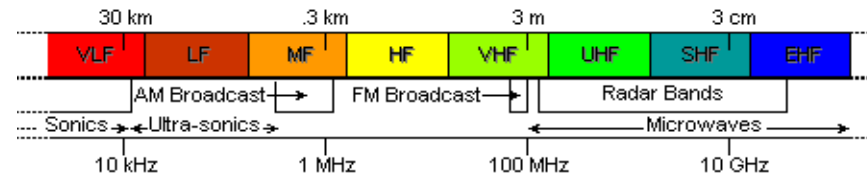


Assessment of Ultrawideband and Global Positioning System Compatibility

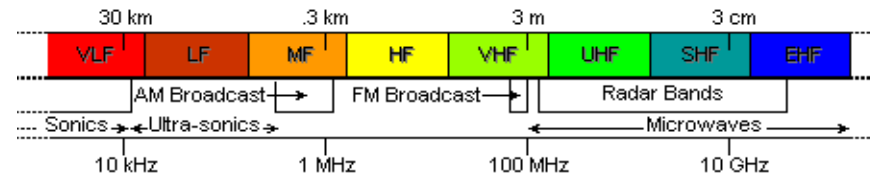
Randy Hoffman and Mike Cotton

ISART March, 2002



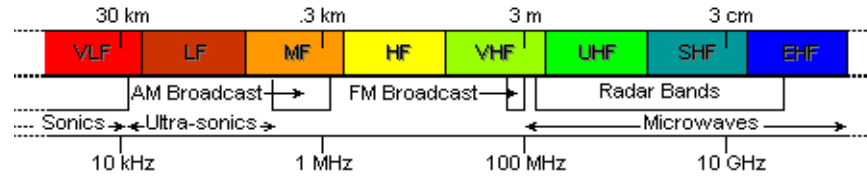
Contents

- Objectives, Test Setup, and Measurement Methodologies
- Ultrawideband (UWB) Parameters and Characteristics
- Interference Results

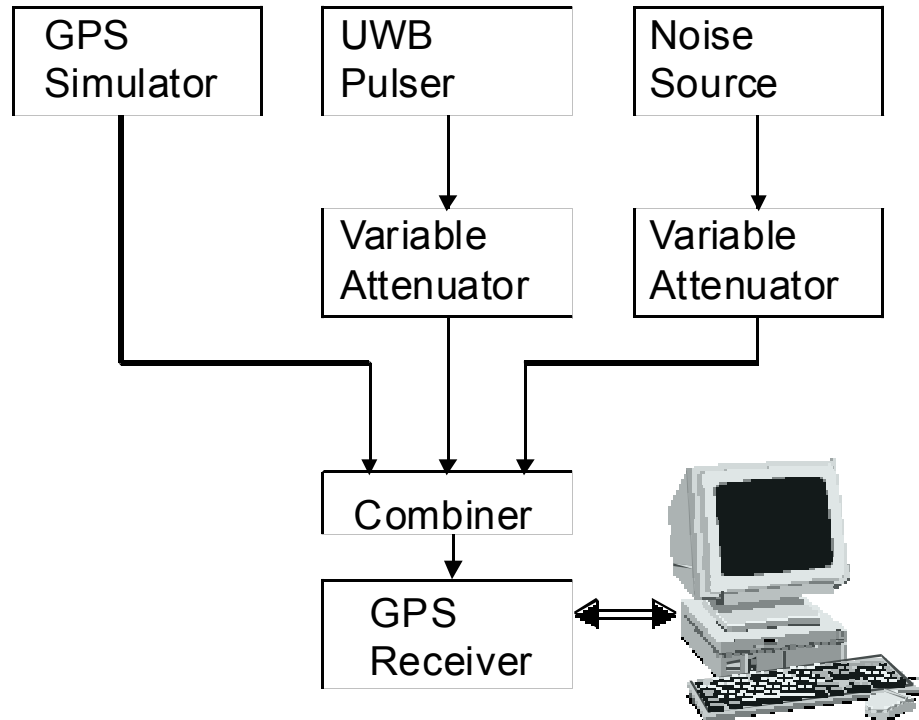


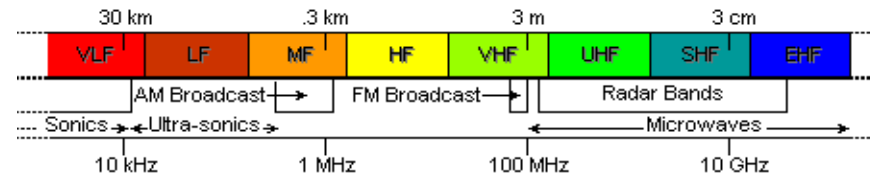
Project Objectives

- **Primary Objective:** assess the interference potential of UWB signals to GPS receivers.
- **Secondary Objective:** Identify GPS receiver performance metrics and establish repeatable measurement methods.



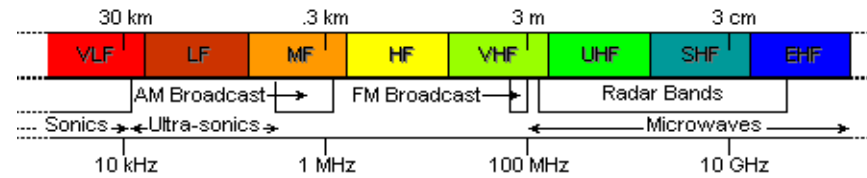
Test Setup - Conducted





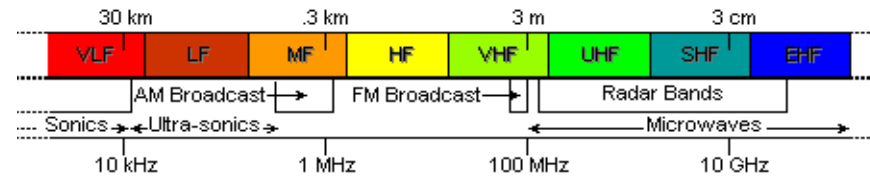
General Conducted Measurement Methodologies

- Metrics
 - Loss of lock
 - Satellite reacquisition time
- Associated performance criteria
 - Maximum UWB signal power below loss-of-lock for which the receiver can regain satellite lock
- Monitor: pseudorange, cycle slip, position, C/N, phase lock, DOP, delta-pseudorange, accumulated Doppler cycles, Doppler



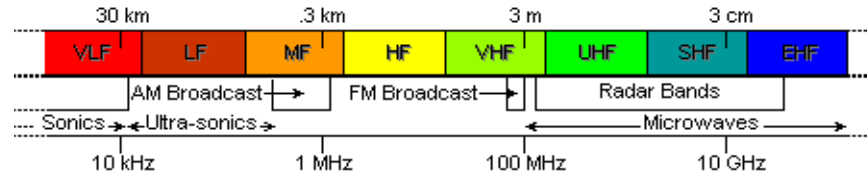
GPS Receivers

Receiver	Code Tracking	Carrier Tracking	<u>Cross Correlator</u>	<u>Narrow-spaced Correlator</u>
1 Agricultural	Yes	Yes	No	No
2 Precision Survey	Yes	Yes	Yes	Yes
3 Precision Approach	Yes	Yes	No	Yes
4 <u>TSO-C129a</u> aviation receiver	Yes	Yes	No	No

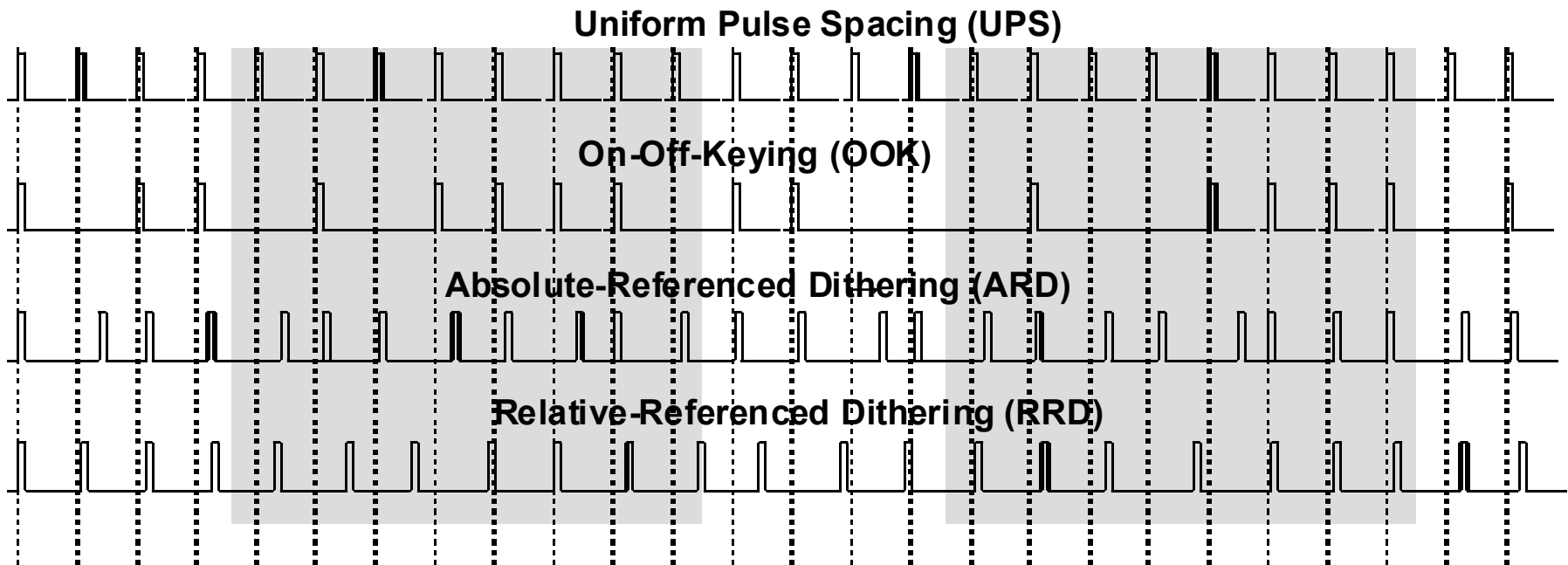


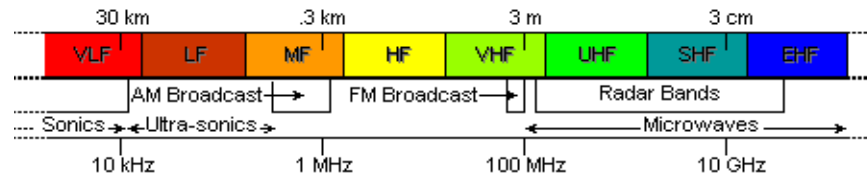
UWB Parameters

- Power levels – peak vs. average
- Pulse shape/width
- Pulse repetition frequency
- Pulse spacing
- Gating

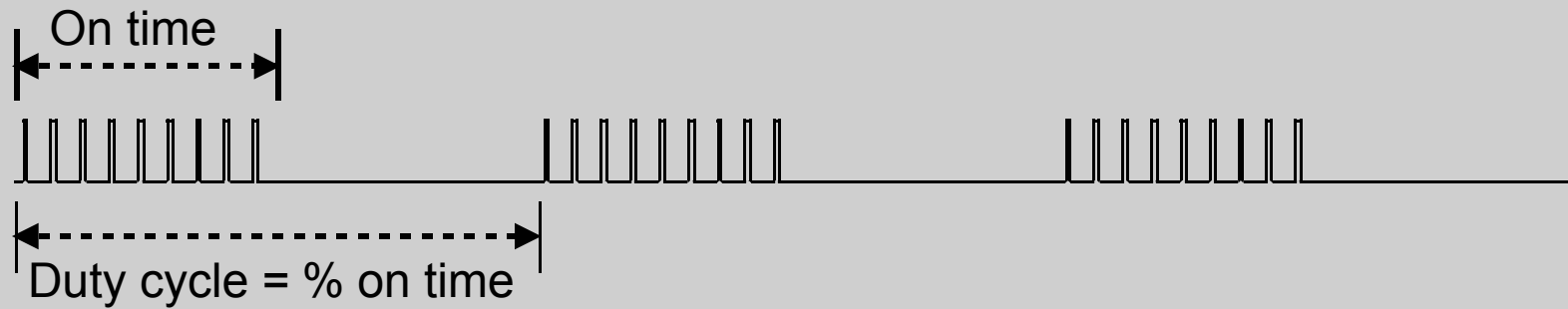


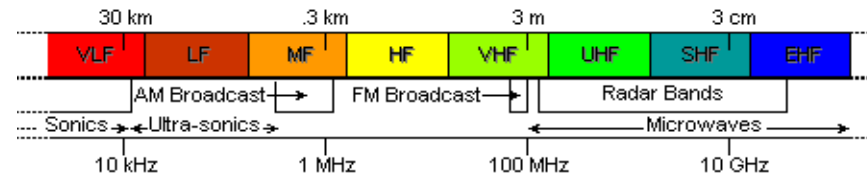
UWB Pulse Spacing





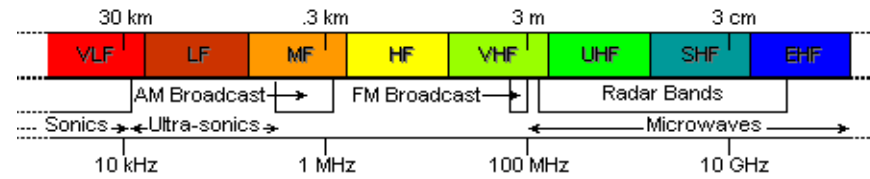
Gating



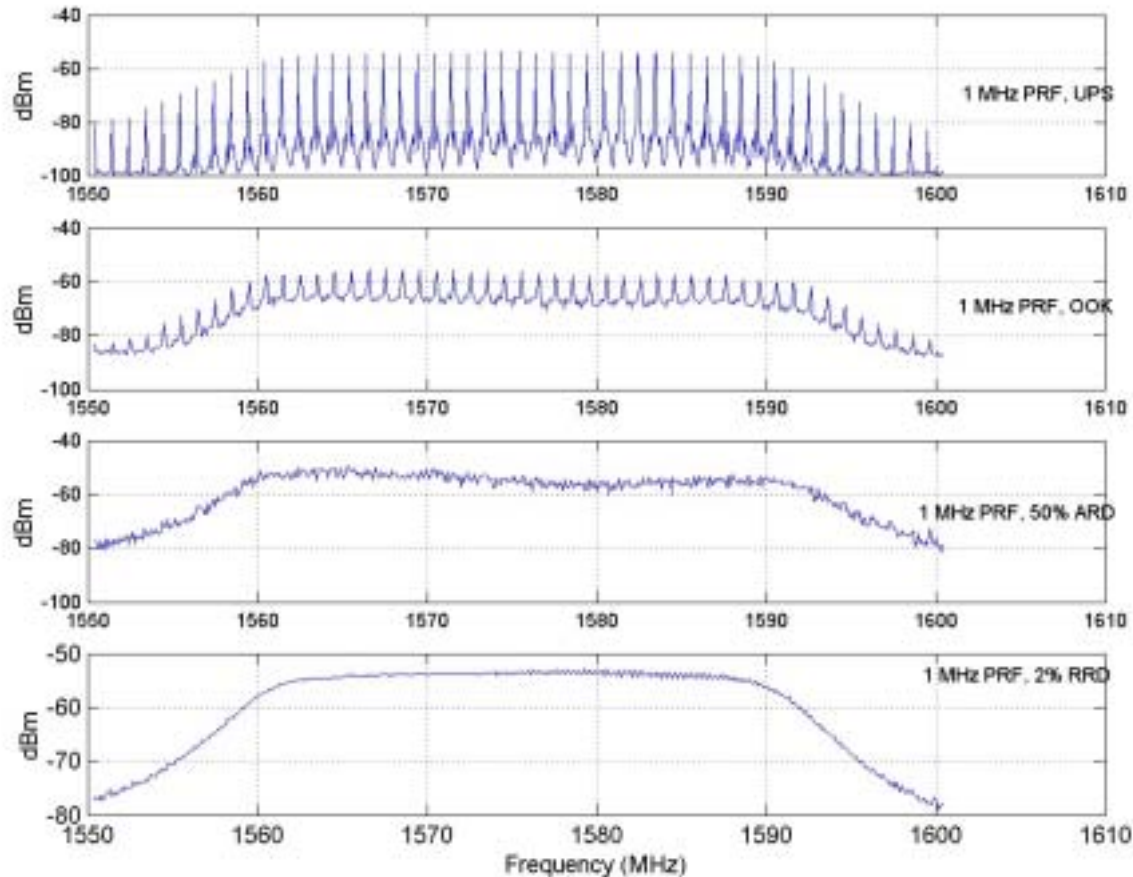


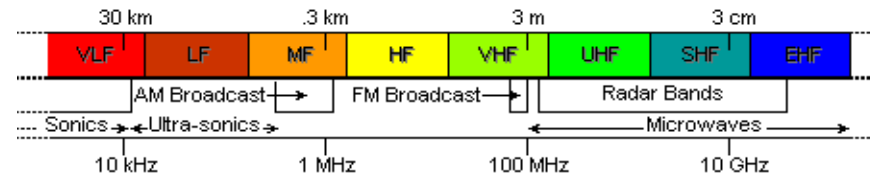
UWB Signal Parameters

UWB Signal Parameter	Range
Average Power Density	As needed to induce effect on GPS receiver.
Pulse Width	0.245 and 0.5 nanoseconds
Pulse Repetition Frequency	0.1, 1, 5, 20 MHz
Modulation, Dithering	UPS, OOK, 50% ARD , 2% RRD
Gating	100% (no gating) and 20% Duty Cycle

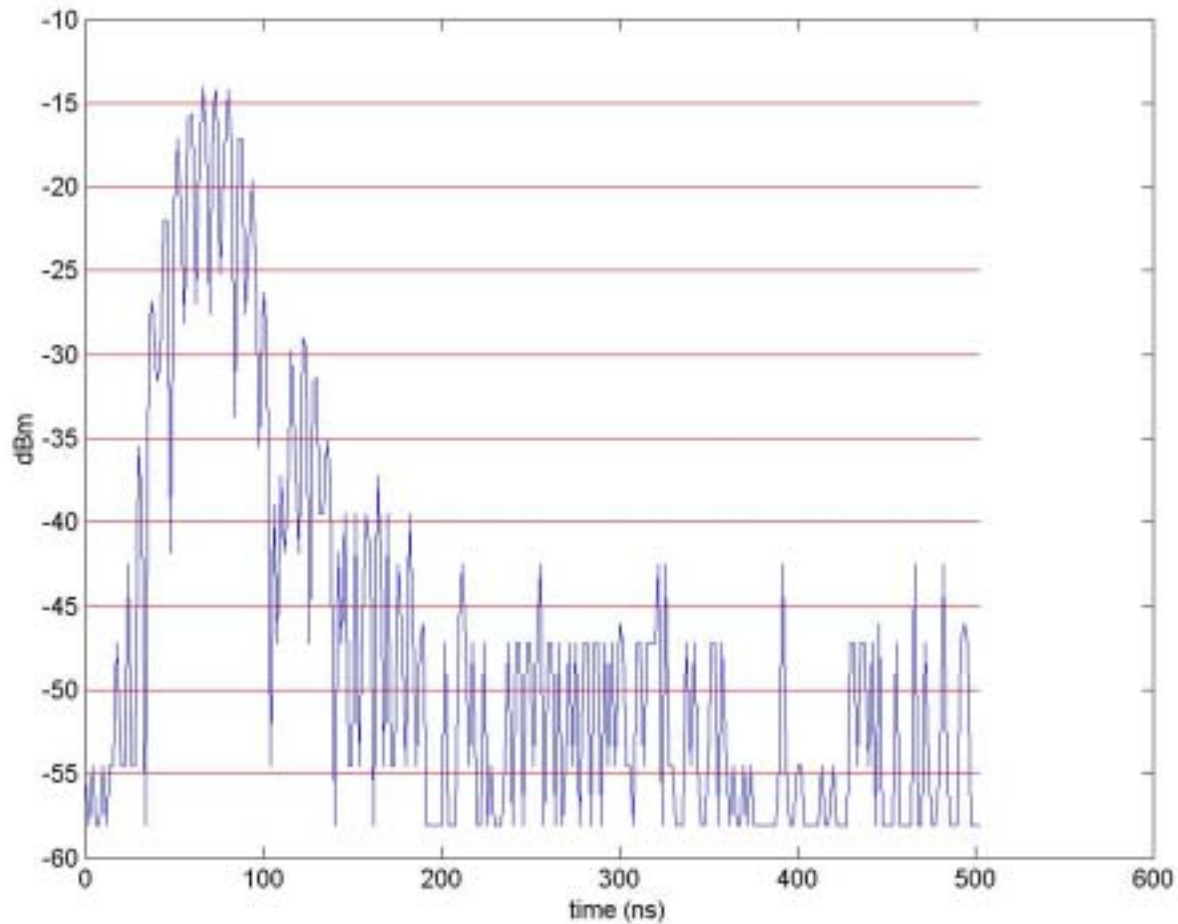


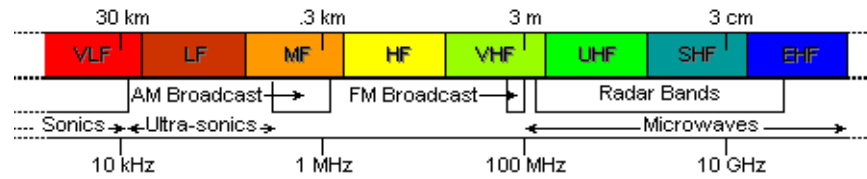
UWB Spectral Characteristics



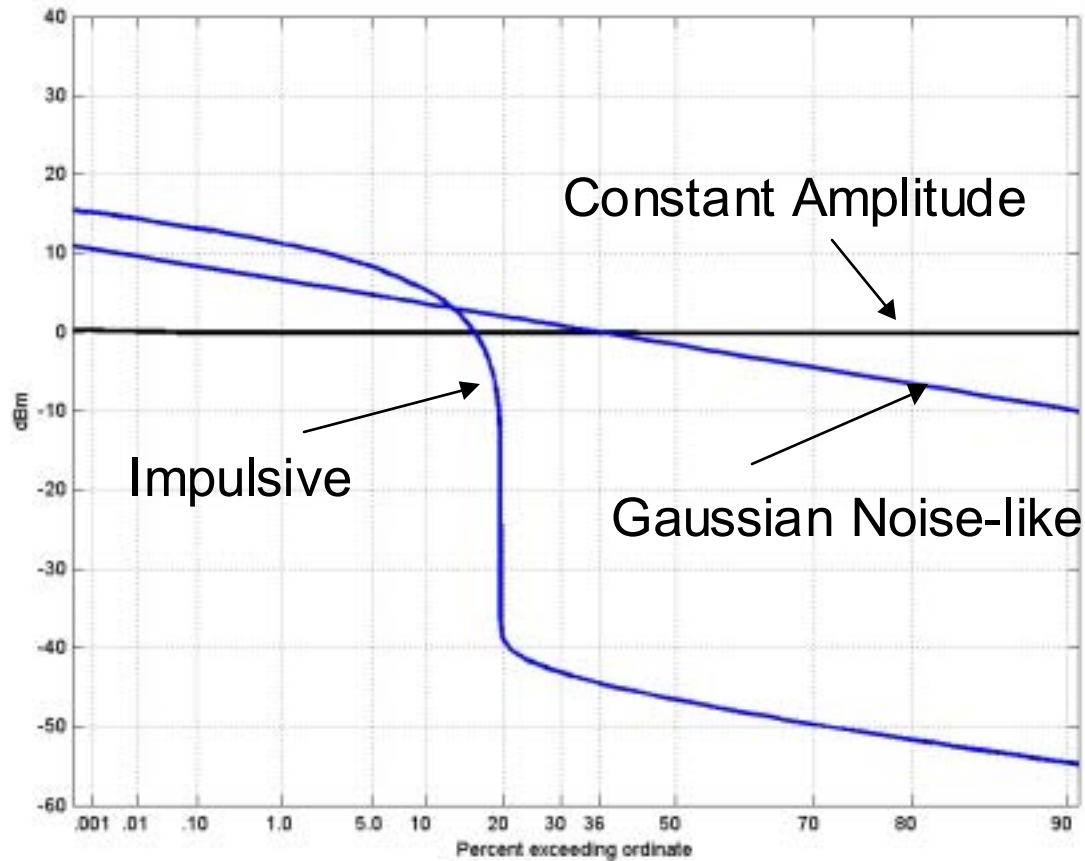


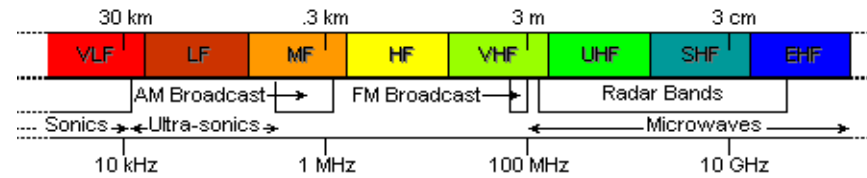
Amplitude Probability





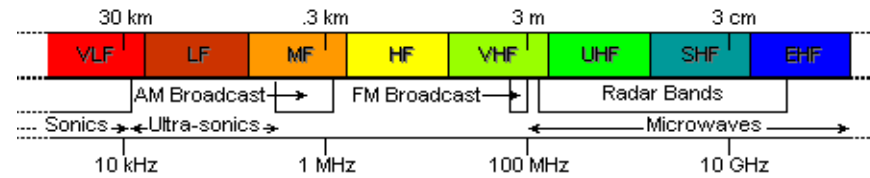
APD Characteristics





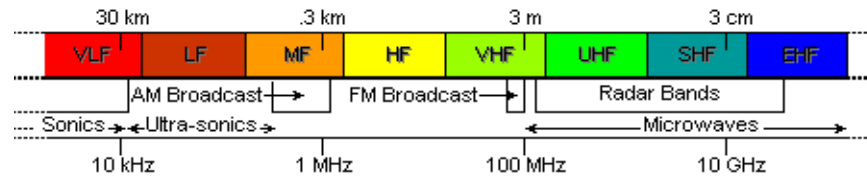
Results

- Characterization of **single-source** UWB signals
- GPS-performance trends due to **single-source** interference

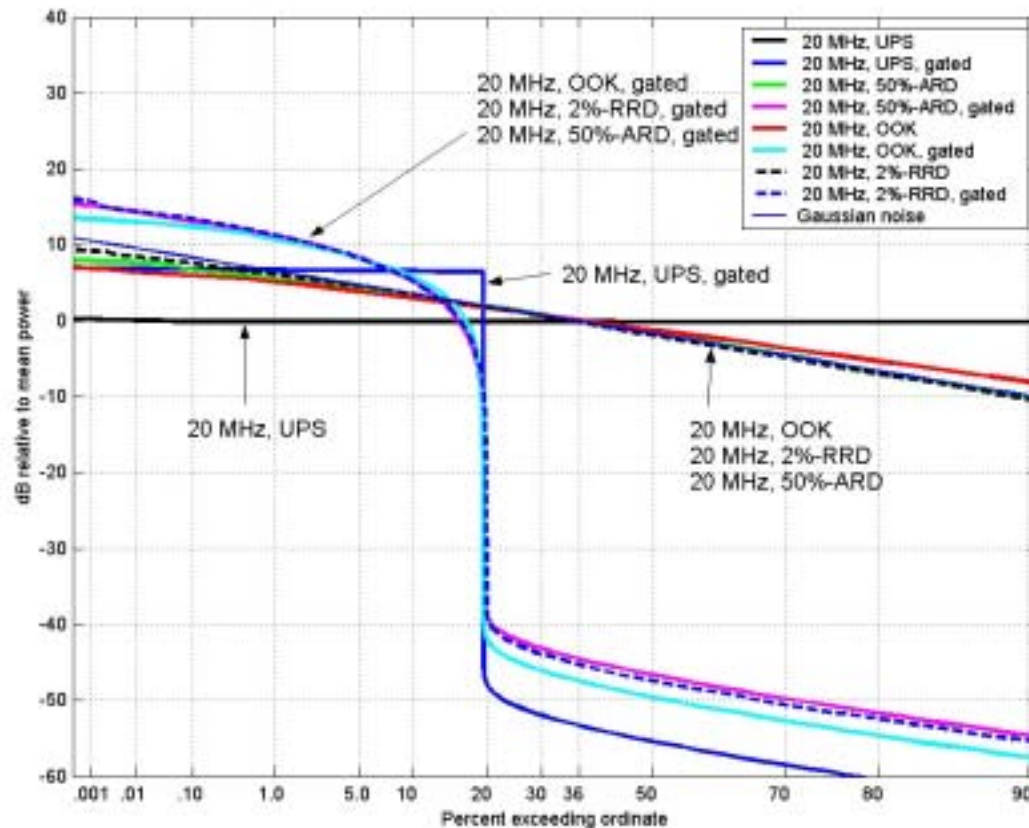


APDs of Single-Source UWB Signals

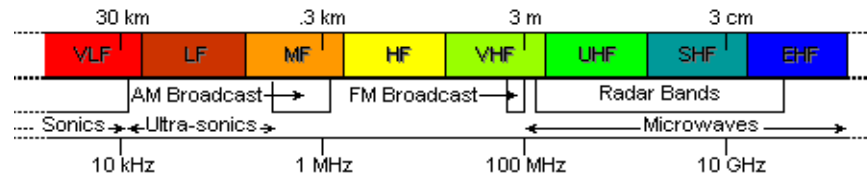
- 2 Bandwidths – 3 MHz and 20 MHz
- Composite plots
 - Across pulse spacing modes for specific PRF values
 - Across PRF ranges for specific pulse spacing mode



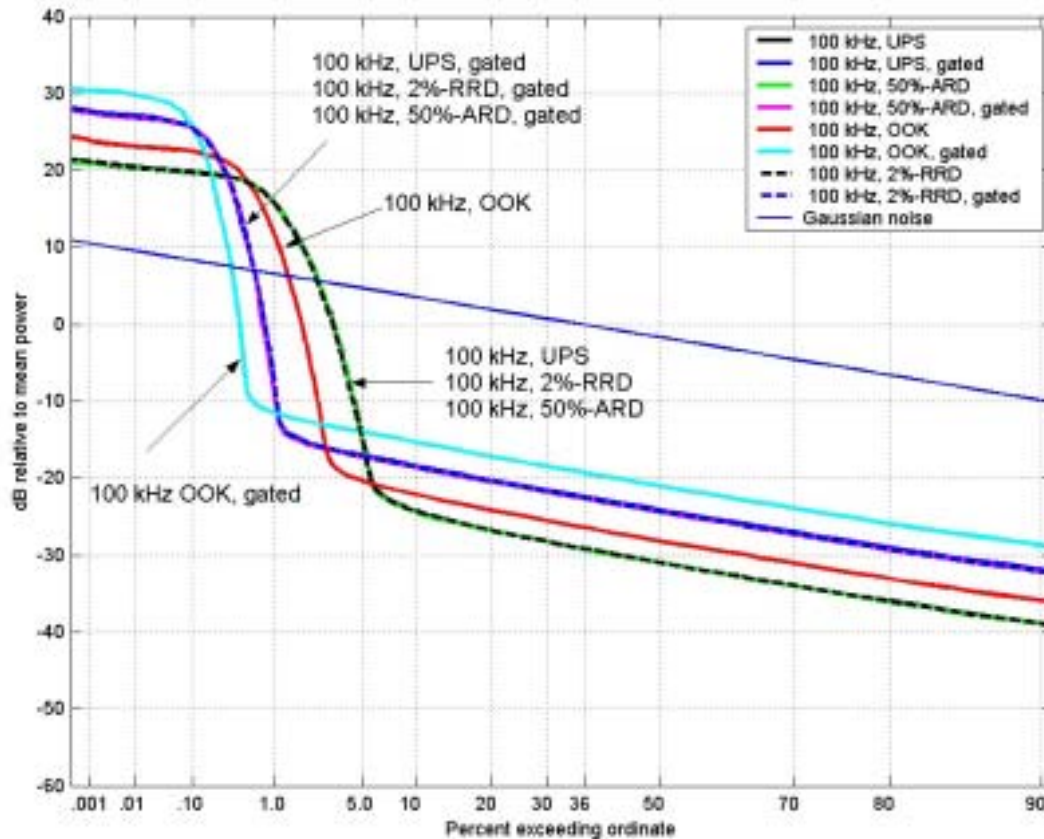
APDs of 20-MHz PRF UWB Signals Measured in a 3-MHz Bandwidth



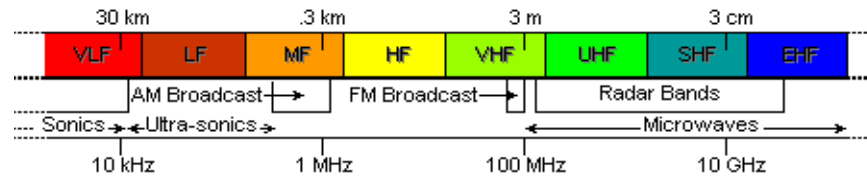
- Constant-amplitude
- Noise-Like
- Gating
- Peak-to-Average



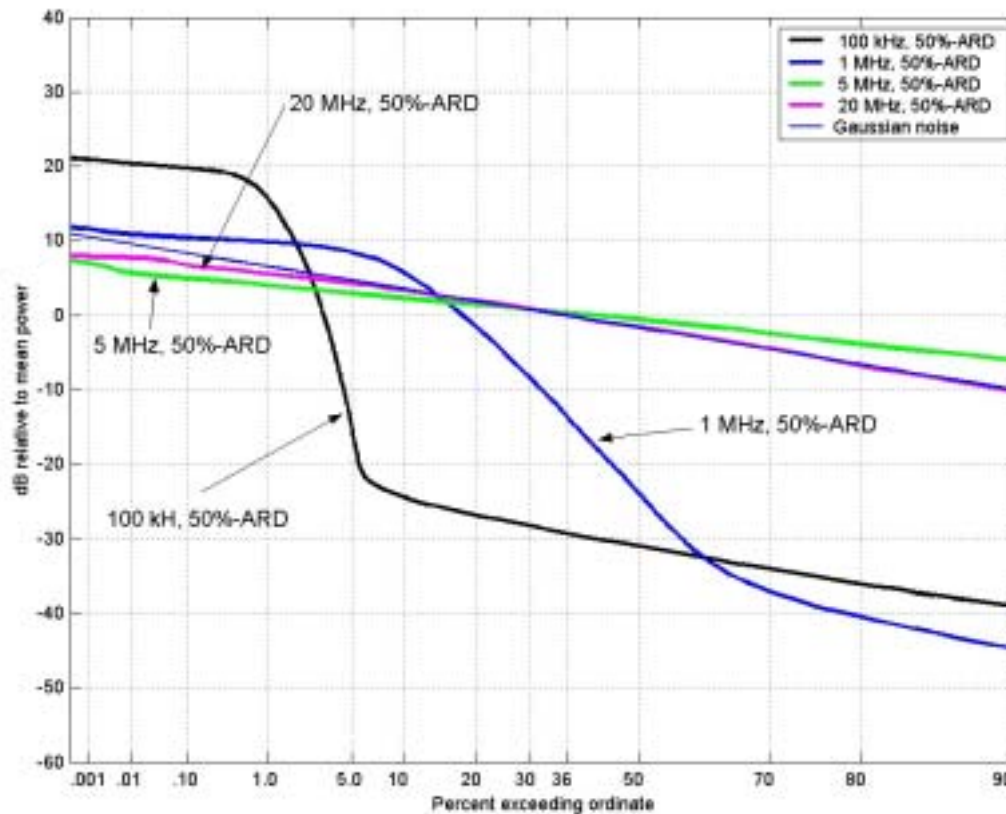
APDs of 100-kHz PRF UWB Signals Measured in a 3-MHz Bandwidth



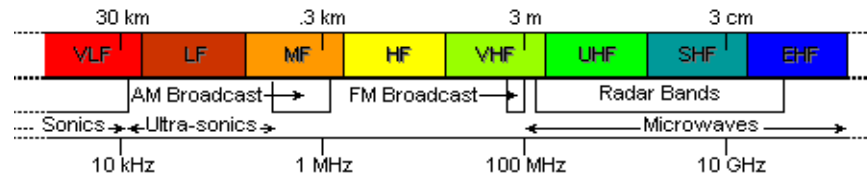
- Low PRF → Impulsive
- Resolved UWB pulses
- Gating decreases the percentage of time the signal is on



APDs of Absolute-Reference Dithered UWB Signals Measured in a 3-MHz Bandwidth

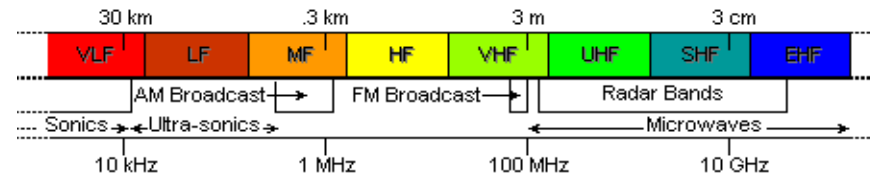


• Higher PRF → Gaussian

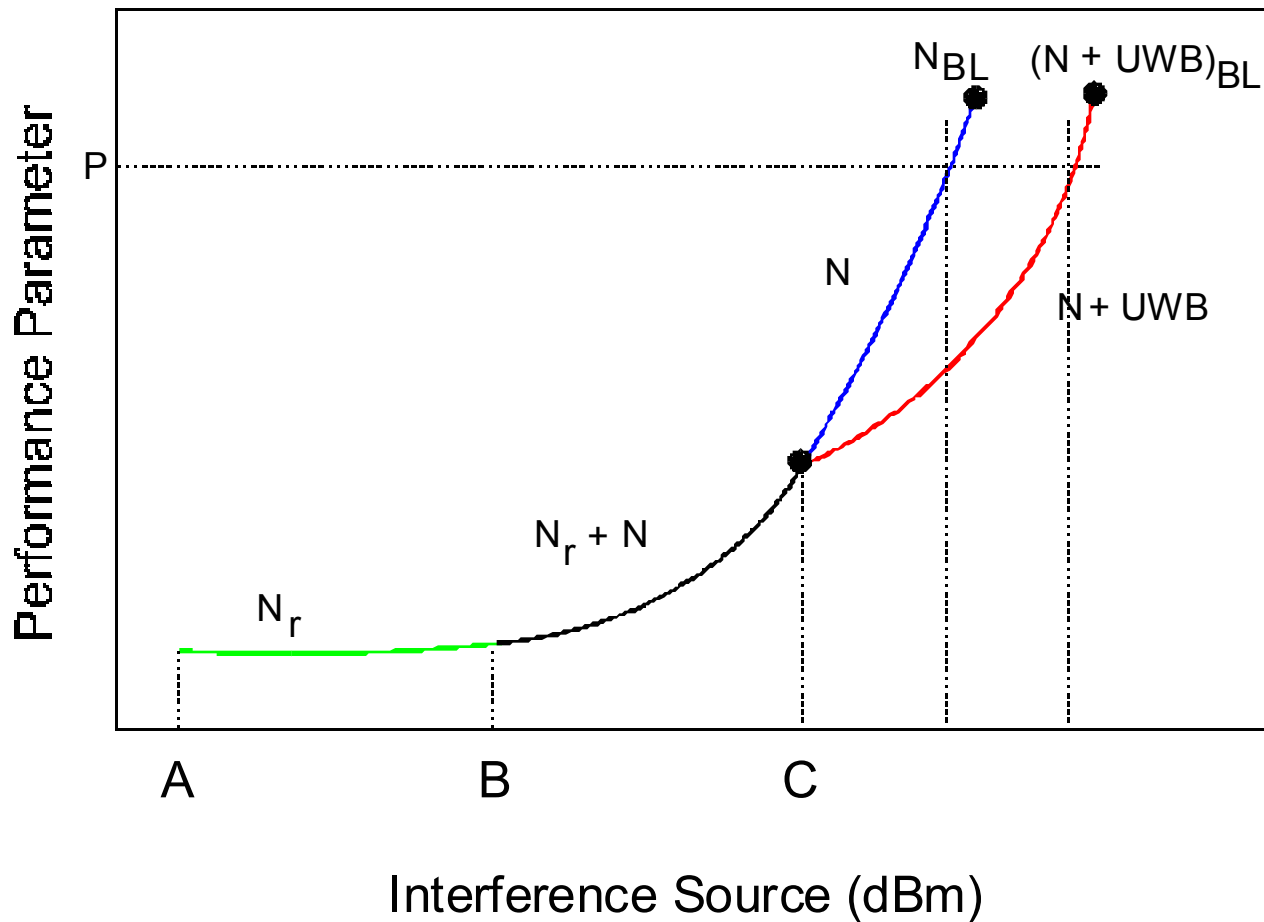


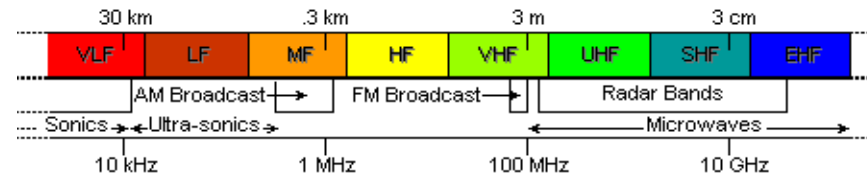
UWB Categorization

ΔW [MHz]	3	3	3	3	20	20	20	20
PRF [MHz]	20	5	1	0.1	20	5	1	0.1
LPS	Amp = k			Impulsive				
OOK								
50%-ARD								
2%-FRD	Gaussian							



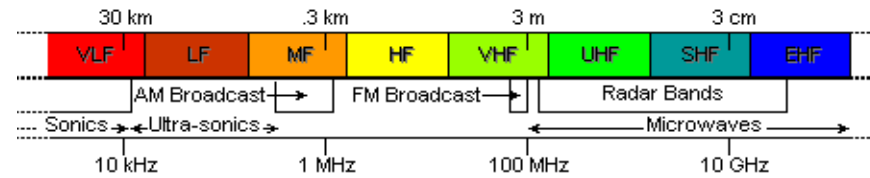
Measurement Procedure



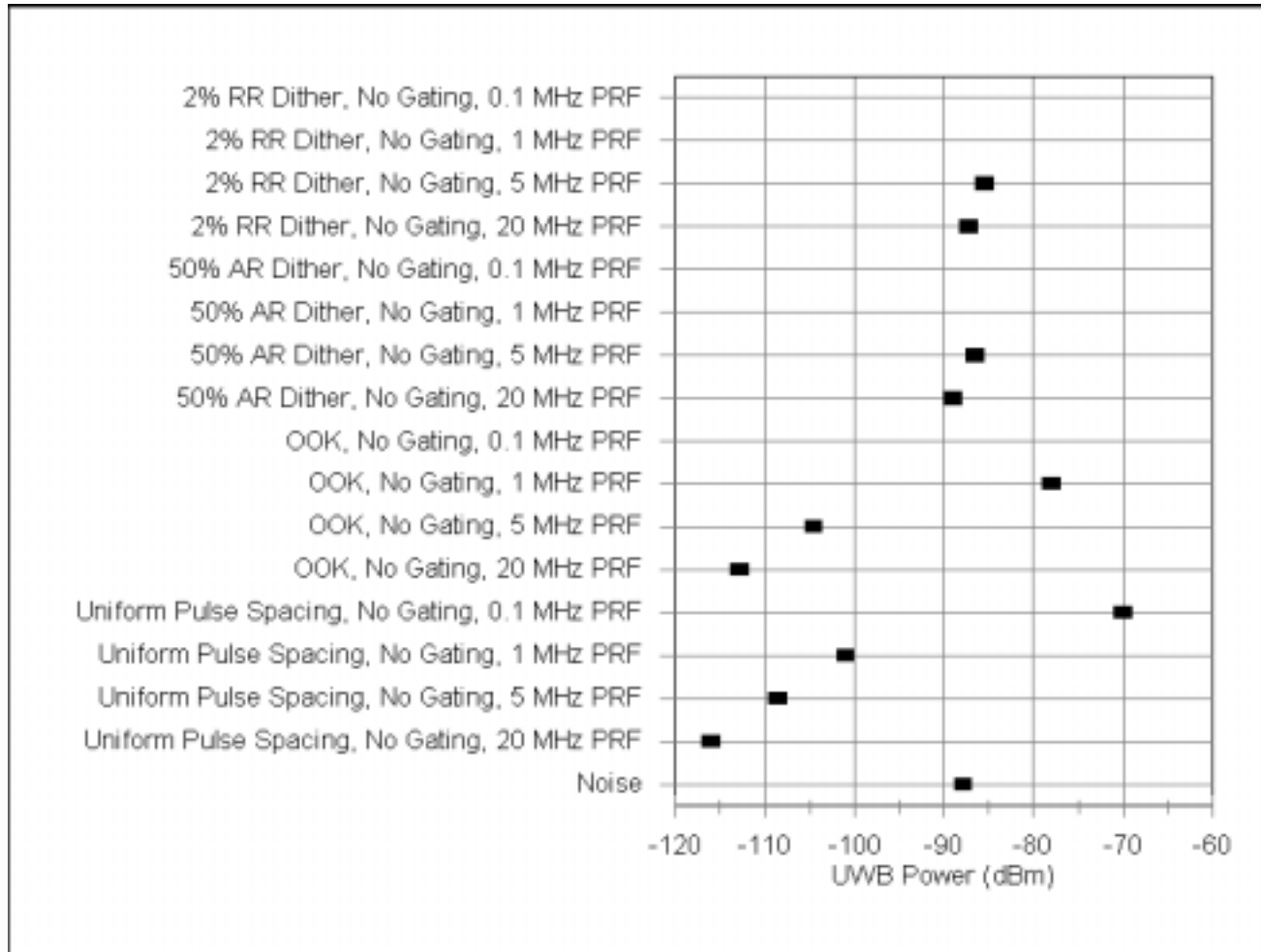


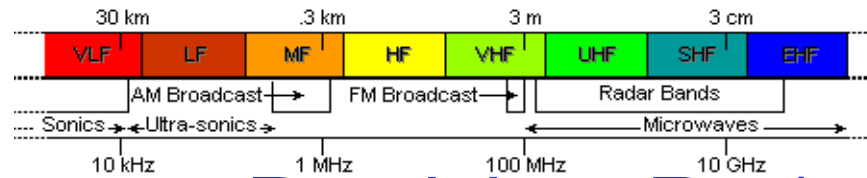
Trends

- Spectral lines are particularly invasive
- Impulsive signals cause little interference
- Higher PRFs have a greater impact
- Dithering can produce effects that are more Gaussian noise-like
- Gating reduces the impact of interference

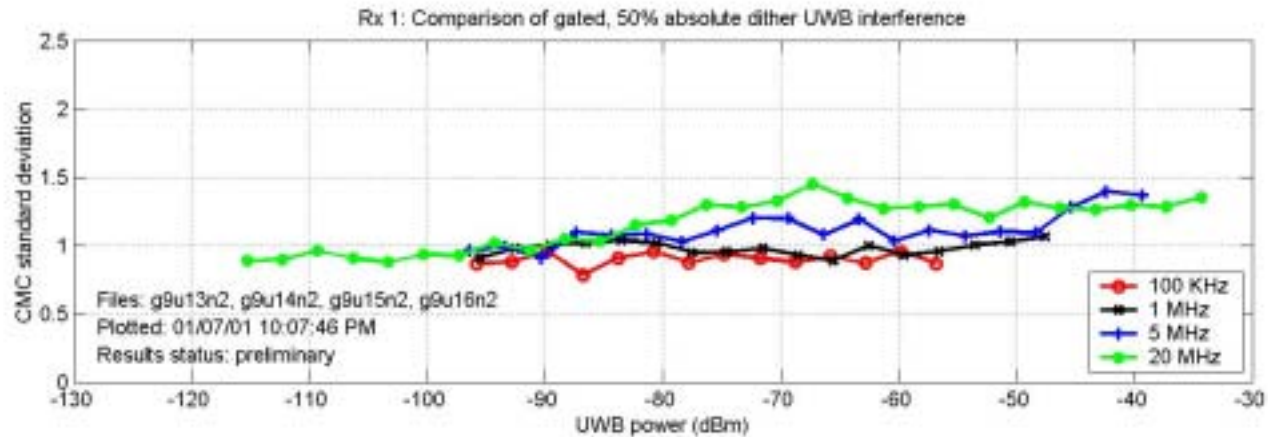
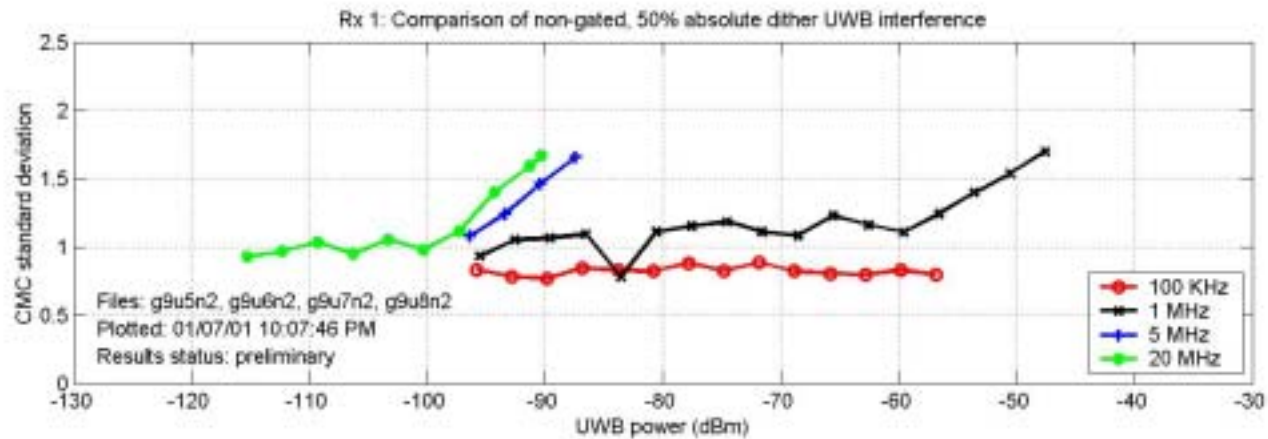


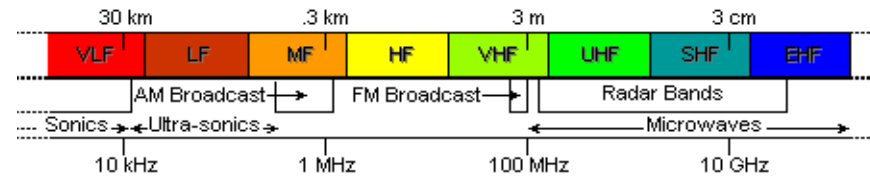
Break Lock: Rx 1, Non-Gated





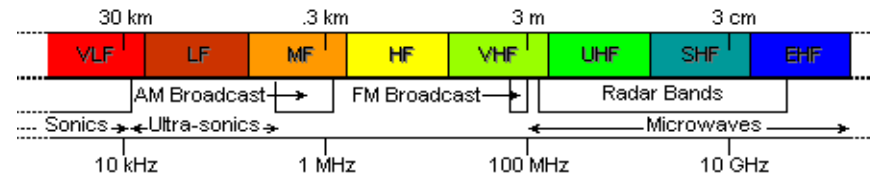
Pseudorange Precision: Rx 1, 50%-ARD



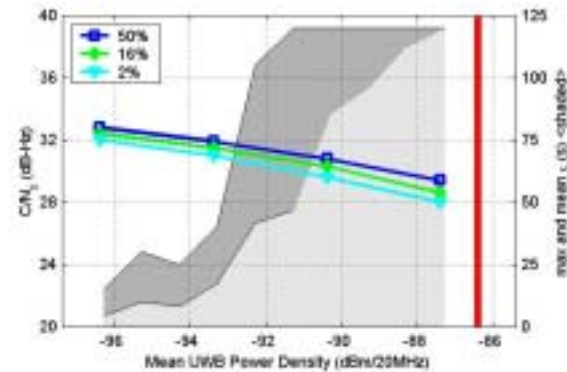
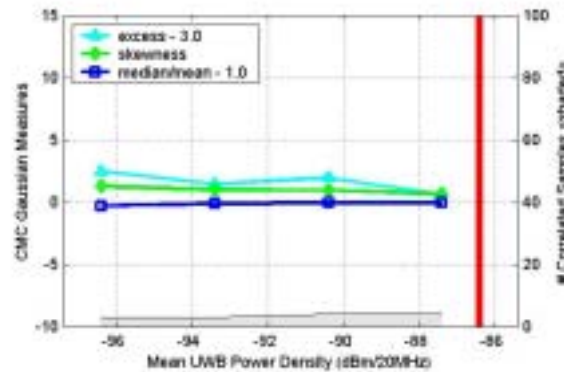
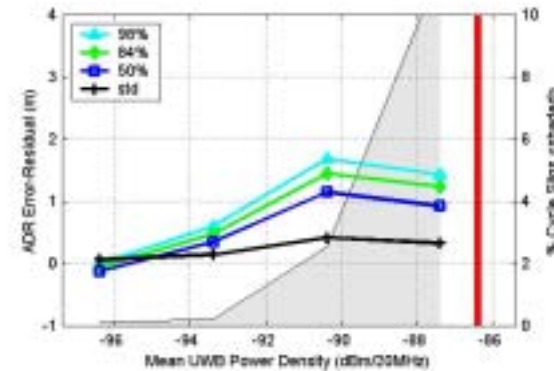
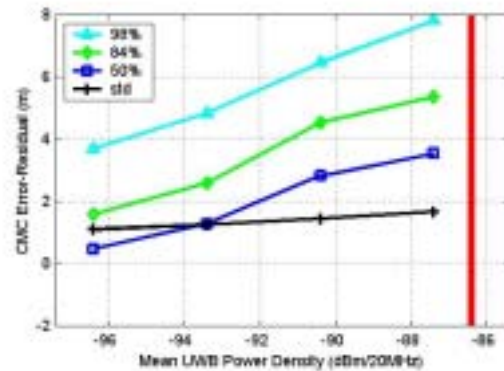


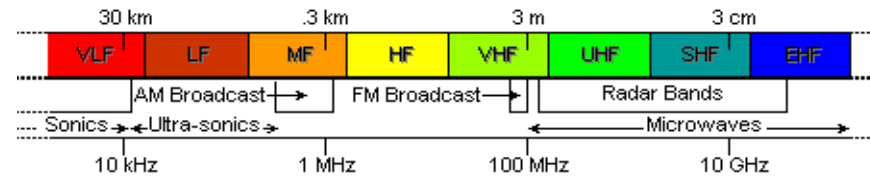
Trends

- Observational results are correlated to BL and RQT.
- RQT has been found to be the most sensitive parameter for identifying interference effects on the receiver.



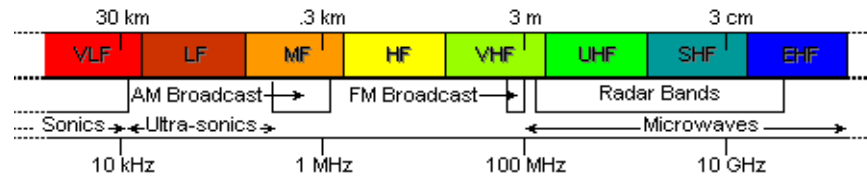
Rx 1, 5-MHz PRF, 50%-ARD, Non-Gated





SUMMARY

- Measurement Approach
- UWB Characteristics
- Interference Trends Related to UWB Characteristics



Contact Information: Institute for Telecommunication Sciences

•J. Randy Hoffman
303/497-3582
rhoffman@its.bldrdoc.gov

•Michael G. Cotton
303/497-7346
mcotton@its.bldrdoc.gov

•Robert J. Achatz
303/497-3498
rachatz@its.bldrdoc.gov

Mailing address:

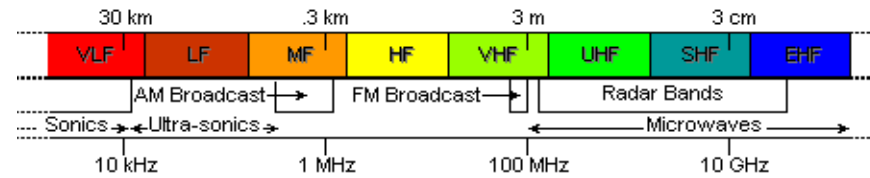
U.S. Department of Commerce
325 Broadway NTIA/ITS
Boulder, CO 80305

Web address for online report:

<http://www.its.bldrdoc.gov/>

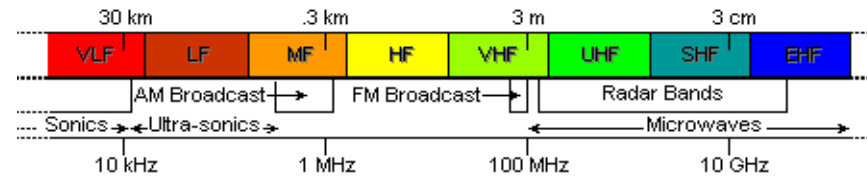
click on <Online Publications>

Scroll down to NTIA Report 01-384

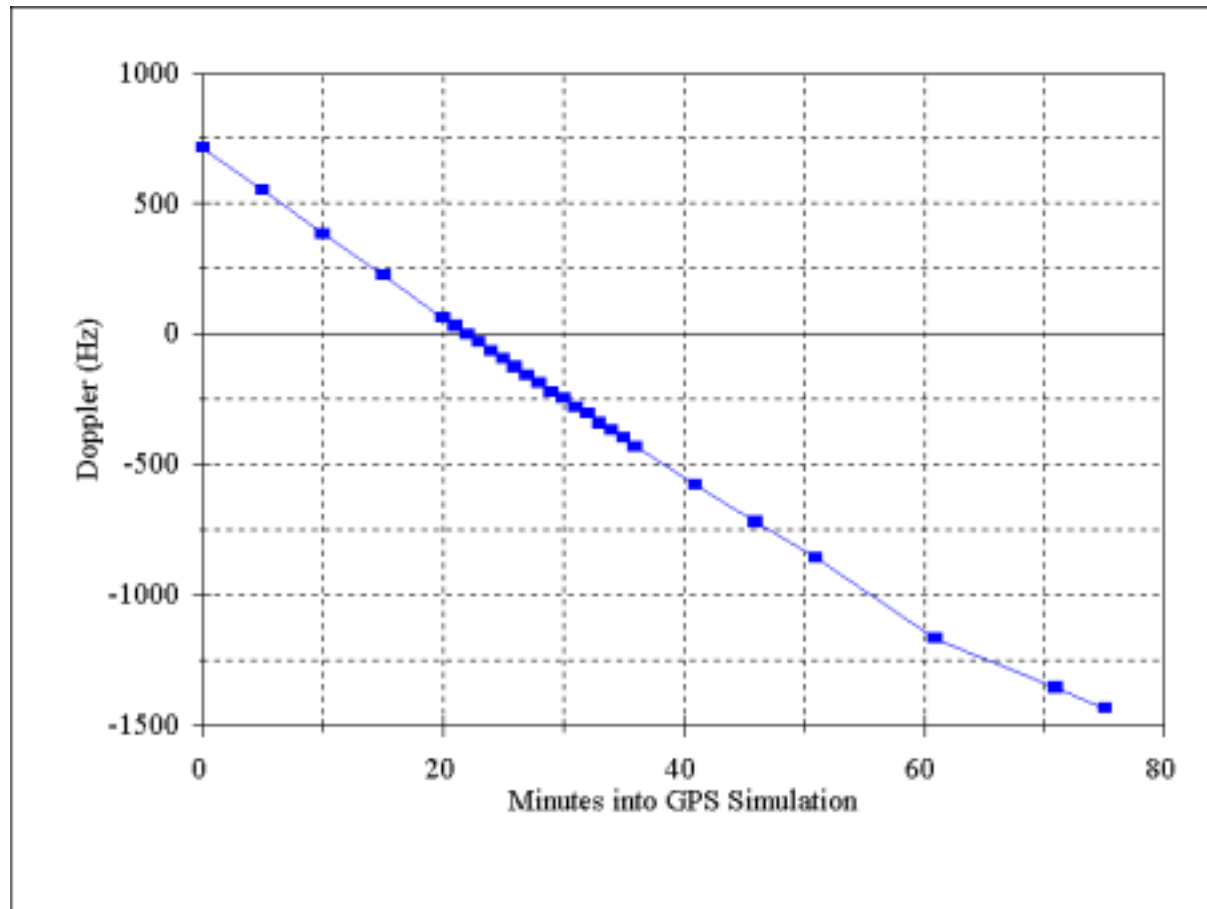


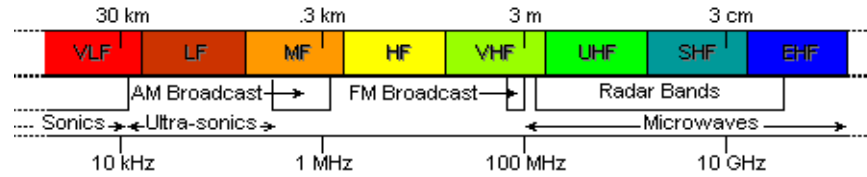
Broadband Noise Power

- Broadband noise accounts for:
 - Sky noise
 - Cross-correlation noise
 - Other satellite signals
- Setting of broadband noise level based on ITU recommendation for minimum C/N_0 required for GPS satellite acquisition. (set at -93 dBm/20 MHz)
- Supported by ITU simulations for worst-case GPS cross-correlation noise.

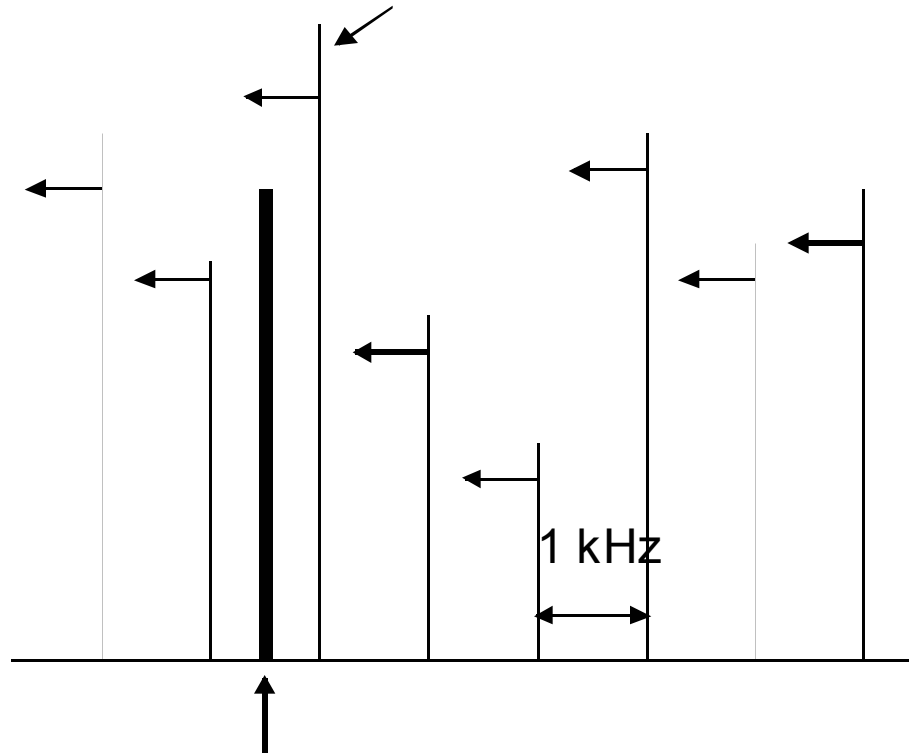


Doppler Frequency of SV25

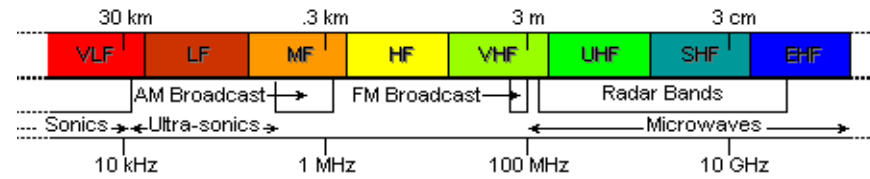




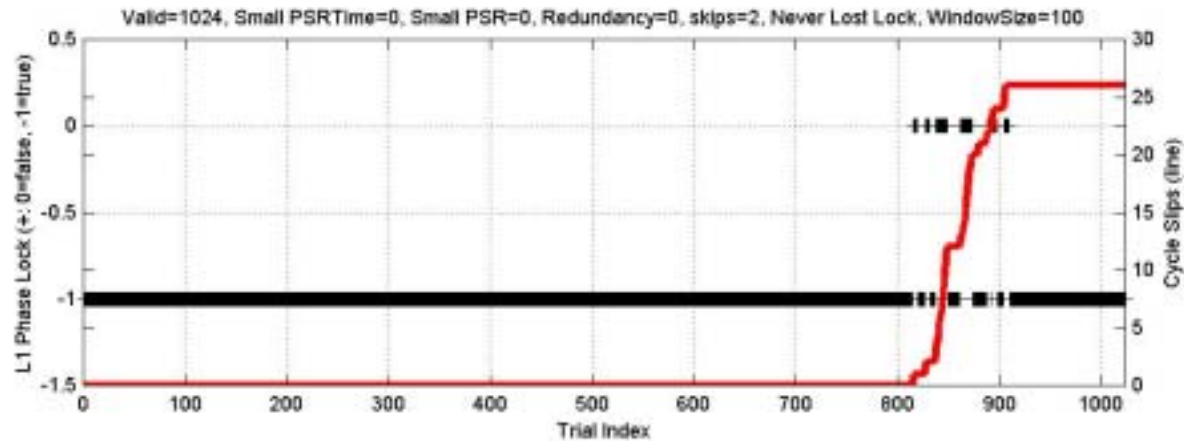
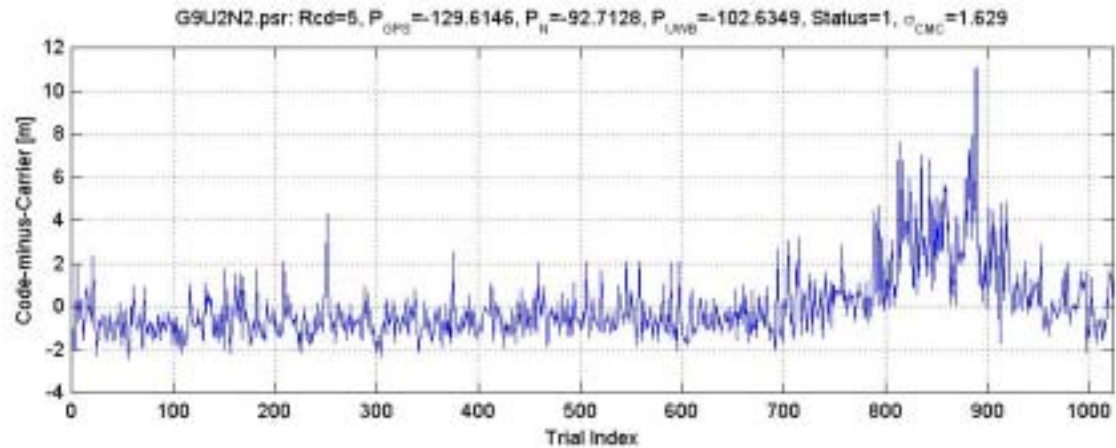
Satellite 25 spectral lines
1575.571 MHz

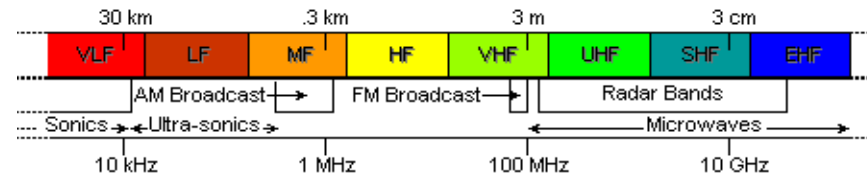


UWB spectral line
1575.570571 MHz



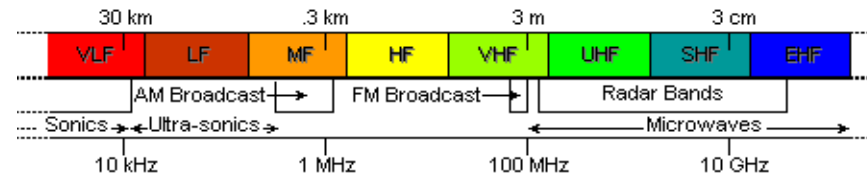
Spectral Line Alignment



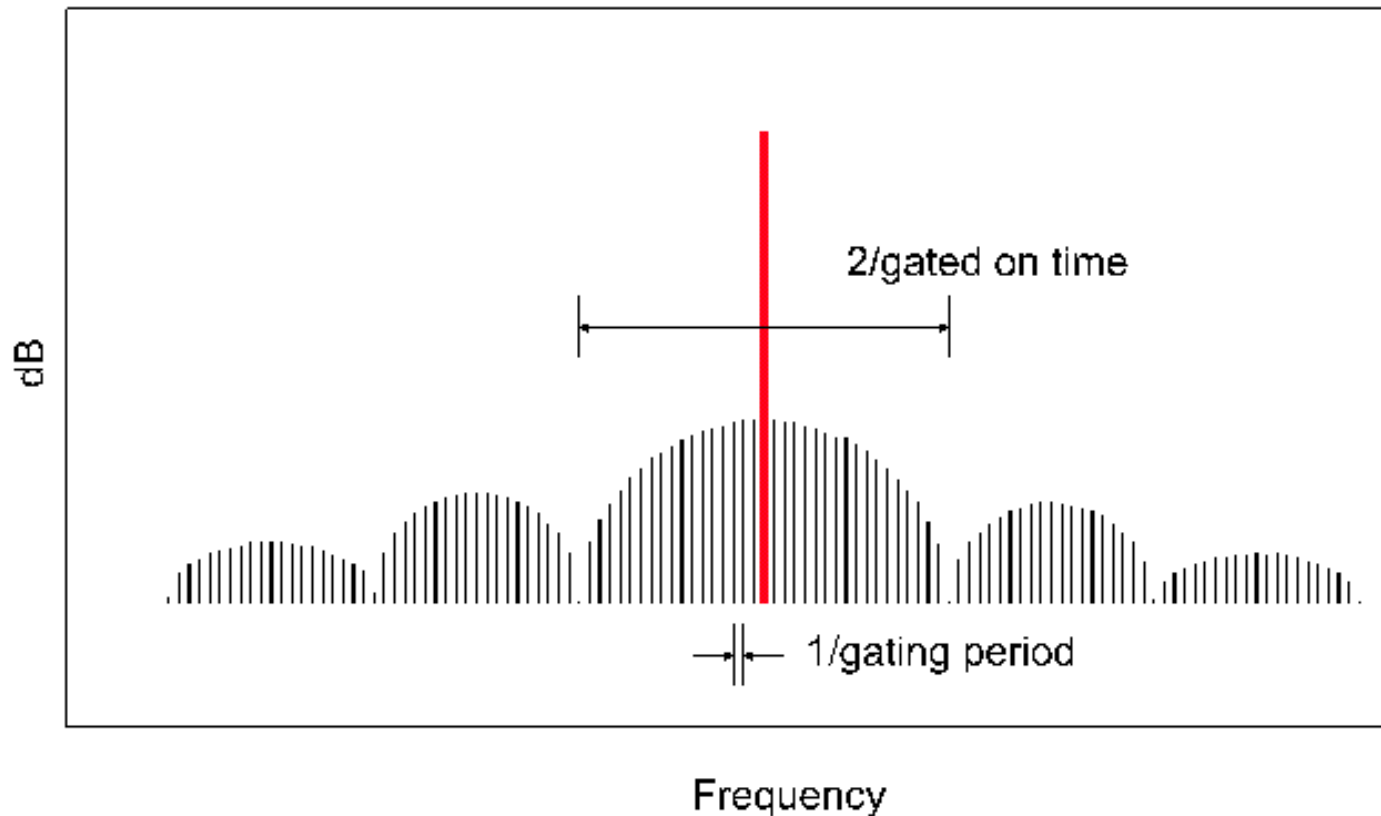


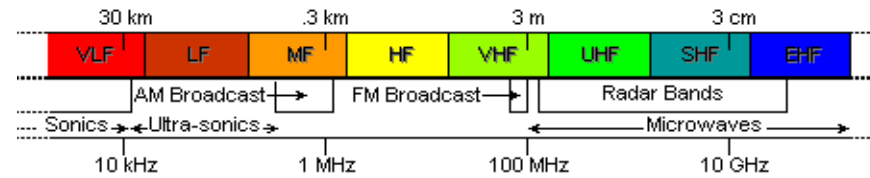
Aggregate Scenarios

Aggregate	UWB Signal Parameters
1	6 × 10-MHz PRF, 2%-RRD, Non-Gated
2	6 × 10-MHz PRF, 2%-RRD, Gated (20% Duty Cycle)
3	2 × 10-MHz PRF, UPS, Non-Gated 1 × 3-MHz PRF, UPS, Non-Gated 3 × 3-MHz PRF, 2%-RRD, Gated (20% Duty Cycle)
4	3 × 3-MHz PRF, UPS, Gated (20% Duty Cycle) 3 × 3-MHz PRF, 2%-RRD, Gated (20% Duty Cycle)
5	(a) 1 × 1-MHz PRF, 2%-RRD, Non-Gated (b) 2 × 1-MHz PRF, 2%-RRD, Non-Gated (c) 3 × 1-MHz PRF, 2%-RRD, Non-Gated (d) 4 × 1-MHz PRF, 2%-RRD, Non-Gated (e) 5 × 1-MHz PRF, 2%-RRD, Non-Gated (f) 6 × 1-MHz PRF, 2%-RRD, Non-Gated



Spectral Effects of Gating





Break Lock: Rx 1, Gated

