The Evolution of Modern UWB Technology:
A Spectrum Management Perspective

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Initiation of UWB Regulatory Framework

- Need for UWB rules recognized in 1998:
  - four manufacturers petitioned FCC for waivers to operate UWB devices under Part 15 (unlicensed) rules
  - FCC made aware of ongoing unregulated GPR operations
- FCC issued Notice of Inquiry (NOI) in September, 1998
- NOI requested information w.r.t. potential UWB characteristics and operations be submitted to public record

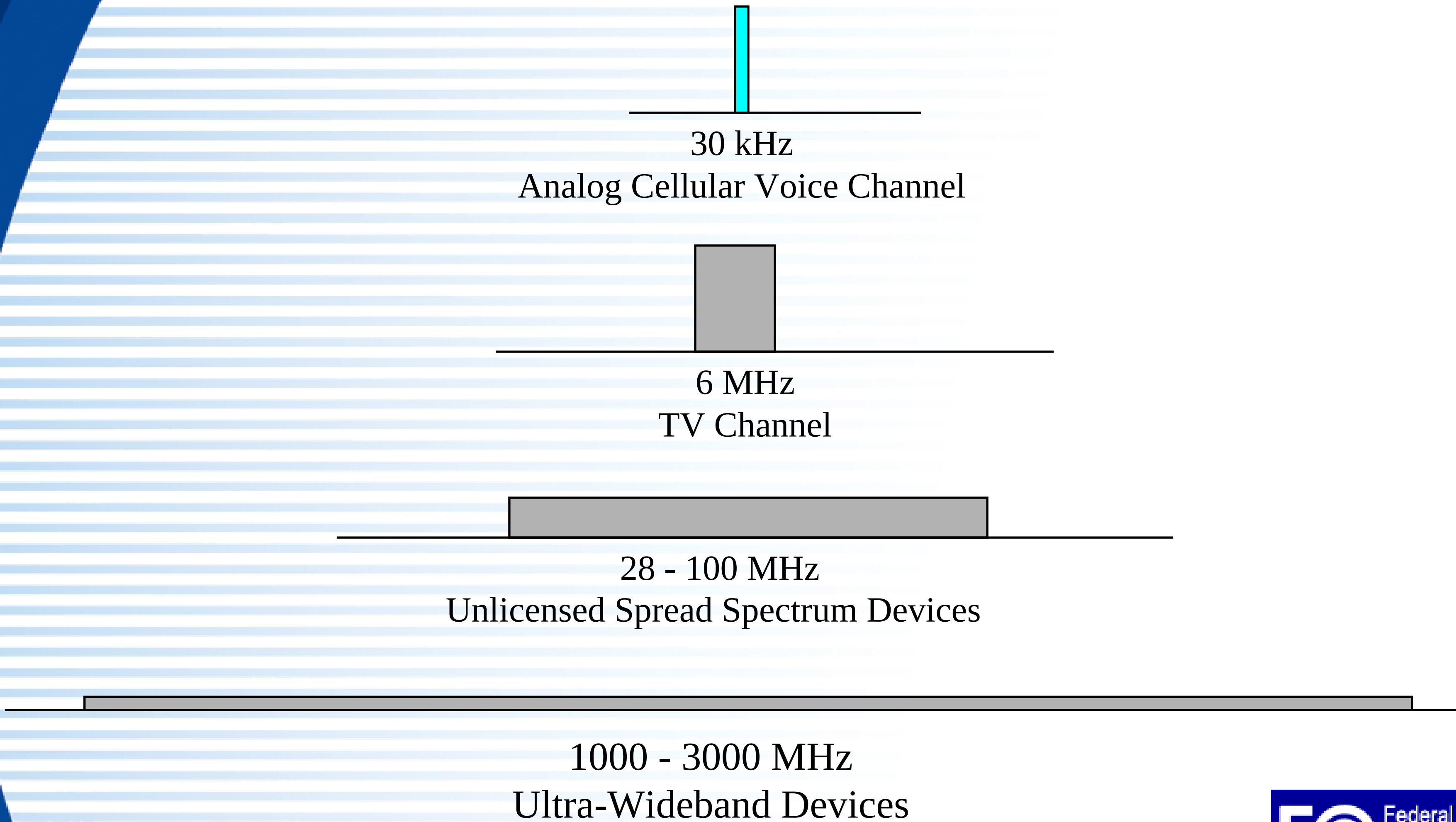
Response to UWB NOI

- Public record filings primarily described direct-pulse (DP) UWB waveforms generated by the edge of very fast rise-time, short-duration pulse (an impulse)
- Resulting impulse used to “shock excite” a resonant antenna
  - Properly designed antenna functions as band-pass filter, shaping resultant spectra
- Extremely (ultra) wideband spectrum signature created in the frequency domain
- Prospect of direct sequence encoding of impulse stream introduced (DS-UWB)

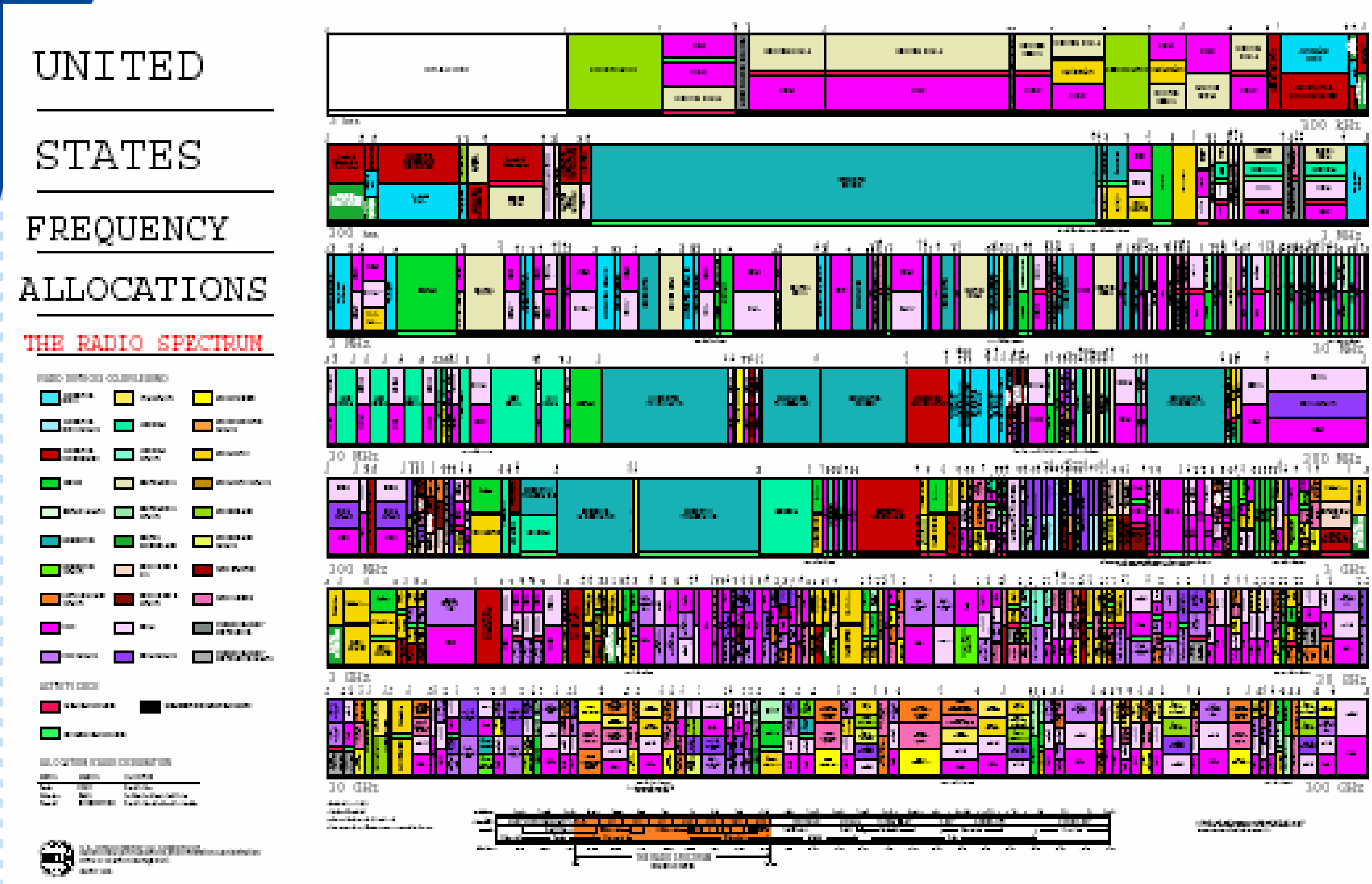
Impact of NOI

- Made clear the need to implement wireless UWB as an underlay technology
- Initiated extensive investigations into potential interference to incumbent services and systems
- Identified likely applications for and benefits associated with UWB technology

Comparison of UWB Bandwidth



Conventional Spectrum Management

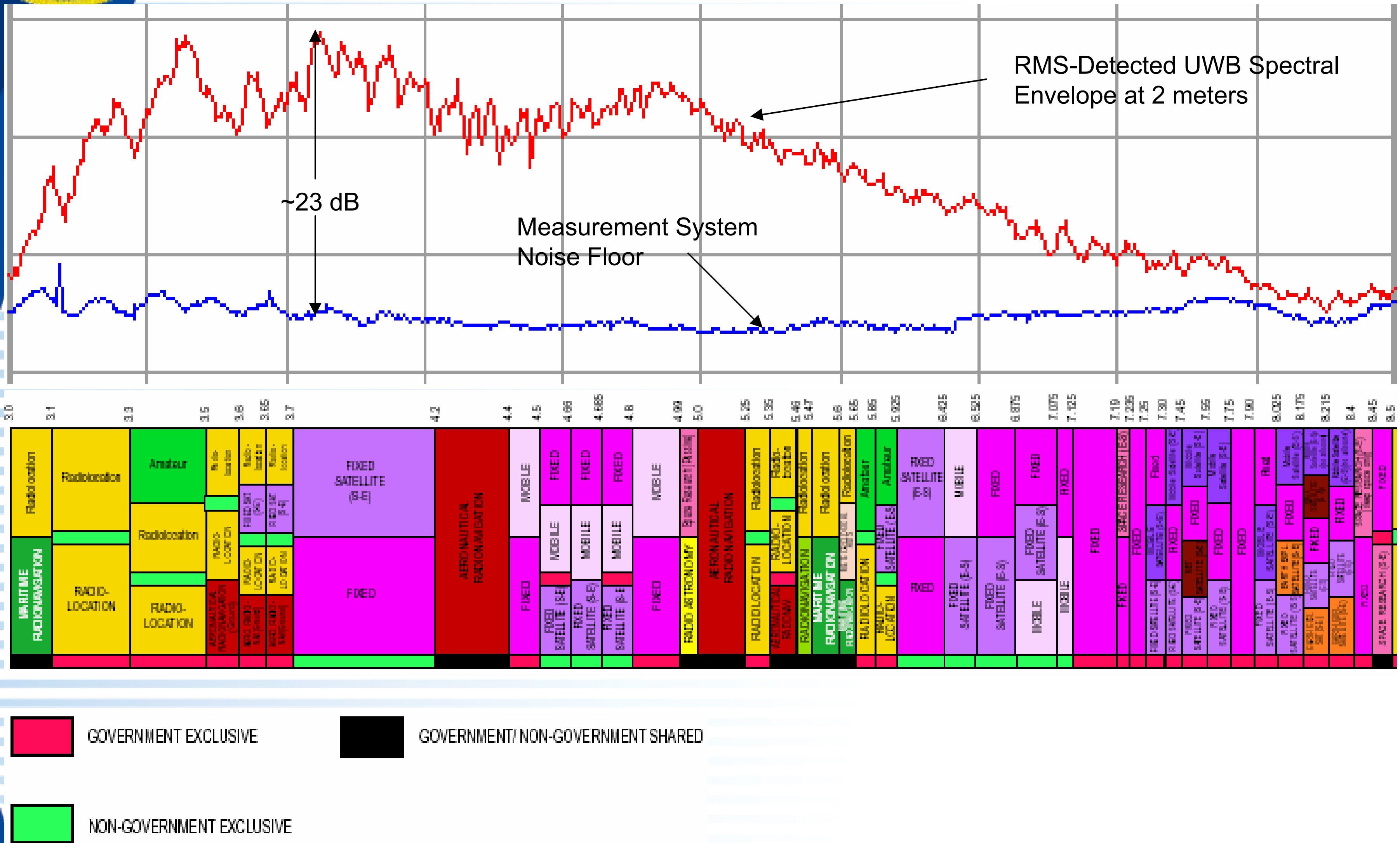


Primary Spectrum Issues

- UWB waveforms require access to large swaths of radio spectrum
- UWB emissions incompatible with existing spectrum management protocol
- Spectrum identified for UWB operation will necessitate access to “restricted bands”
  - Restricted bands typically reserved for Safety-of-Life, National Security and/or Scientific Research operations
- Requires operation in spectrum long used by incumbent licensees, often on a sole basis (i.e., entrenched)

UWB Spectral Envelope

Not to Scale – For Illustration Only



Potential Benefits of UWB Technology

- Low Cost
  - Utilizes base-band radio architecture implemented in CMOS
- Low Power Consumption
  - Low transmit duty cycles
- High Capacity
  - via wide occupied bandwidth
  - Shannon-Hartley theorem
- Multi-path Robustness

Notice of Proposed Rulemaking

- Released in May 2000
- Used information from public record to develop proposed regulations
- Acknowledged and encouraged ongoing EMC tests and analyses
- Requested public comment on rules proposals

UWB EMC Tests and Analyses

- NTIA/ITS
  - Measured UWB characteristics
  - Measured interference potential to GPS and other Government systems
  - Assessed UWB compatibility w.r.t. incumbent Government systems
- DOT/SU/Rockwell Collins
  - Measured interference potential to GPS
  - Assessed UWB compatibility w.r.t. aviation applications of GPS

UWB EMC Tests and Analyses (continued)

- TDC/UT/APL
  - – Measured interference potential to GPS
  - – Assessed UWB EMC w.r.t. GPS and other systems
- FAA/RTCA
  - – Analyzed potential interference to GPS
- AARL
  - – Analyzed EMC w.r.t. Amateur stations

UWB EMC Tests and Analyses (continued)

- Motorola/Sprint/Qualcomm/Telcordia/TDC
  - – Analyzed EMC w.r.t. PCS
- Cisco Systems, Inc
  - – Analyzed EMC w.r.t. MMDS systems
- XM Satellite Radio
  - – Analyzed EMC w.r.t. DARS systems
- DARPA NETEX
  - – Measured and analyzed UWB potential interference to selected legacy military systems

Measurement Results

- Measured interference levels relatively consistent among various test efforts
- Interference levels w.r.t. GPS validate thresholds previously defined by RTCA/FAA and documented within ITU
- UWB interference found to appear as either “noise-like” or “CW-like” within an incumbent receiver’s passband
  - Traditional interference analysis techniques are applicable

Interference Analysis Results

- Very little consistency among competing factions
- Incumbents utilized extremely conservative assumptions in analyses
  - often ignored realistic UWB operational constraints and application proliferation probabilities – NIMBY syndrome
- UWB proponents favored more liberal assumptions in analyses

First UWB Report and Order (R&O)

- Issued in February, 2002
- Incorporated information obtained from measurement and analysis efforts and from other comments submitted to the public record
- Coordinated closely with Government agencies via NTIA and IRAC
- Established a regulatory framework to facilitate the introduction of UWB for use in limited applications

First UWB Report and Order (R&O) (continued)

- Defined a UWB waveform
  - 500 MHz minimum bandwidth @ -10 dB points, or
  - fractional bandwidth ≥ 0.20
  - upper, lower, center frequencies and frequency of maximum emission
- Identified permissible UWB applications
  - Imaging
  - Surveillance
  - Communications (Indoor and Outdoor)
  - Vehicular Radar

First UWB Report and Order (R&O) (continued)

- Established application-based emissions masks for:
  - Imaging (GPRs, surface and medical imaging)
  - Surveillance (proximity detection)
  - Communications (digital file transfers)
  - Vehicular radar
- Specified additional requirements to further protect incumbents
  - trained operators for GPRs
  - no outdoor infrastructure for communications
  - off-axis attenuation of vehicular radars

Memorandum of Opinion and Order

- MO&O and Further NPRM released in Feb, 2003
- Through-Wall Imaging recognized as permissible UWB application
  - established applicable emissions limits
- Modified band requirements for GPRs
- Responded to petitions for reconsideration of the initial R&O

MBOA Waiver Petition

- Filed in August, 2004
- Proposed a multi-band (MB) orthogonal frequency division multiplexed (OFDM) implementation of UWB
- Requested clarification and waiver from requirement to stop band sequencing when performing compliance testing of emission levels

MBOA Waiver Petition
(continued)

- Waiver request approved by FCC in March, 2005
- Approval of waiver constituted no change to existing UWB rules or emissions masks
- Only change affected was in the way radiated emissions are measured
  - Requirement to suspend band sequencing (hopping) when measuring for compliance to the emissions mask was removed
  - Now permissible to perform the measurement with the device radiating in normal operating mode

UWB Measurement Procedures

- Procedures consistent with ANSI C63.4 with some technology-specific variations
- Detailed information can be obtained from developing ITU TG1/8 contribution
  - Available at: http://www.fcc.gov/oet/ITU_tsk_grp/int-documents/Chair_report_9_18_Jun_04/Annex_4_PDNR_UWB_MEAS.doc
- FCC also maintains an FAQ regarding UWB compliance measurements
  - Available at: http://gullfoss2.fcc.gov/prod/oet/cf/kdb/forms/FTSSearchResultPage.cfm?id=20253&switch=P
  - Currently undergoing update

UWB Measurement Procedures (continued)

- Verification of UWB emissions to limits must utilize radiated emissions measurements
- CISPR quasi-peak detector must be used below 960 MHz
- Average (rms) and peak detector must be used above 960 MHz
  - Average measurements integrated over 1 ms
  - Discourage use of a sample detector and post processing to determine rms average

UWB Application-Specific Measurement Issues

- Radiated emissions from UWB GPRs can be measured with the DUT placed on a sand bed.
- If this option is exercised, 4.7 dB must be added to the measured levels.
- Care must be taken to identify and address ambient signals within the measurement space

UWB Application-Specific Measurement Issues

- UWB Communications Devices
  - Detecting radiated emissions to levels specified by the emissions mask in the 960-1610 MHz band is challenging
  - Measurement system must be sensitized to the greatest possible extent by employing a very low noise preamplifier (less than 1 dB NF) and high gain antenna
  - Recommended measurement range of one meter

UWB Application-Specific Measurement Issues

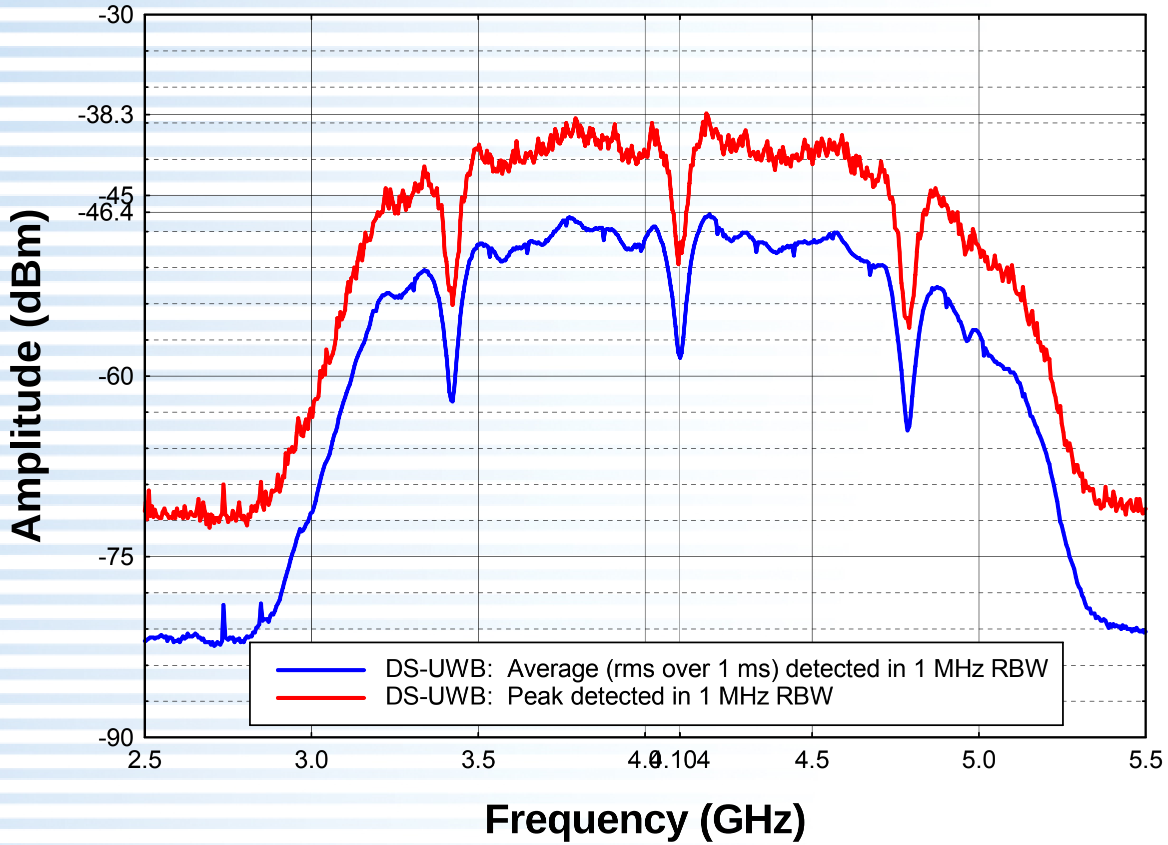
- UWB Communications Devices (continued)
  - – A spectral line test required within the GPS bands (1164-1240 MHz and 1559-1610 MHz)
  - – For this test, the RBW can be narrowed to reveal spectral lines
    - Rules specify no less than 1 kHz RBW, but practical limit is more like 10 kHz
  - – A peak detector must be used to measure peak emission level
    - Maximum hold feature should be employed
    - Measured level must then be expressed in a 50 MHz bandwidth by adding 20log(50/RBW)

UWB Application-Specific Measurement Issues

- Vehicular Radar
  - Measurements must be made at very close range to overcome increased propagation path losses
  - Problems identified with measuring off-mainbeam-axis emissions and harmonic emissions above 31 GHz to levels specified by emissions mask
    - Currently under review
    - Further guidance will be forthcoming

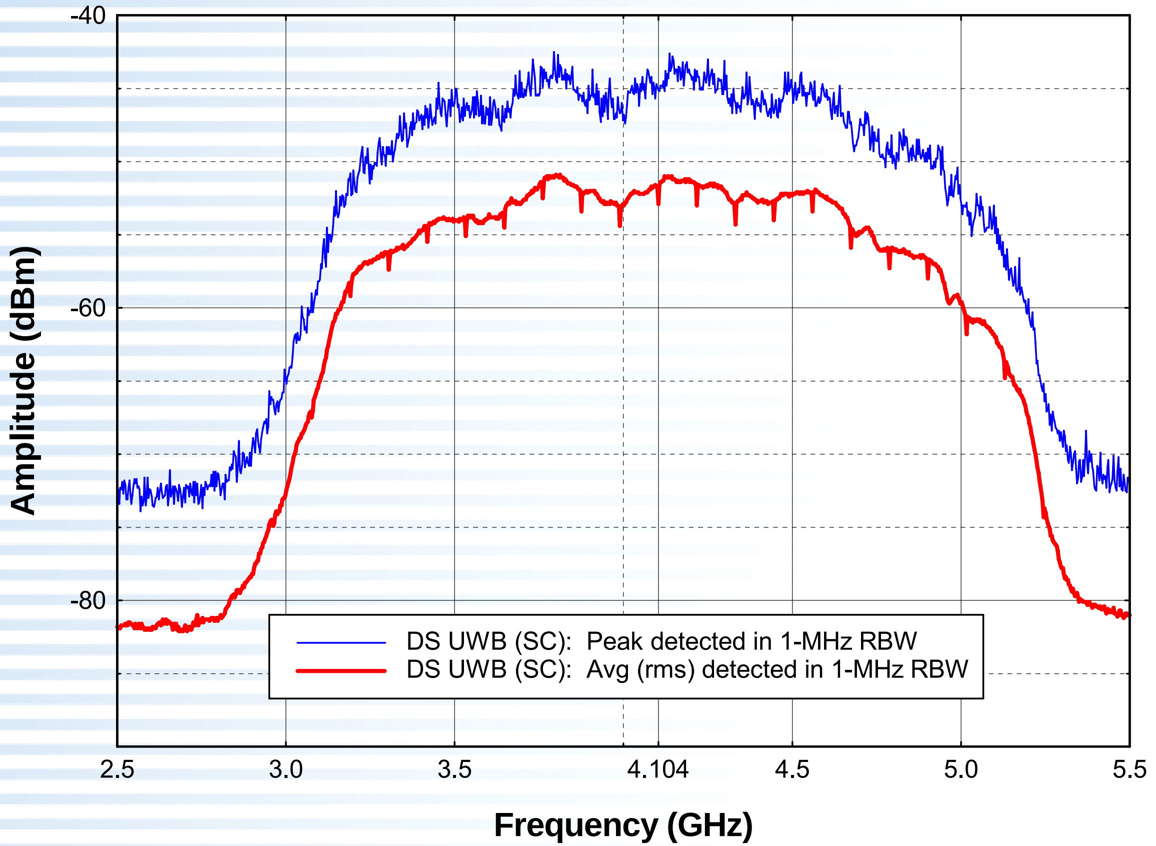
Example Spectrum Signatures DS-UWB

DS-UWB (full code) Peak and Average Spectral Envelopes

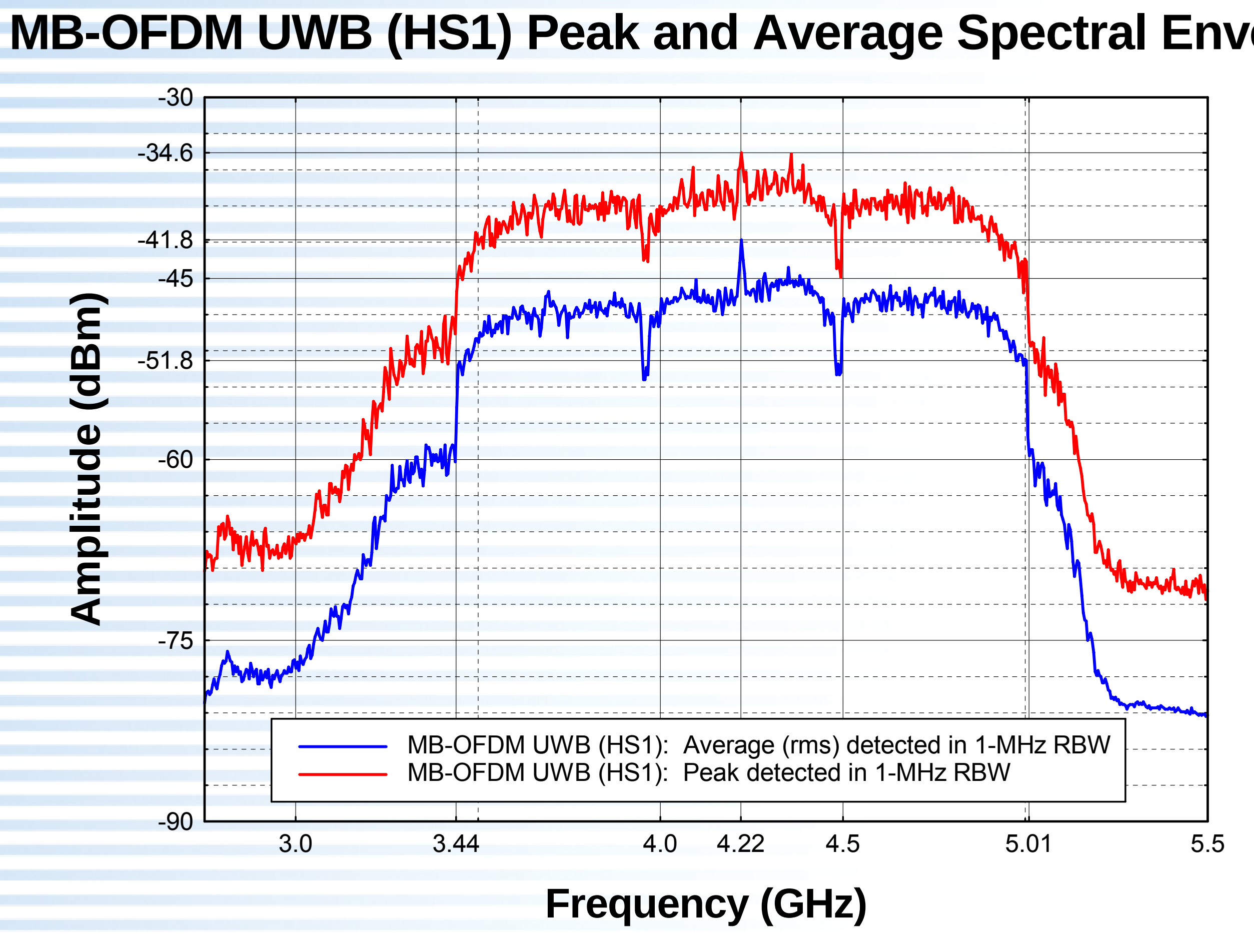


Example Spectrum Signatures DS-UWB

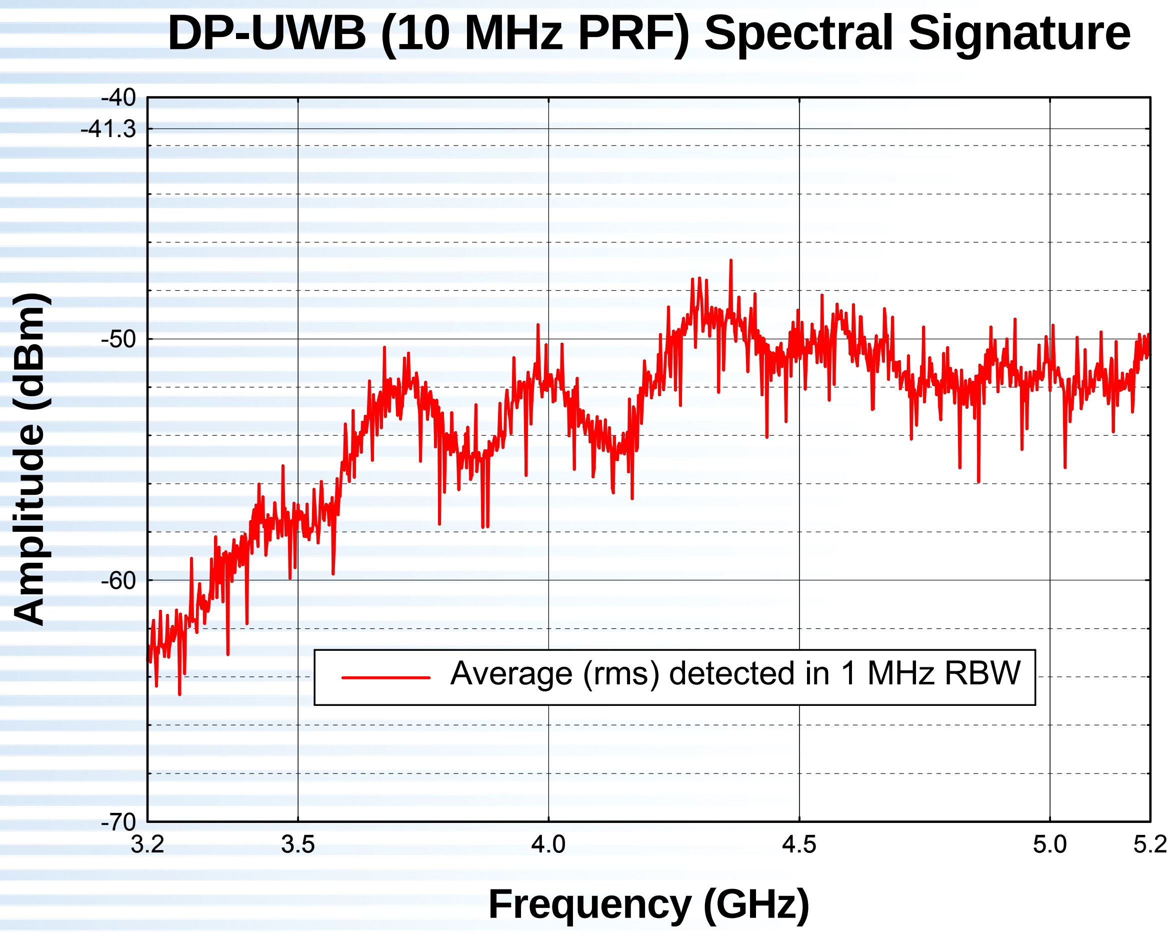
DS-UWB (sparse code) Peak and Average Spectral Envelopes



Example Spectrum Signatures MBOA-UWB



Example Spectrum Signatures DP-UWB



Example Spectrum Signatures Vehicular Radar