWB ultrashort signals of 1 nanosecond in duration, then the peak power is 1 megawatt, while the average power remains 1 milliwatt - and for the same amount of energy transferred as in the continuous signal case. The real interference problem comes when multiple megawatt pulses are stacked up next to each other, whether coming out of two or more radars or coming out of a network. This will jam everything in this local area, not just GPS. So, in addition to monitoring and regulating peak power, the Commission needs to be in a position to monitor and regulate peak power per nanosecond across the entire span of time transmissions occur.

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[74] *See* Hopkins, J-M. & Sibbett, W., *Ultrashort-Pulse Lasers: Big Payoffs in a Flash*, Scientific American, vol. 283 (No. 3) pp. 72-79 (September 2000).

As a final matter, the Commission inquires whether it should require scrambler technology for UWB communications systems.[75] UWB scrambling weakens, but does not eliminate UWB interference to GPS. Scrambling introduces pseudo-random modulation of the UWB pulse positions or on-off-keying of the pulses. Scrambling does not remove UWB interference entirely, it simply causes the trains of UWB signals to be more noise like. In addition, the length of the scrambling sequence must be chosen carefully. Short sequences simply do not provide the same protection as long sequences.[76] Moreover, scrambling does not affect the interference arising from the individual UWB pulse at all.

2. It Is Premature For The Commission To Developing Specific Emission Limits And Means To Monitor Or Allocate Those Limits As A Function Of Time.

In the *NPRM*, the Commission opines that the general, spectral-power-density based emission limits contained in Section 15.209 of its Rules "appear appropriate for UWB operations."[77] For UWB operations below 2 GHz (2.9 GHz under the Council's proposal), the Commission proposes that emissions be attenuated by at least 12 dB below the general emission limits, in order to provide additional protection to spectrum in this region without affecting the viability of UWB operations.[78]

As an initial matter, the Council strongly agrees with the Commission's forceful rejection of the notion, advanced by certain commenters responding to the 1998 *UWB NOI,* that emissions from UWB systems be characterized as having the same potential for causing harmful interference as

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75 *See NPRM*, FCC 00-163, slip op. at 18 (¶ 37).

76 All UWB transmitters produce a line spectrum at the average frequency of the individual pulse. When employing high levels of random pulse positioning in a train of such individual signals, the spectrum can appear to be more like Gaussian noise - but only at a sampling rate less than that of the average frequency of the individual pulse. The emission only appears as noise depending on the selective settings of the measurement instrumentation. The spectral line at the average frequency of the individual pulse is not diminished by random pulse positioning.

77 *See* id.

78 *Id.*

emissions from unintentional radiators. The Commission correctly notes that emissions from UWB transmission systems are considerably different from those of unintentional radiators, and points to such attributes as the high peak-to-average ratio of emissions, the extremely narrow pulsewidths, and the PRFs of UWB devices. Significantly, the Commission also correctly points out "the difficulty in controlling the location of UWB devices," and that their likely outdoor use could result in increased amounts of harmful interference to other radio operations.[79]

With regard to the specific limits proposed, the Council has the same difficulty with the use of the "500 mV/m at 3 meters, less 12 dB" metric for in-band emission limits as it expressed above in connection with the discussion of the same metric as a limit on unwanted emissions. That metric, which has been developed and applied successfully for assessing unwanted emissions in a continuous wave environment, is not directly applicable in the discontinuous, transient-pulsed environment of UWB transmission signals. Rather, it is necessary for the Commission to specify a limit on the peak instantaneous power on a nanosecond by nanosecond basis – something the Commission is not presently capable of providing.[80]

3. The Commission Must Require The Use Of A 20-50 GHz Sample-and-Hold Oscilloscope To Measure Peak Emissions From UWB Signals.

It was recognized above that it is necessary to assess the peak emissions from UWB transmission signals in bands above 1 GHz. This recognition is only a small part of the issue. The real challenge here is one of measurement and compliance. A state-of-the-art spectrum analyzer will provide an accurate reading of the peak and average power in the case of the continuous wave

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[79] *Id.* at 18-19 (¶ 40). The Council endorses the Commission's rejection of calls for measurements of UWB interference to be taken outside the building in which the UWB equipment is operated. *See id.* at 19 (¶ 40). The fact that UWB operators deigned to make such a request is very telling as to the high levels of expected interference, and the Commission's rejection properly emphasizes the mobile nature of many UWB applications.

[80] *See supra* at Section III.A.2.c. Of course, given the Council's call for an absolute preclusion of UWB devices other than properly-conditioned GPRs and WIDs in bands below 2.9 GHz, the reach of a limitation on in-band emissions from UWB devices into the GPS bands would be relatively limited. This may enable the Commission to adopt provisional rules on emission limits for GPRs and WIDs, pending an evaluation of the most appropriate manner in which to specify the peak instantaneous power on a nanosecond by nanosecond basis.

signal, but cannot do so in the case of the ultrashort pulse UWB signal.[81] It is clear, however, that the only type of test equipment capable of providing an accurate peak power measurement in the case of the UWB signal is a 20-50 GHz sample-and-hold oscilloscope, which has a much higher sampling speed. It can achieve this Nyquist sampling rate required, whereas conventional spectrum analyzers cannot. Even the 20-50 GHz sample-and-hold oscilloscope is limited in its capability to characterize UWB signals. Such oscilloscopes sample high frequency signals utilizing a low A-D sampling rate and utilizing "random interleaved sampling" of a periodically repeated signal. That is, by periodically repeating a signal such oscilloscopes permit high effective sampling rates with a lower actual sampling rate.

Accurate digitization depends on being able to sample a different part of each repeating waveform and the using the samples to reconstruct a shorter interval of the signal. However, this form of measurement presupposes repeated partial measurement of exactly the same signal. Therefore, this measurement technique cannot be used to measure the peak power obtained from an aggregate of asynchronously arriving individual pulses at a variety of interpulse intervals, because such asynchronous aggregate additions are due to large permutations of additions and cannot be

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[81] The use of spectrum analyzers for estimating the peak power of UWB individual pulses should be discouraged. Power spectrum estimation and spectrum analyzers emphasize the frequency content of a signal, but suppress the phase relations between signal components. In other words, two different signals may have the same power spectrum but different waveforms, and hence different instantaneous peak powers. Moreover, state-of-the-art spectrum analyzers sample at rates well below the Nyquist-sampling rate necessary to capture the peak power of UWB signals. Therefore state-of-the-art spectrum analyzers not only provide an ambiguous measure of UWB pulses, but a distorted measure of the peak power of those pulses.

repeatedly presented to the oscilloscope for partial sampling.[82] At the present time, however, such equipment has not progressed beyond the planning or design stage.[83]

Thus, it is not enough for the Commission merely to identify the need to regulate peak and average power in bands above 1 GHz. Once it establishes the appropriate emission levels, it must ensure that the proper equipment is used to determine compliance with the levels established – i.e., it must require that compliance be determined through the use of a 20-50 GHz sample-and-hold oscilloscope to measure peak power.[84] In this respect, the Commission's proposals to measure the peak emission level of UWB signals directly in the time domain, through the use of sampling oscilloscopes, is the correct one.[85]

Beyond the problem of measuring peak power for a single UWB device is the problem encountered with multiple UWB devices, whether or not located in a network, when all the adjacent

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[82] See Jungerman, R.L. & McQuale, D.J., Development of an optical modulator for a high speed lightwave analyzer. *Hewlett-Packard J.*, vol. 42, No 1, 1991; Kano, F., Fukuda, M., Sata, K. & Oe, K., High-speed intensity modulation of 1.5 μm DBR lasers with wavelength tuning, *IEEE J. Quantum Optics*, vol 26, No 8, 1340-1345, 1990; Rivoir, J. & Pless, W., Data processing in the correlating optical time-domain reflectometer. *Hewlett-Packard J.*, vol 39, No 6, 29-34, 1989; Wong, R.W., Hernday, P.R. & Hawkins, D.R., High-speed lightwave component analysis to 2 GHz. *Hewlett-Packard J.*, vol 42, no 1, 6-13, 1991, etc.

[83] The deficiencies of the sample-and-hold oscilloscope in measuring peak powers arising from aggregated networks of disparate UWB emitters, motivate examination of other methods which do not rely on repetition of the measured signal, and would supply a genuine time-domain measure of the aggregated interference. Such measurement equipment is being considered in the academic and commercial communities, and relies on fiber optic, semiconductor laser amplifiers, fiber optic modulators and photodiodes.

[84] In its discussion on peak and average emission levels (*See NPRM*, FCC 00-163, slip op. at 16 (¶ 36)), the Commission notes that the impact of evenly-spaced UWB signals typical of a radar application (i.e., a signal with narrow spectral lines spaced at the PRF) can be modeled by treating each spectral line as a narrowband conventional signal, and speculates that it may be possible for UWB designers to select system parameters that increase protection to GPS by avoiding GPS signal bands and thereby not causing co-channel interference. *See id.* The Commission specifically inquires whether spacing UWB spectral lines in places within the GPS band where receivers are less sensitive to interference is applicable to GPRs and WIDs, and asks about the cost implications of using a stable frequency reference to ensure that the PRF creates a signal avoiding the GPS bands. As an initial matter, the Council does not believe that any basis whatsoever has been established at this point for any in-band use of GPS bands by UWB devices, and therefore must defer the GPR/WID portion of the inquiry until after test results are available. *See* Section III.C, *supra.* The Council is believes that the expense of a stable frequency oscillator may be inconsistent with the nature of the planned consumer applications of UWB, and the Council is concerned that this approach may not provide the robust protection that safety services require.

[85] *See NPRM,* FCC 00-163, slip op. at 24 (¶ 52). It is essential, of course, that the oscilloscope be capable of sampling at the appropriate speed; a 20-50 GHz oscilloscope is sufficient in this regard, and should be required.