



Institute for Telecommunication Sciences

Boulder, Colorado

Measuring Interference Effects

Institute for Telecommunication Sciences (ITS)

National Telecommunications and Information Administration (NTIA)

U.S. Department of Commerce

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Interference Protection Criteria

- NTIA/ITS provides receiver susceptibility data to support the development of Interference Protection Criteria.
- **Dfn. Interference Protection Criteria (IPC):** A relative or absolute interfering signal level defined at the receiver input, under specified conditions, such that allowable performance degradation is not exceeded.



Satellite DTV Susceptibility to undesired UWB signals.

UWB Regulatory Timeline

Sep 98: FCC issued a Notice of Inquiry [1] to investigate authorization of unlicensed UWB. Responses highlighted UWB emissions would overlay restricted bands and outdated measurement procedures.

May 00: FCC issued a Notice of Proposed Rulemaking [2] for unlicensed UWB calling for testing and analyses.

Jan 01: NTIA/ITS studied the temporal and spectral characteristics of state-of-the-art pulsed UWB devices [3].

Jan 01: NTIA/OSM studied compatibility between UWB and selected Federal systems [4] (e.g., radar, air traffic control, fixed sat, and precision landing).

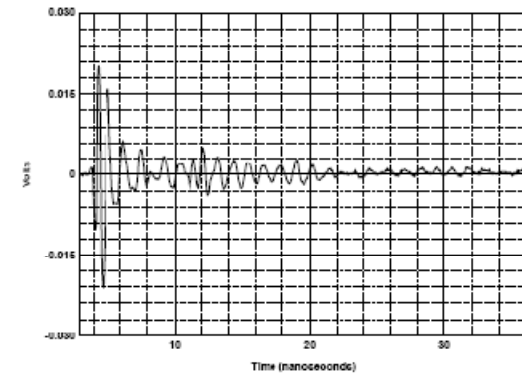


Figure ES.1(c). The shape of the pulse shown in (a) radiated, i.e. "in space."

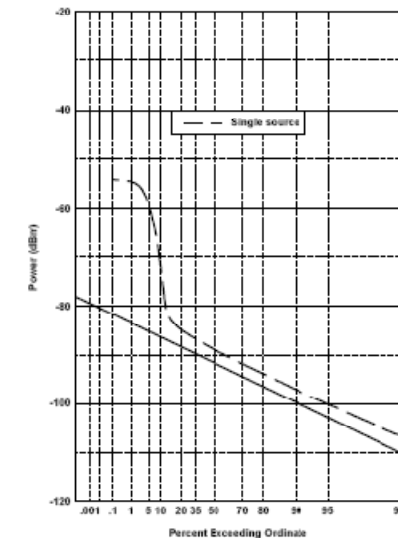


Figure ES.2. APDs for Gaussian noise and a UWB signal.

UWB/GPS Compatibility Analyses

Feb 01: NTIA/ITS performed a conducted experiment to obtain GPS interference protection thresholds (referenced at the GPS antenna) for various types of pulsed UWB signals [5].

Mar 01: NTIA/OSM analyzed a number of potential UWB/GPS operational scenarios and determined the maximum allowable EIRP at which UWB devices can operate w/o causing interference to GPS [6].

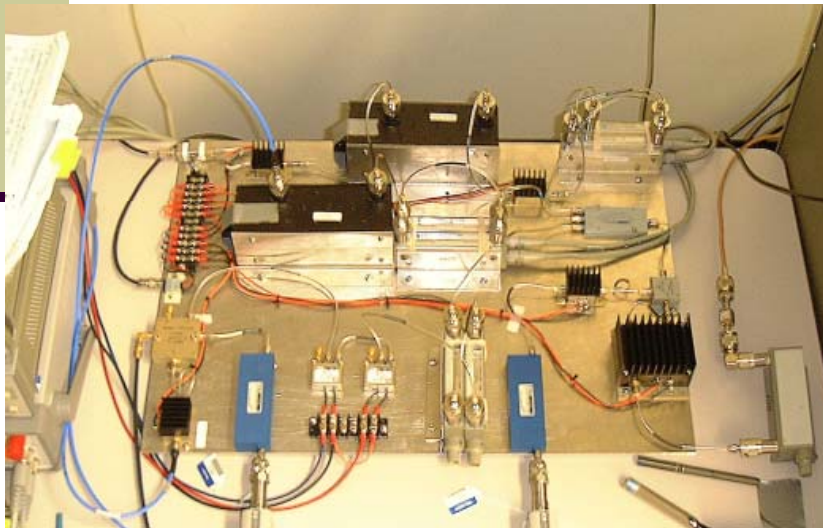
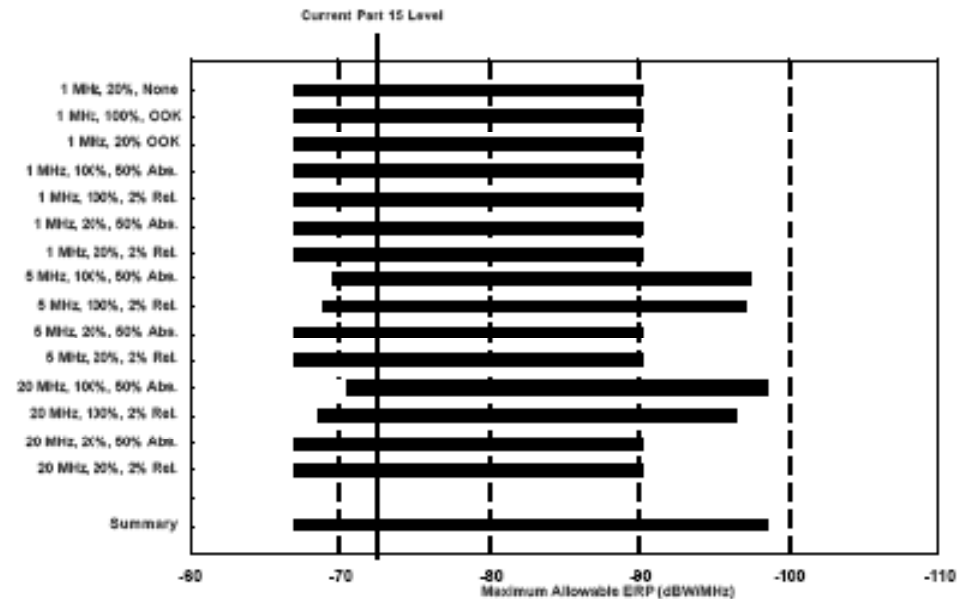


Figure 4.1.1. GPS Interference test bed.

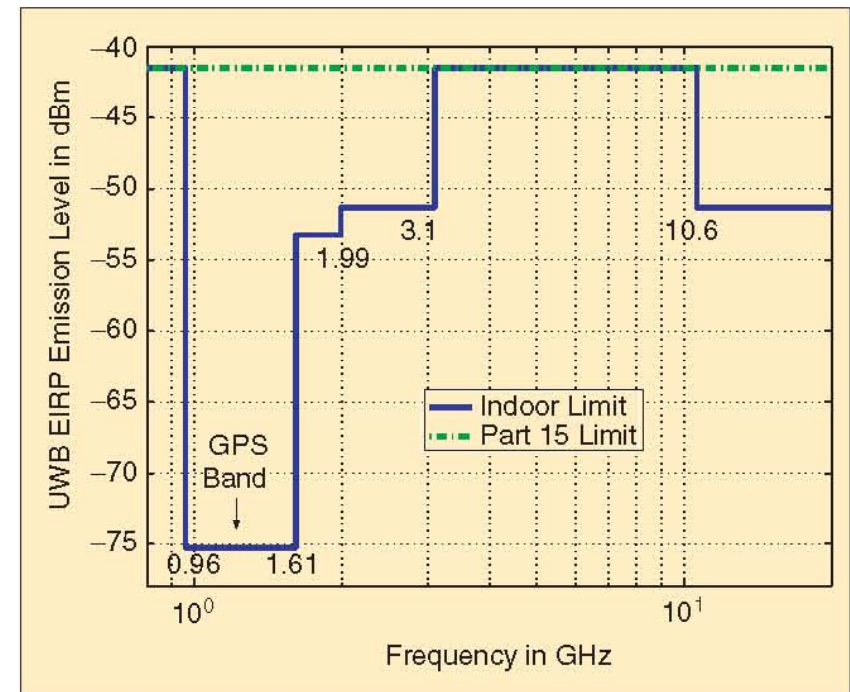


Indoor UWB Communications

Apr 02: FCC legalized unlicensed UWB emissions for indoor comm from 3.1 – 10.6 GHz [7].

Mar 04: DS-UWB and MB-OFDM UWB seek standardization from IEEE 802.15 working group 3a on high-rate (>20 Mbps) wireless personal area network (WPAN) devices.

Feb 05: NTIA/ITS measured interference effects of modern UWB signals on C-band satellite DTV [9] – [11].



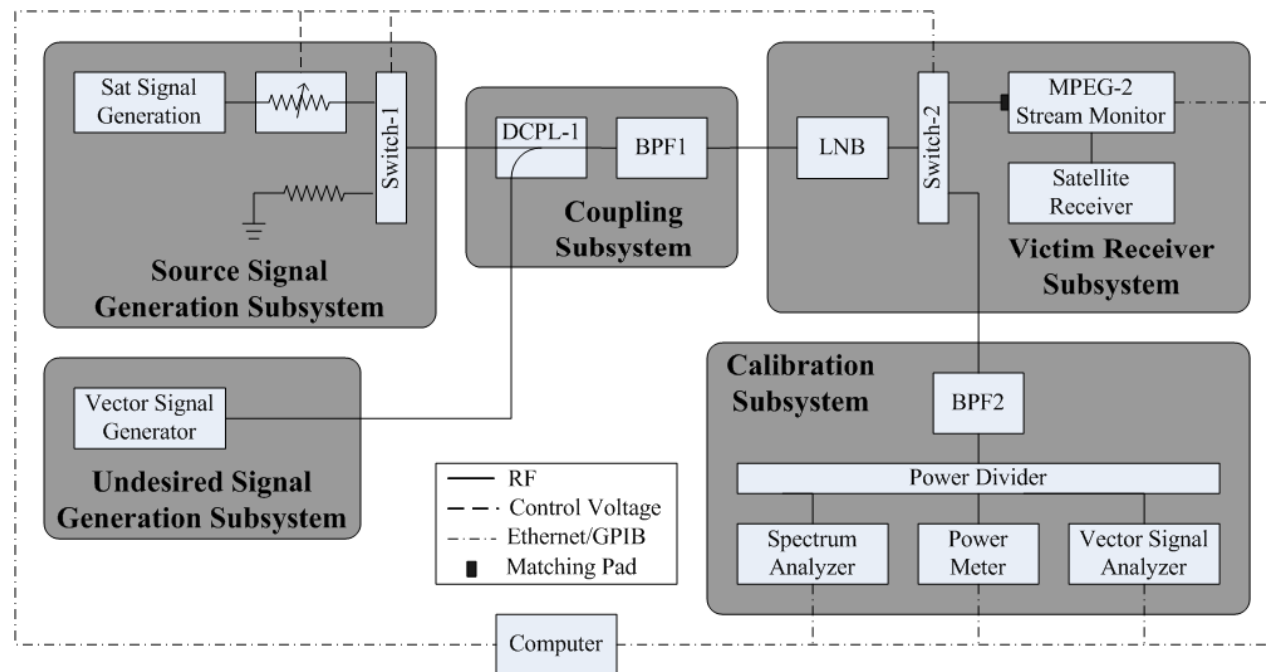
▲ 1. FCC spectral mask for indoor commercial systems.

C-Band Satellite DTV

- Operational frequencies (3.7 – 4.2 GHz) are within UWB band.
- Satellite signals are weak at Earth stations making them vulnerable to interference.
- Satellite TV broadcast technologies cover a broad range of communication techniques.
- Quantitative performance metrics are available from instruments developed by TV broadcasters.



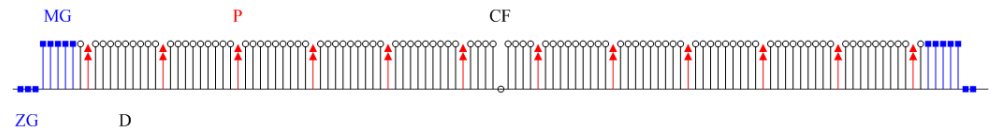
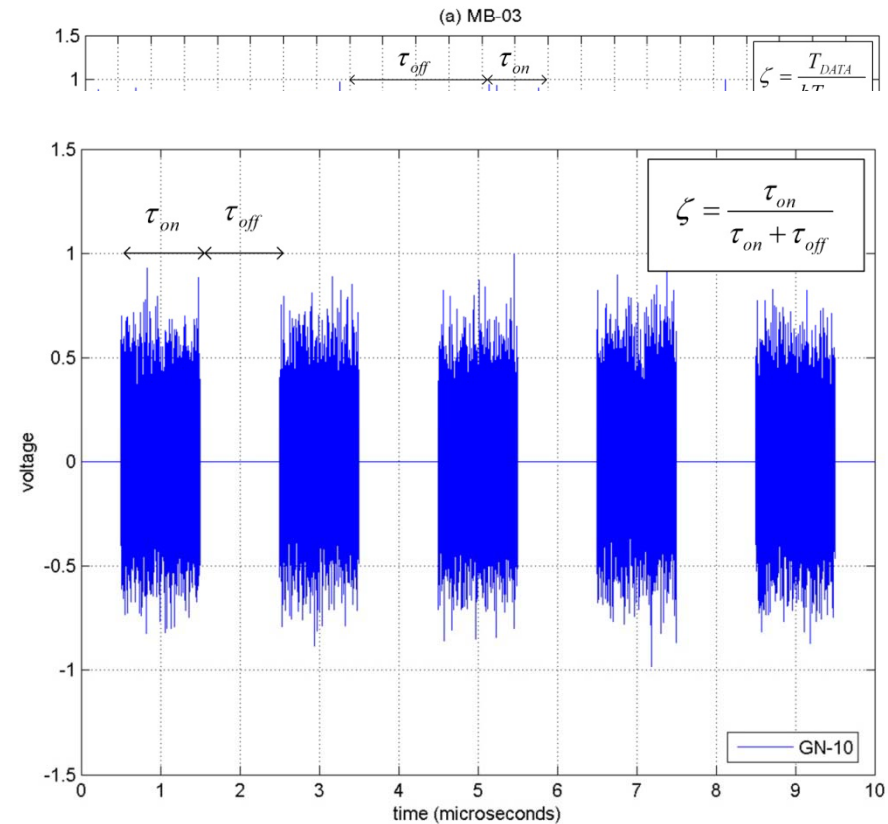
Methodology



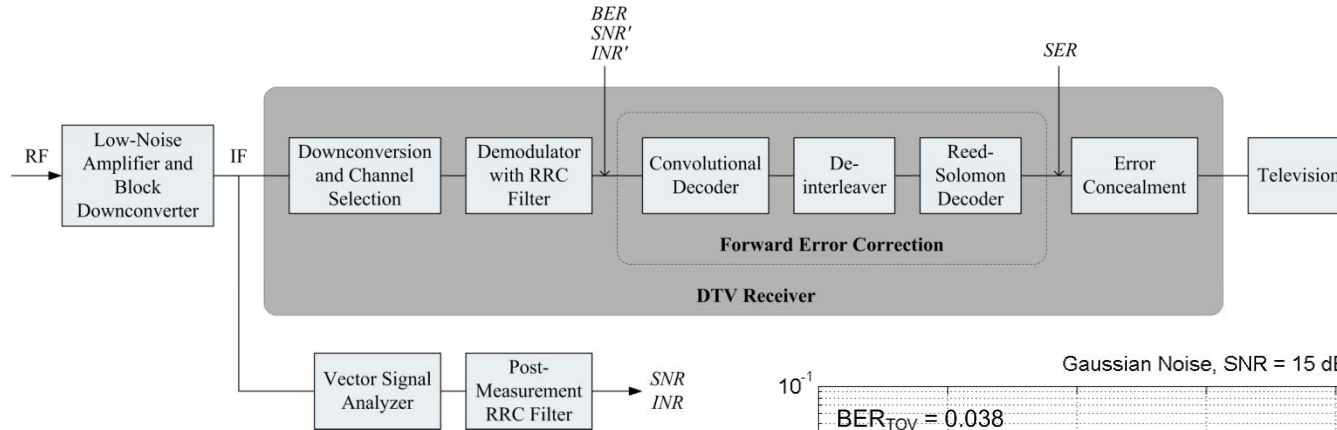
- ❑ **Conducted, computer-controlled laboratory experiment** to improve precision.
- ❑ **Modular test bed** allows for other systems to be evaluated more easily.
- ❑ Undesired signals are generated with **Vector Signal Generator** to remove dependence on manufacturers to provide signal sources.
- ❑ **Objective performance metrics, e.g., BER and SER**, quantify interference effects of the undesired signals.

Undesired Signals

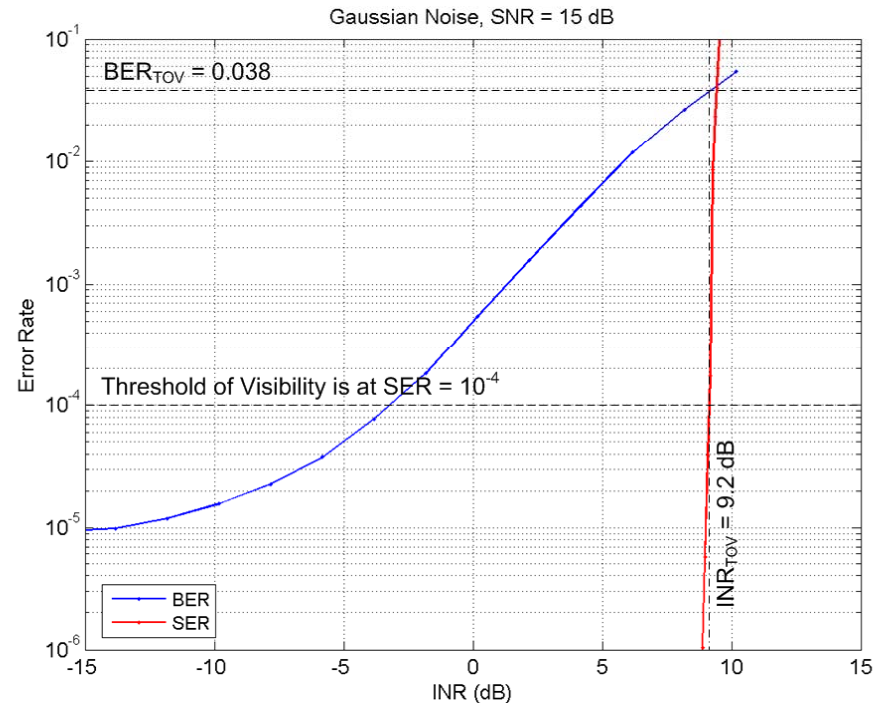
- Direct-Sequence UWB
- MB-OFDM UWB
- Dithered-Pulse UWB
- Gaussian noise
- Periodic Gated Gaussian Noise
 - On-times = 10, 100, 1000, 10000 ns
 - Duty cycle = 50%, 25%, 12.5%, 6.25%
- Gated Gaussian noise with temporal characteristics of MB-OFDM



DTV Susceptibility Metrics

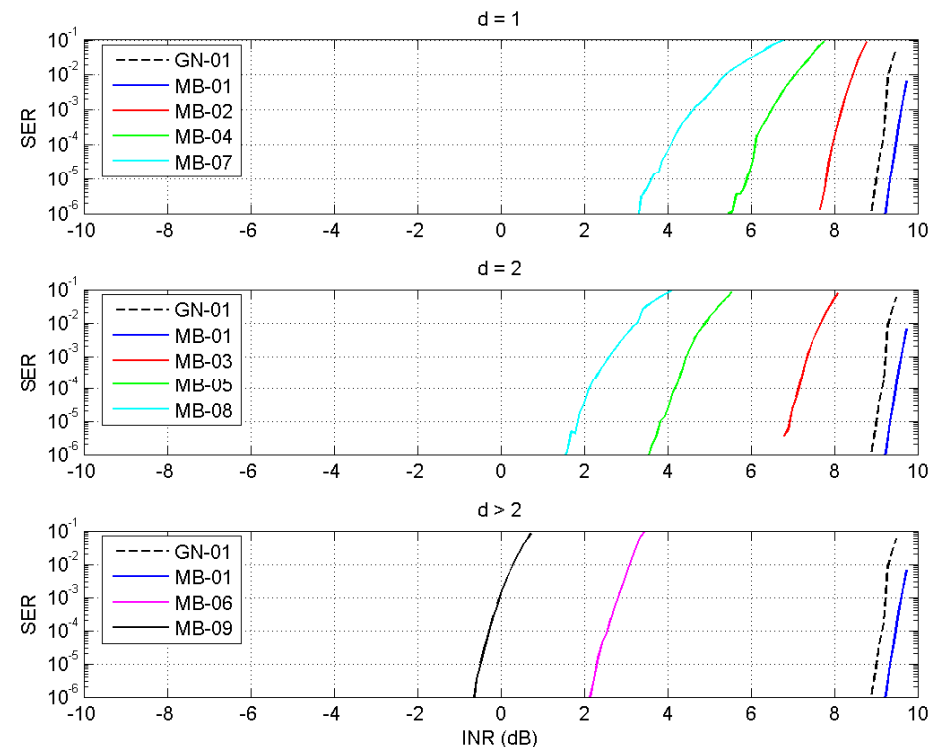


- Bit Error Rate (BER) quantifies demodulator performance.
- Segment Error Rate (SER) quantifies performance of demodulator + signal processing.



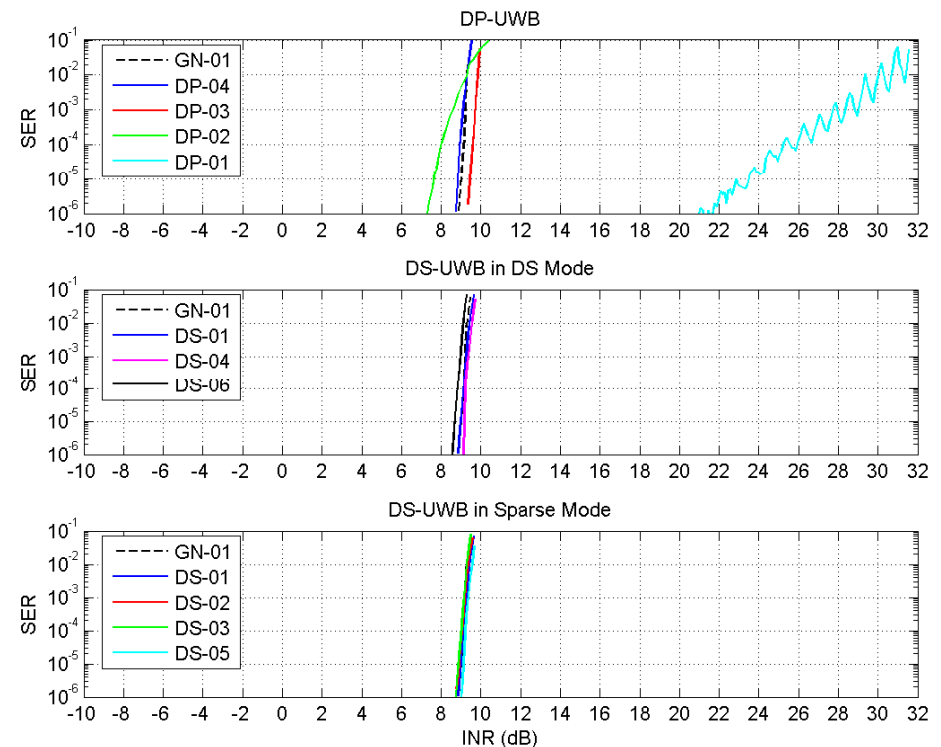
Gated Noise Parameter Study

- GN with short temporal characteristics relative to $1/BW$ (51 ns) of DTV receiver have interference effects similar to that of Gaussian noise.
- Slightly longer temporal characteristics cause more interference in terms of mean power because off-times are too short to allow much recovery, and lower duty cycles correspond to less average power.
- Same goes for MB-OFDM.



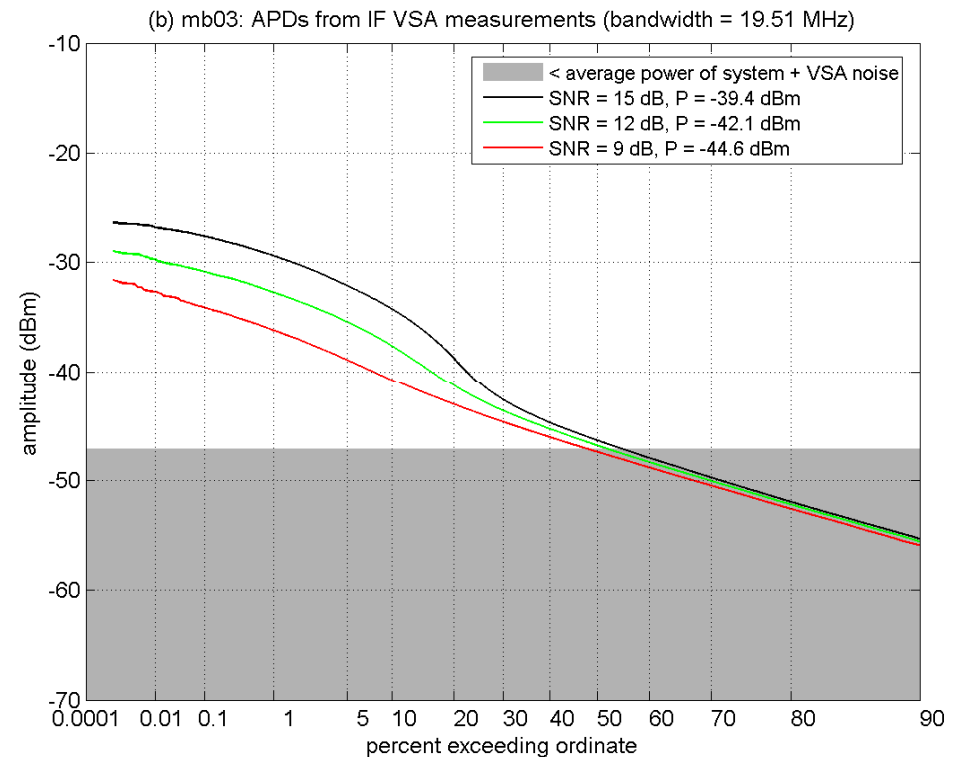
DP- and DS-UWB Parameter Study

- Again, DP- and DS-UWB with short temporal characteristics (relative to $1/BW$ of DTV receiver) have interference effects similar to that of Gaussian noise.
- All tested DS-UWB signals were similar to Gaussian noise when limited to BW of DTV receiver.
- DP-01 with a pulse period of 10 microseconds causes less interference because FEC has time to recover.



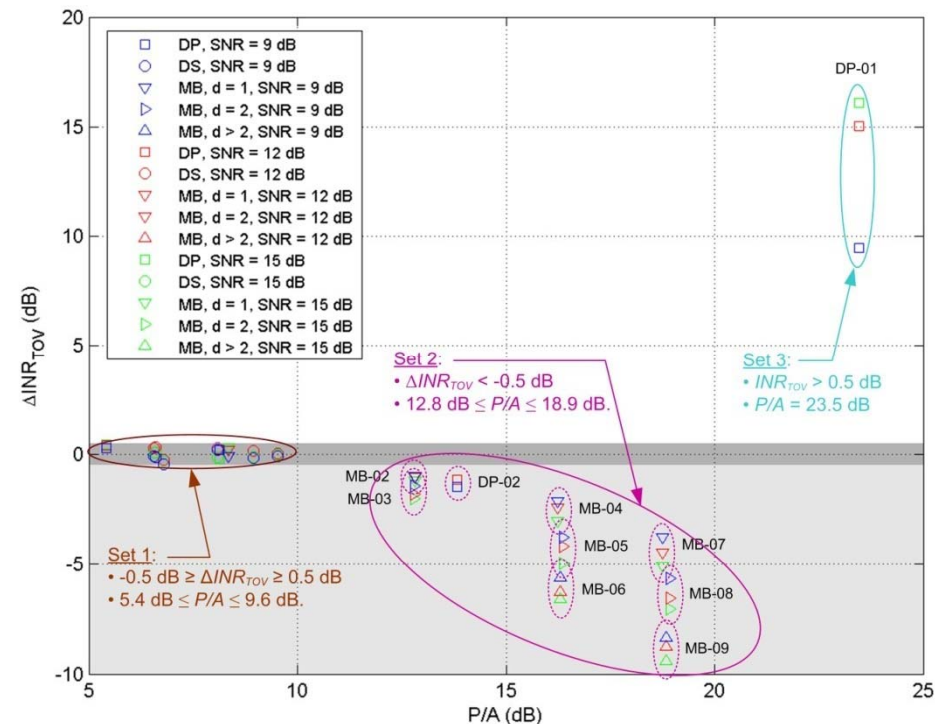
Signal Characterization

- Signal characterization measurements with a Vector Signal Analyzer provided amplitude and phase information for post-measurement filtering and analyses.
- Statistical measures describe the signals amplitude, frequency, and temporal characteristics.
- Measurements were made of undesired signals only and undesired signals plus receiver noise.



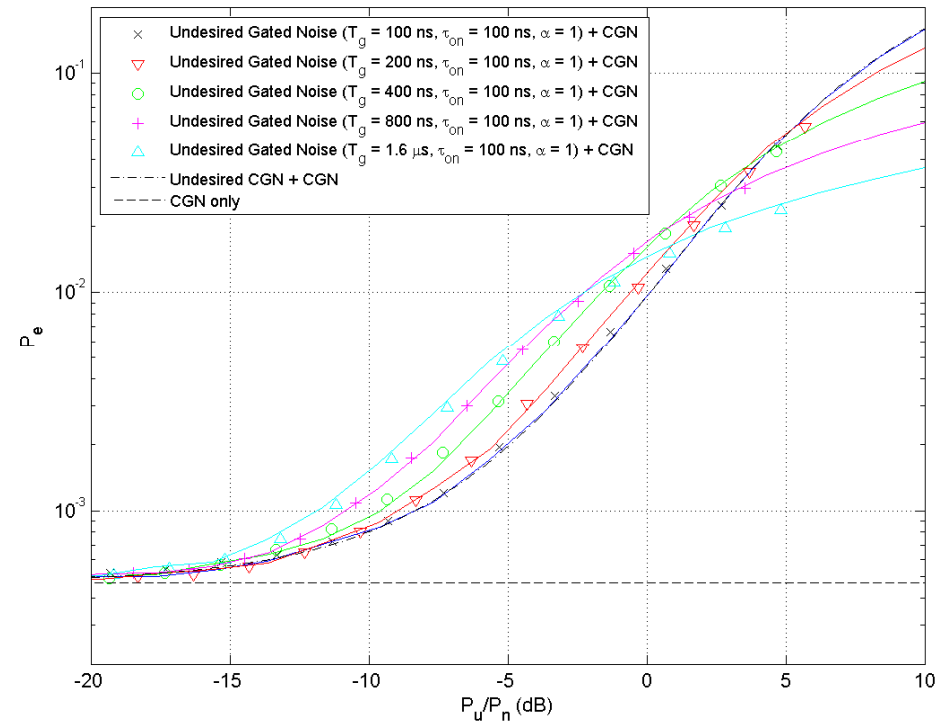
Susceptibility vs Signal Characteristics

- Amplitude, frequency, and temporal characteristics were calculated for the undesired signals.
- Some characteristics of the undesired signals band-limited to BW of DTV receiver are useful for predicting susceptibility.
- There is a long way to go, however, before generalizations can be made.



Analytic and Simulation Results

- Recently, NTIA has dedicating resources to developing Best Practices for Spectrum Engineering.
- One outcome was the development of a quasi-analytic approach to assessing digital modulator performance in the presence of various undesired signals [12].
- Preliminary results show good agreement with measurements.
- Simulation tools are also being developed at NTIA/ITS for a more time-efficient evaluation of the effects of undesired signals on receiver signal processing.



UWB Publications

- [1] *Revisions of Part 15 of the Commission's Rules Regarding UWB Transmissions*, FCC Notice of Inquiry, ET Docket No. 98-153, 63 Fed. Reg 50184, Sep. 21, 1998.
- [2] *Revisions of Part 15 of the Commission's Rules Regarding UWB Transmissions*, FCC Notice of Proposed Rulemaking, ET Docket No. 98-153, FCC 00-163, May 11, 2001.
- [3] W.A. Kissick, et al., *The temporal and spectral characteristics of UWB signals*, NTIA TR-01-383, Jan. 2001.
- [4] L.K. Brunson, et al., *Assessment of Compatibility Between UWB Devices and Selected Federal Systems*, NTIA SP 01-43, Jan. 2001.
- [5] J.R. Hoffman, et al., *Measurements to determine potential interference to GPS receivers from UWB transmission systems*, NTIA TR-01-384, Feb. 2001.
- [6] D.S. Anderson, et al., *Assessment of Compatibility Between UWB Systems and GPS Receivers*, NTIA SP 01-45, Feb. 2001.
- [7] *First Report and Order in the matter of ET Docket 98-153, FCC 02-48*, Apr. 22, 2002.
- [8] J.R. Hoffman, et al., *Measurements to determine potential interference to public safety radio receivers from UWB transmission systems*, NTIA TR-03-402, Jun. 2003.
- [9] M.G. Cotton, et al., *Interference potential of UWB signals, Part 1: Procedures to characterize UWB emissions and measure interference susceptibility of C-band satellite DTV receivers*, NTIA TR-05-419, Feb. 2005.
- [10] M.G. Cotton, et al., *Interference potential of UWB signals, Part 2: Measurement of gated-noise interference to C-band satellite DTV receivers*, NTIA TR-05-429, Aug. 2005.
- [11] M.G. Cotton, et al., *Interference potential of UWB signals, Part 3: Measurement of UWB interference to C-band satellite DTV receivers*, NTIA TR-06-437, Feb. 2006.
- [12] M.G. Cotton, *A Methodology for Approximating BPSK Demodulator Performance in the Presence of Various Undesired Signals*, ISART, Jun. 2008.

*http://www.its.bldrdoc.gov/programs/uwb_interference/

