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Magalie Roman Salas, Commission's Secretary
Office of the Secretary
Federal Communications Commission
445 12th Street, S.W.
TW-A325
Washington D.C. 20554

Regards: ET Docket 98-153: "Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems"

To: The Commission

The GPS Research Laboratory at Stanford University is currently funded by the Department of Transportation to conduct tests to help understand the potential of interference from Ultra-Wideband (UWB) transmissions to the Global Positioning System (GPS). These tests have already provided useful data, and preliminary results have been presented to the RTCA. A copy of that presentation is attached to this letter.

Through our sponsor, we intend to provide updated results by October 30, and will be happy to support the subsequent comment period called for by the Commission. During that period, we also look forward to examining the interference test results provided by the University of Texas (UT) and the National Telecommunications and Information Administration (NTIA). Our results will certainly benefit from comparison to the results from our colleagues, and such cross-validation is absolutely necessary when safety is at stake.

However, our experience with the development of safety-critical systems teaches that a *single* test phase will *not* provide an adequate basis for any major decisions, and we urge the Commission to plan on additional test phases before any rule making. *Testing is iterative*. Preliminary results provide increased understanding, but also generate sharper questions that motivate a second phase of more focused testing. Such iteration is especially likely when safety dictates multiple test programs, because additional tests may be required to simply complete a satisfactory cross-validation. Additional tests may also be motivated by the maturation of the UWB to GPS interference scenarios. Our tests are designed to support the analysis of a breadth of scenarios, but it is difficult to anticipate every aspect of the myriad of possible UWB to GPS interference situations. For example, our tests only include one UWB transmitter and we understand that UWB local area networks are anticipated. Such networks could place several UWB transmitters close to a GPS receiver.

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Most importantly, additional testing will be required because *UWB to GPS interference is complicated and very variable*. UWB to GPS interference certainly depends on the UWB power in the GPS band, but it also depends on the UWB pulse repetition frequency (prf). For example, UWB signals at prfs below 100,000 pulses per second (pps) may have 1000 times less interference effect than UWB signals with prfs at 1Mpps or above. UWB to GPS interference also depends on whether or not scrambling is used to spread the power in the UWB spectral lines, and it depends on the length of the scrambling codes. When lines exist, interference depends on the frequencies of those spectral lines. UWB interference also depends on whether or not the UWB signal is time gated to create bursts of pulses. In this case, the interference depends on the duty cycle of the burst and the on-time of the burst.

All of this variability gives additional credence to the Commission's already compelling argument that UWB signals cannot be equated to emissions from unintentional radiators. Different UWB signals have very different interference potential, and no simple qualitative equivalence will serve this ambitious process well. It also supports the Commission's interest in scrambling for UWB and concern over the location of the UWB spectral lines.

However, this variability also complicates the evaluation of UWB to GPS interference. It compounds the already appreciable task of cross-validating results from three test organizations, and the task of accommodating interference scenarios that continue to mature. Finally, it hints at the strides in understanding that are really required to launch this new technology. We urge the Commission to proceed with great caution and deliberation.

Sincerely,

Per Enge
Associate Professor

Donald Cox
Professor

Bradford Parkinson
Professor

J. David Powell
Professor (Emeritus)

UWB Interference Test Preliminary Results

Ming Luo, Dennis Akos, Sam Pullen, Per Enge

Stanford University

funded by Department of Transportation (DoT)

August 4, 2000

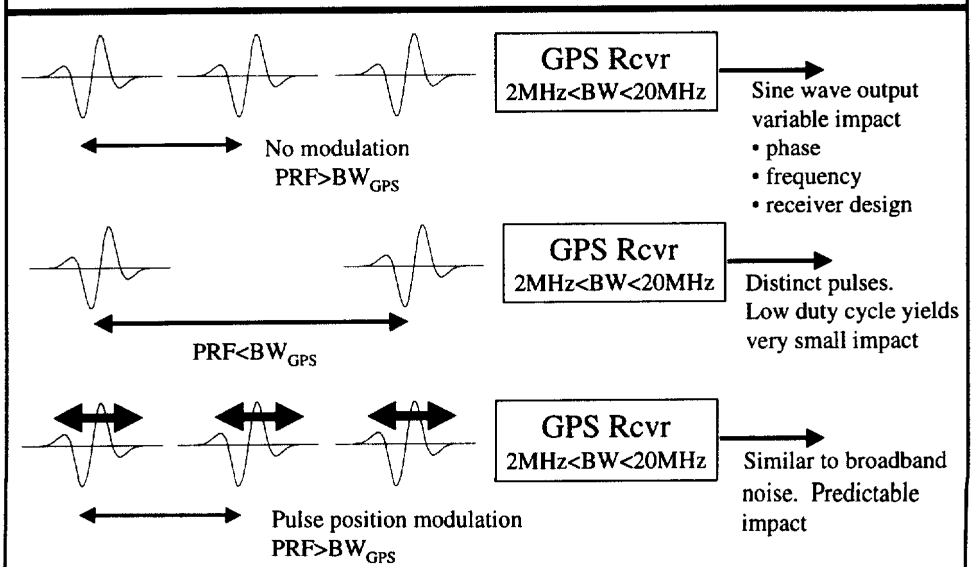
Contents

- Test philosophy & setup
- Measurement duration
- Receiver test and normalization
- UWB test data
  - different PRF (100Kpps-20Mpps)
  - different burst duty cycle (10%-100%)
  - different burst on-time (10us-10ms)
  - no modulation and random PPM
- Summary

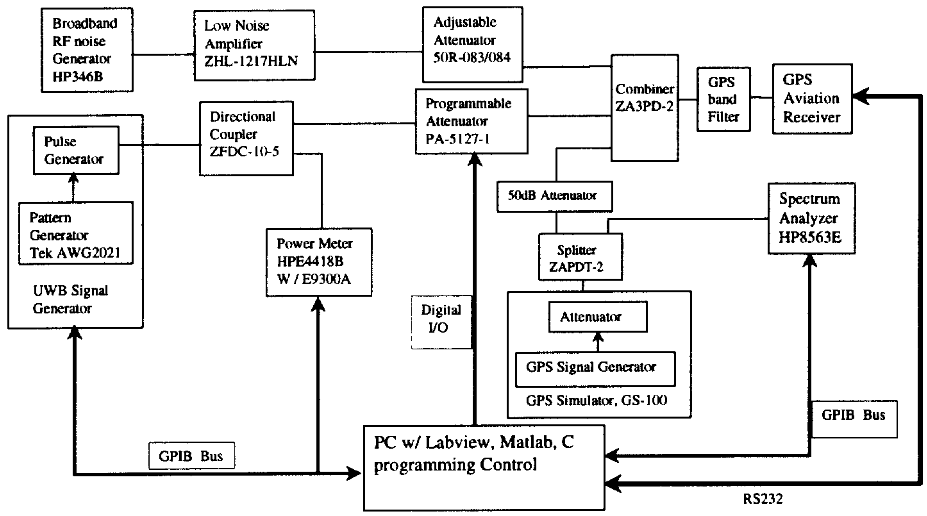
Overview of Test Philosophy

- Quantify UWB to random noise equivalence to support the analysis of any operational scenario with or without other interference sources.
- Quantify sensitivity to UWB signal parameters. Attempt to span the space of anticipated parameters.
- One channel simulator for controlled & repeatable tests
- Interference criteria:
  - accuracy for aviation (LAAS reqm't of 15 cm.)
  - reacquisition time for land (E-911 reqm't of 1 s)
- Aviation rcvrs of DO229/253 interference quality.
- Normalize receivers under test to DO229/253 interference masks.

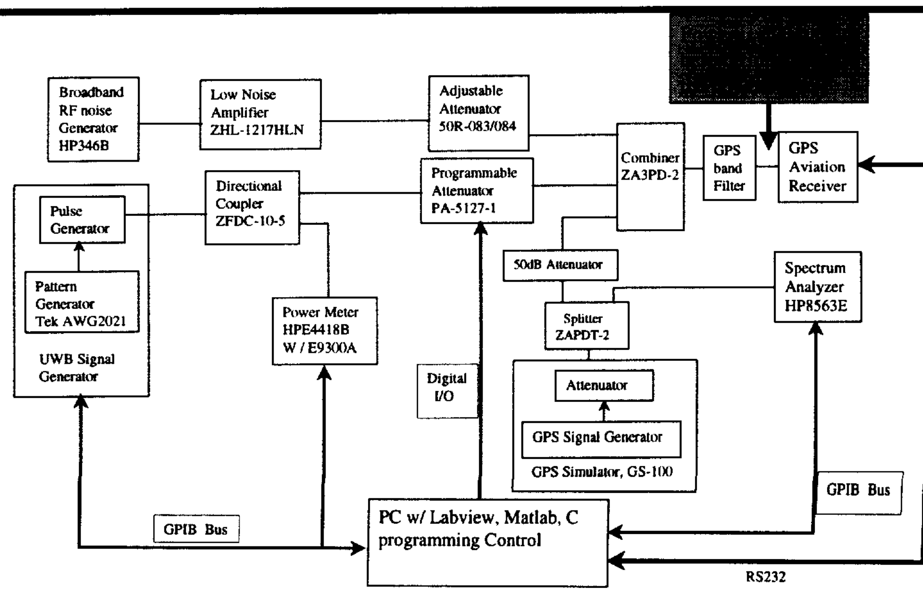
Sensitivity to UWB Signal Parameters



UWB Test Setup

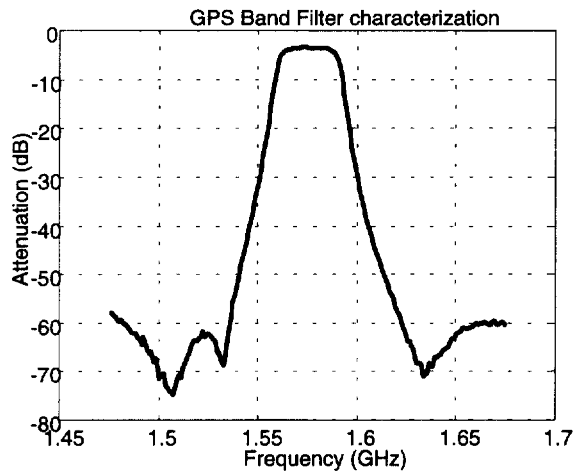


Power Measurement



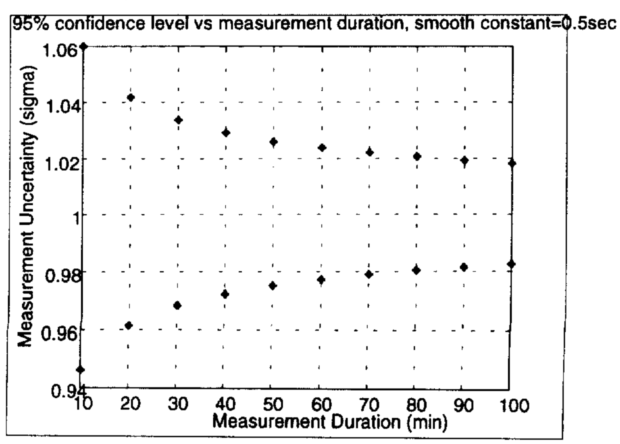
GPS Band Filter

Both broadband noise power and the UWB power were measured through the GPS L1 band filter. The filter characteristic was shown as below.

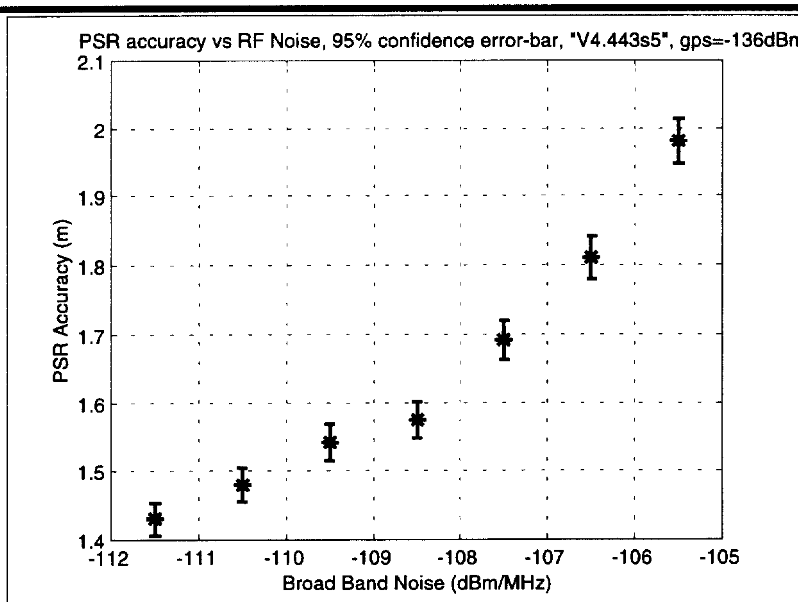


Test Duration Consideration

There is a tradeoff between measurement certainty and test duration. We decided to take 1 hour of data (~ 3600 independent samples when smooth time constant is 0.5 second) for each accuracy measurement setup. The uncertainty is about +/- 2.4% for 95% confidence level.



Is 1dB of RF Separation Distinguishable?



Choose Operational Point

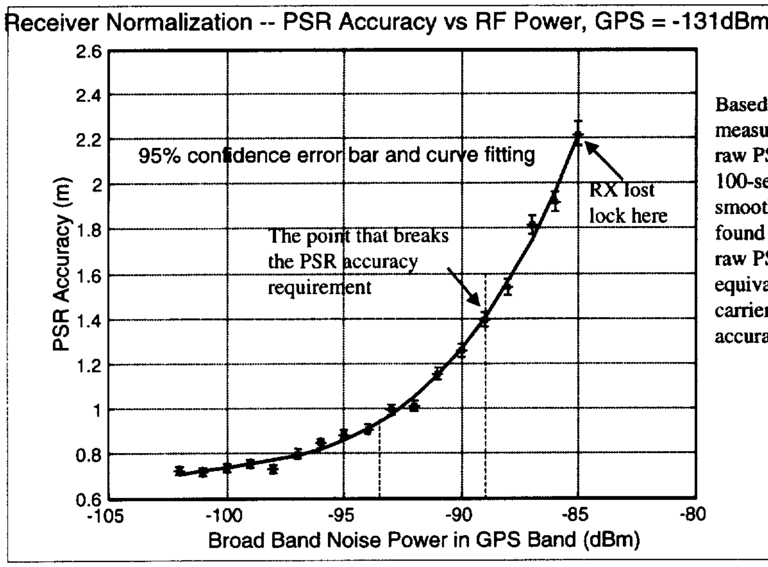
- Consider:
  - Linear region
  - Test duration
  - 1 dB of RF distinguishable
  - Accuracy requirement

=> Set GPS power = -131dBm

=> Set broadband RF region: -93.5 to -89dBm (in GPS L1 band)

=> Use unsmoothed (raw) pseudorange accuracy measurements (see next slide)

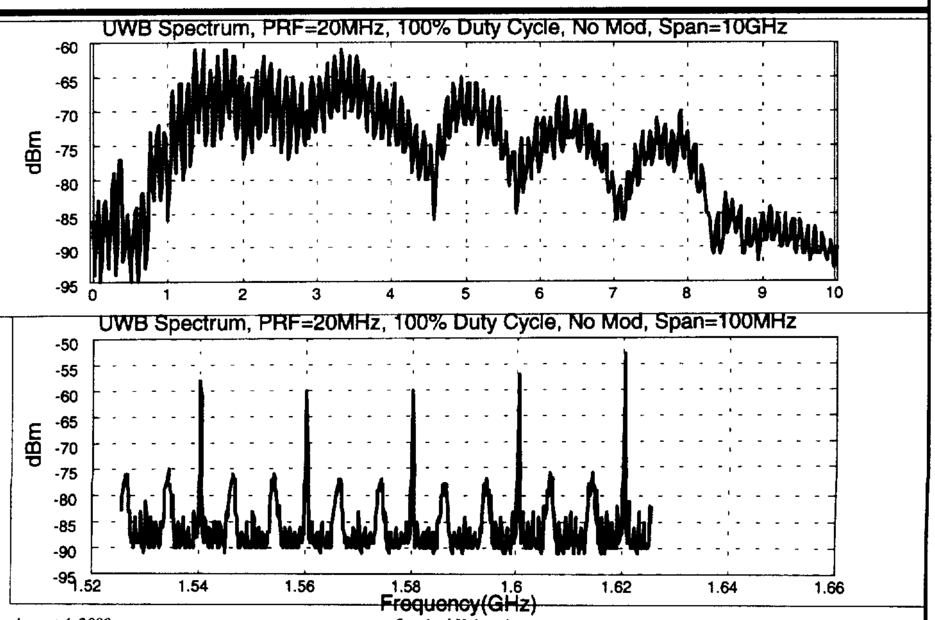
GPS Receiver Normalization



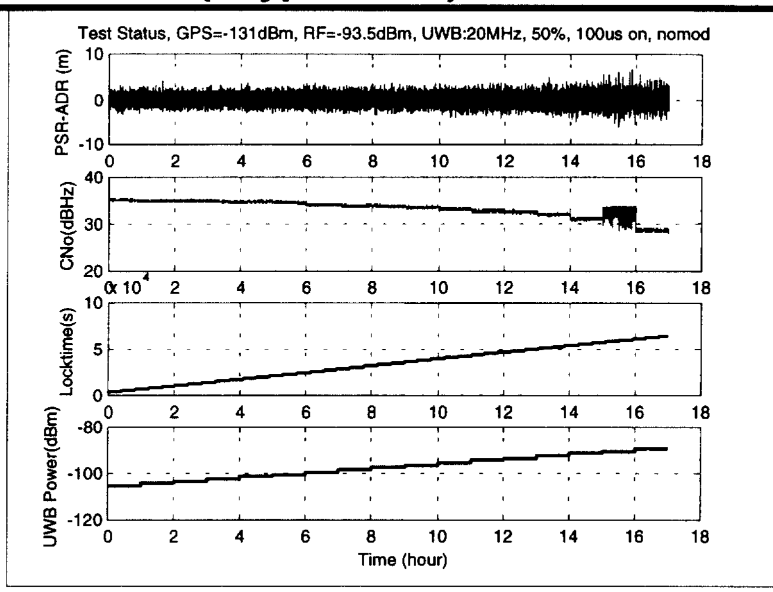
Note:

Based on variance measurements from raw PSR and from 100-sec carrier smoothed PSR, we found that 1.4 m of raw PSR accuracy is equivalent to 15 cm of carrier-smoothed PSR accuracy.

UWB Spectrum, PRF=20MHz, No Mod

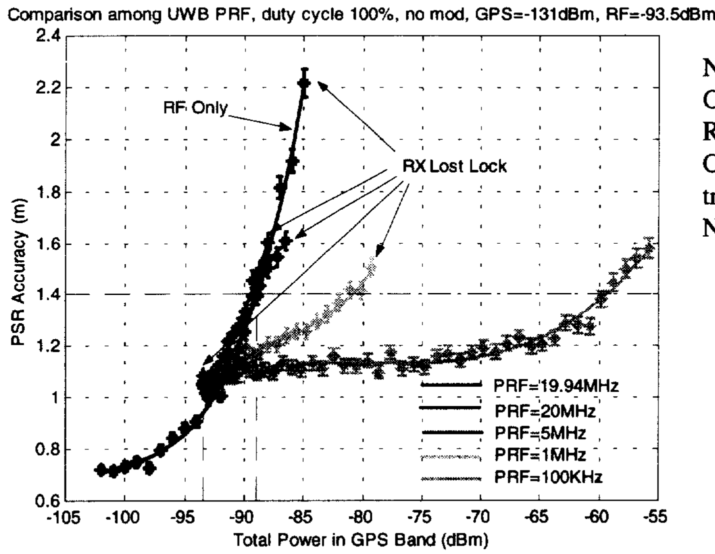


Test Status During UWB Power Sweeping (a typical run)



Comparison of PRF

Comparison among PRFs, 100%duty cycle, no modulation



Notes:
Only 1 GPS Receiver
Only 1 UWB transmitter
No aggregation

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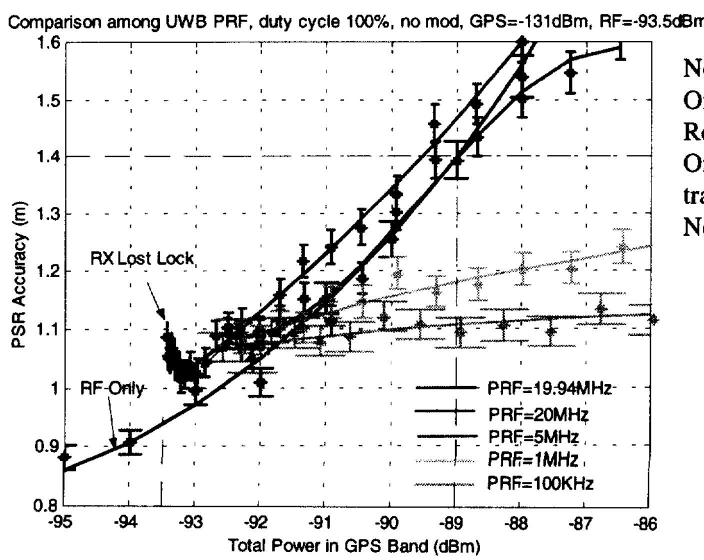
Comparison among PRFs, 100%duty cycle, no modulation (zoomed)



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No aggregation

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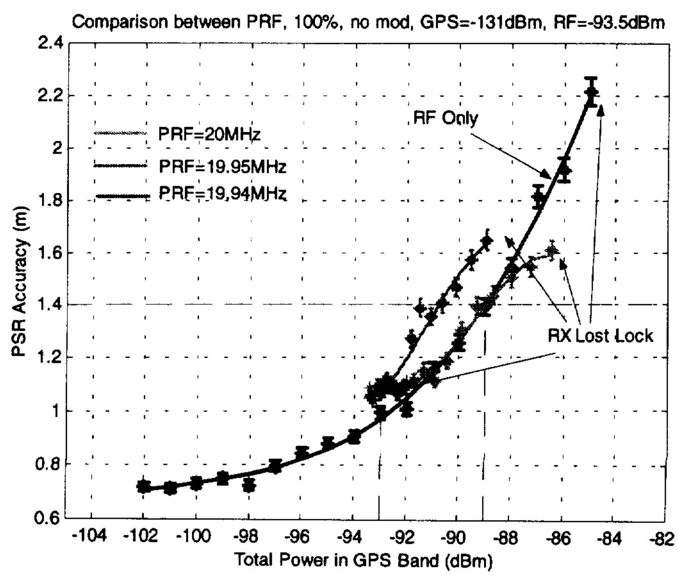
Spectral Line Sensitivity

Comparison among PRF=20MHz, 19.95MHz, 19.94MHz, 100%, no mod



Notes:
Only 1 GPS Receiver
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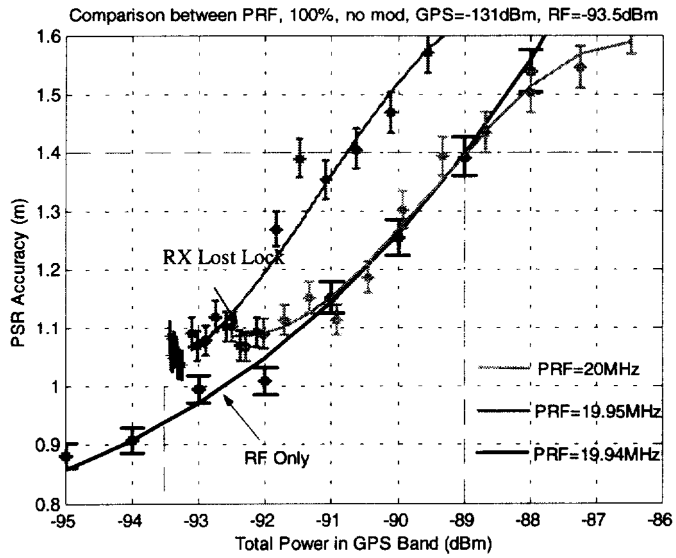
No aggregation

Comparison among PRF=20MHz, 19.95MHz, 19.94MHz, 100%, no mod (zoomed)



Notes:
Only 1 GPS Receiver
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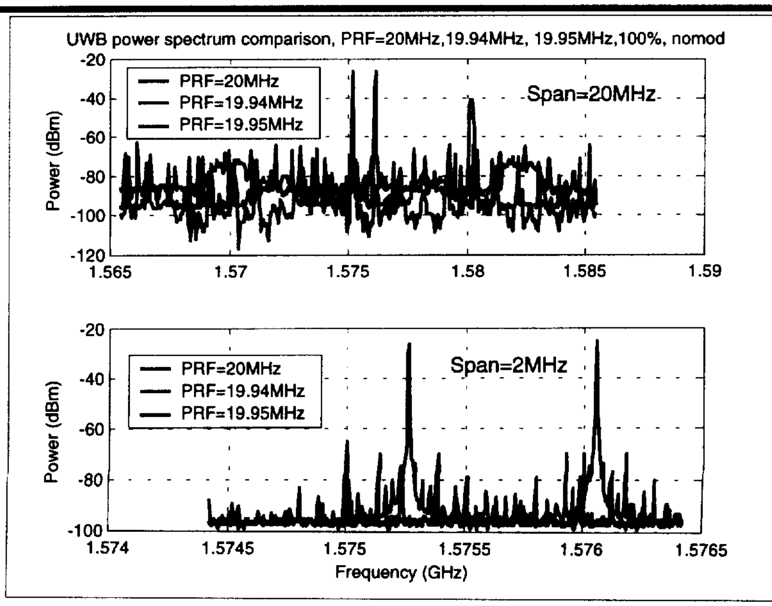
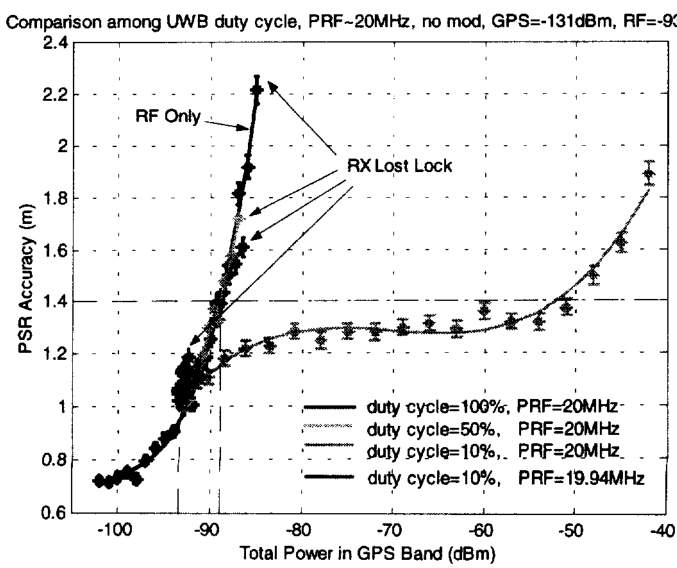
No aggregation

UWB spectrum comparison between PRF=20MHz ,19.94MHz, 19.95MHz



Comparison of Duty Cycle

Comparison among UWB burst duty cycle, PRF~20MHz, no modulation



Notes:
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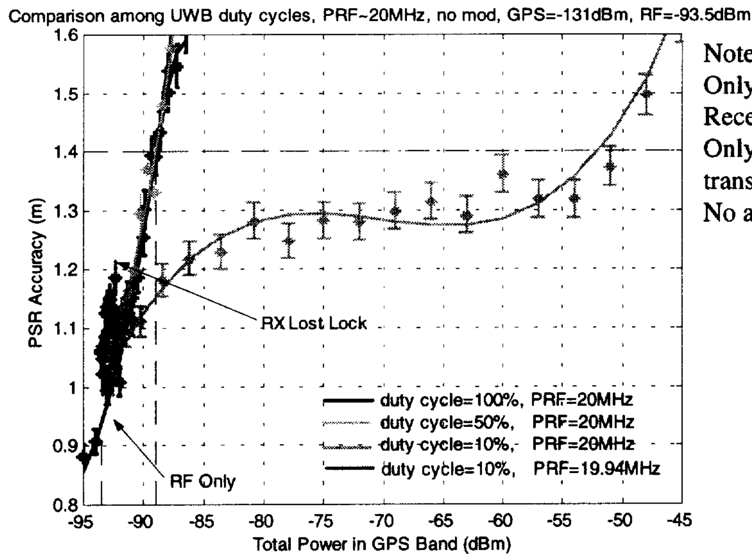
No aggregation

Comparison among UWB burst duty cycle, PRF~20MHz, no modulation (zoomed)



Notes:
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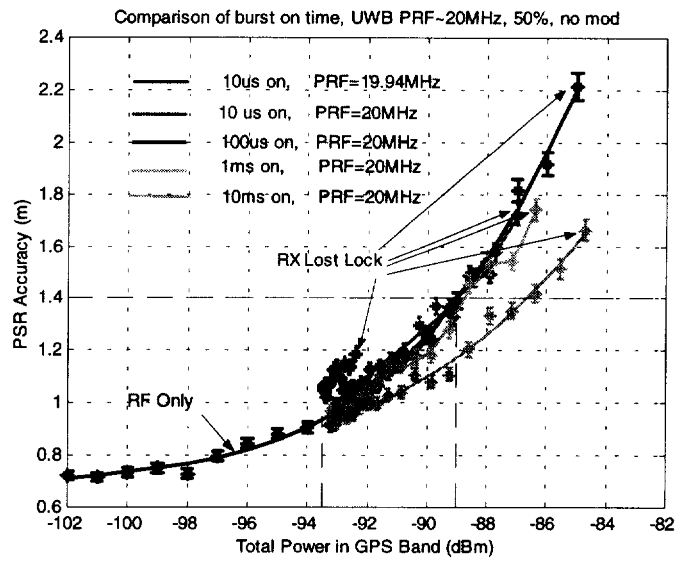
Only 1 UWB transmitter
No aggregation

Burst on-Time Comparison

Comparison among Burst On-Time, PRF=20MHz, 50%, no mod



Notes:
Only 1 GPS Receiver
Only 1 UWB transmitter
No aggregation

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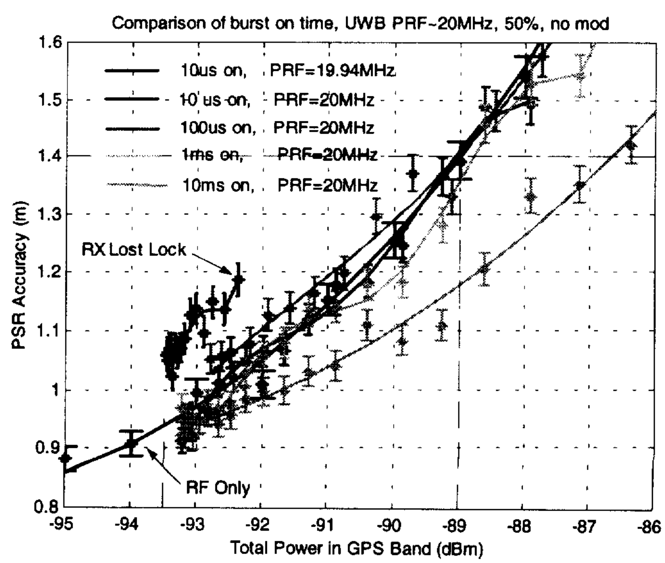
Comparison among Burst On-Time, PRF=20MHz, 50%, no mod (zoomed)



Notes:
Only 1 GPS Receiver
Only 1 UWB transmitter
No aggregation

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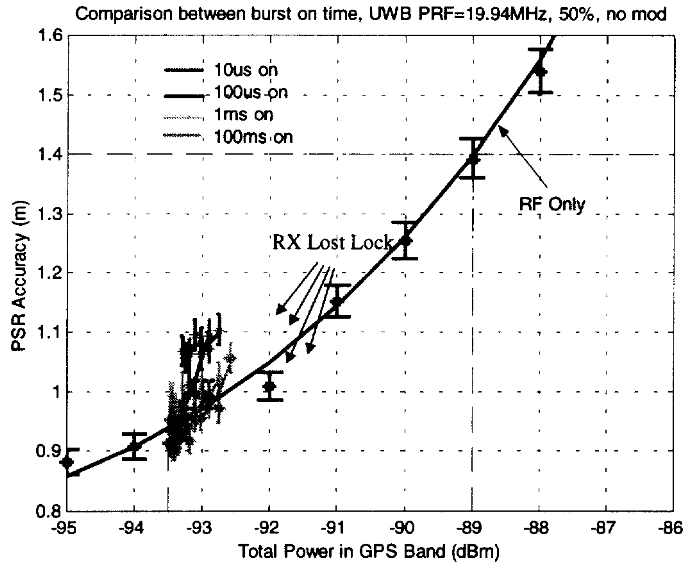
Comparison among Burst On-Time, PRF=19.94MHz, 50%, no mod



Notes:
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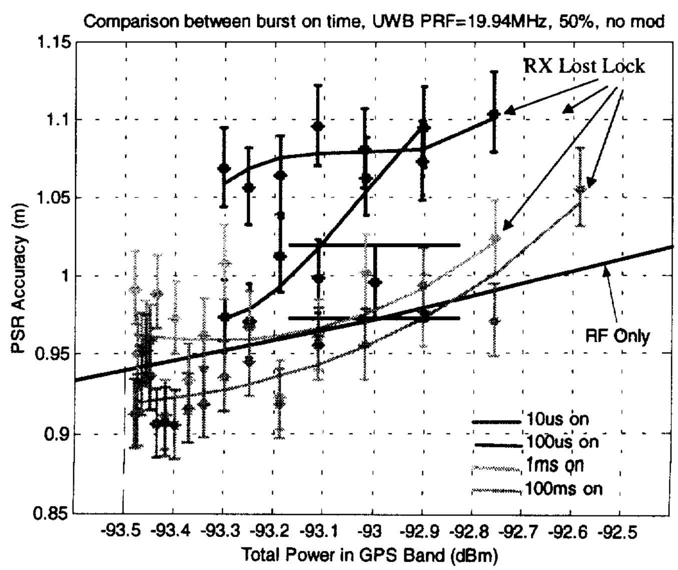
Only 1 UWB transmitter
No aggregation

Comparison among burst on-time, PRF=19.94MHz, 50%, no mod (zoomed)



Notes:
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Only 1 UWB transmitter
No aggregation

Random PPM Cases

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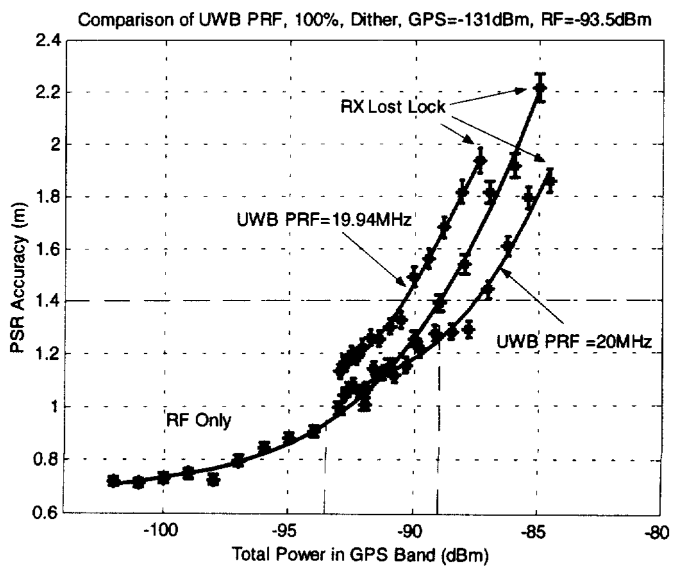
Comparison of UWB PRF, 100%, Dither



Notes:
Only 1 GPS Receiver
Only 1 UWB transmitter
No aggregation

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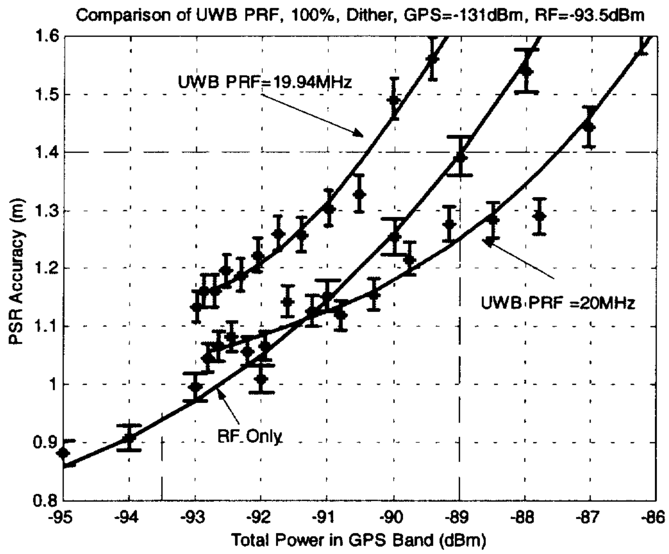
Comparison of UWB PRF, 100%, Dither (Zoomed)



Notes:
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Only 1 UWB transmitter
No aggregation

Summary

- **<u>For this first receiver</u>, we have demonstrated the expected dependence on UWB parameters:**
  - **location of spectral lines relative to GPS**
    - **important for all PRFs, duty cycles, on-times & modulation**
  - **PRF (lower is better)**
  - **duty cycle (lower is better)**
  - **burst on-time (longer is better)**
  - **modulation (modulation is worst)**
- **Near term plans:**
  - **finish aviation test matrix (40-50% done)**
  - **begin land receiver test**
  - ***understand connection between results and potential rules***