Radio Communications for Emergency Responders in High-Multipath Outdoor Environments

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Wireless technology

Responders would like to use new wireless technology *reliably*
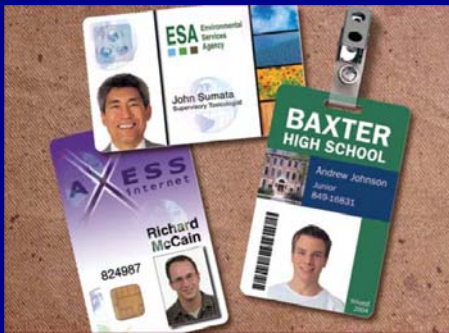
Unique needs of emergency responder community:
- Large public buildings
- Tunnels, parking garages, basements
- Factories, refineries, utility plants

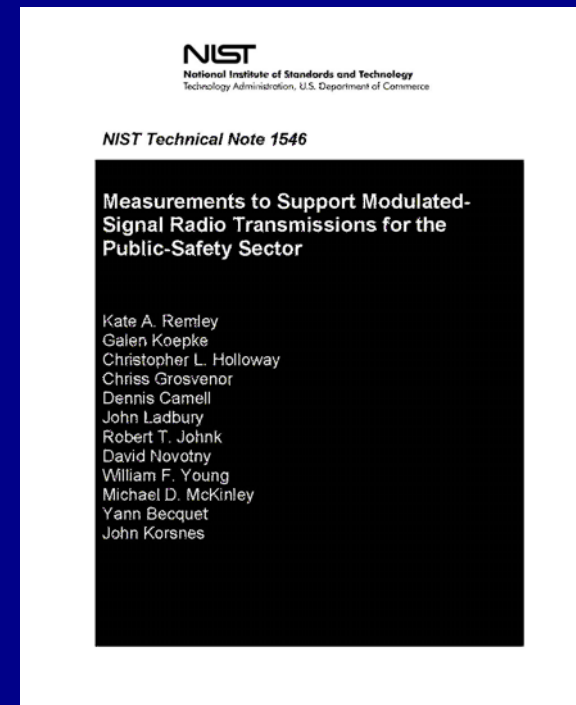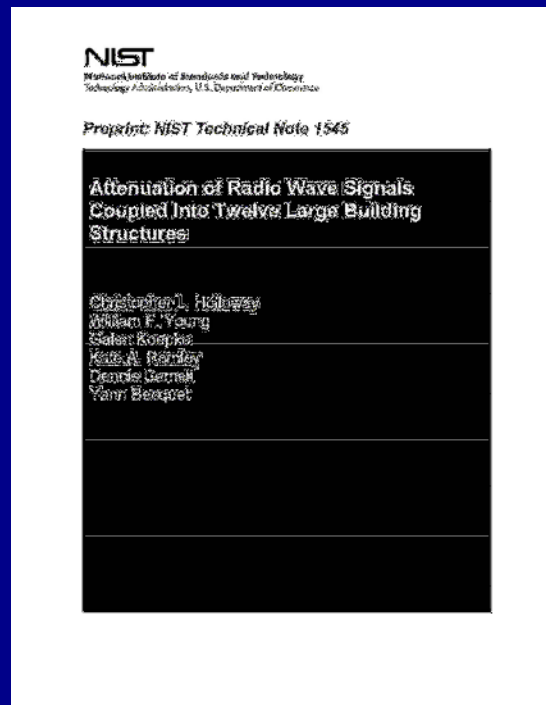# Wireless environment for emergency responders

NIST project to gather propagation data in large public structures

- Large body of measured data in open literature
- Interpretation of key environmental effects
- Development of performance metrics, lab-based tests
- Support for standards development efforts
- Funded by DOJ Community-Oriented Policing Services and DHS Office of Standards

Wireless environment for emergency responders

Measurements consist of:

- Received signal strength at key frequencies
- Wideband excess path loss, RMS delay spread
- Modulated-signal measurements

Building Structures:

- Five office buildings
- One supermarket
- One large shopping mall
- One large sports stadium
- One hotel/small convention center
- One large convention center
- Oil refinery
- One large apartment building
- Subterranean tunnel
- Office building corridor

Radiowave penetration in large public buildings

Standing structures

Frequency: 448.6 MHz
Mean: -45.7
Std Dev: 5.9

Frequency: 162.0 MHz
Mean: -38.9
Std Dev: 6.8
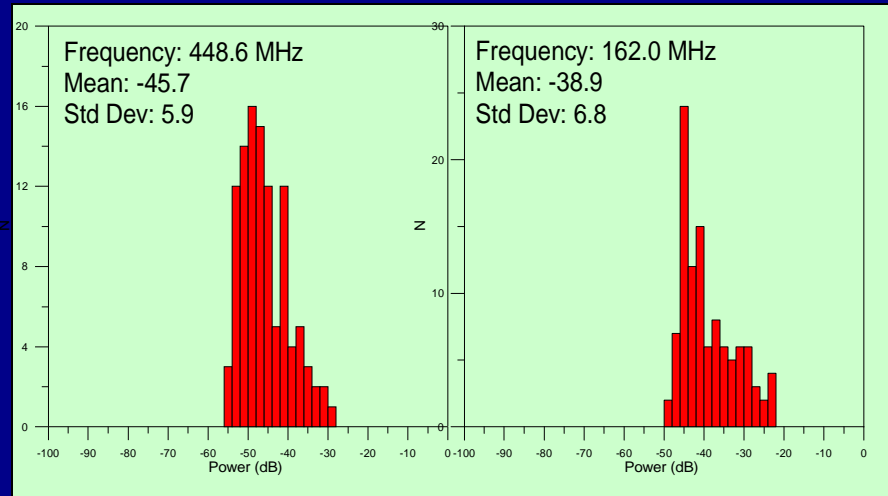
Radiowave penetration in large public buildings

Collapsed buildings
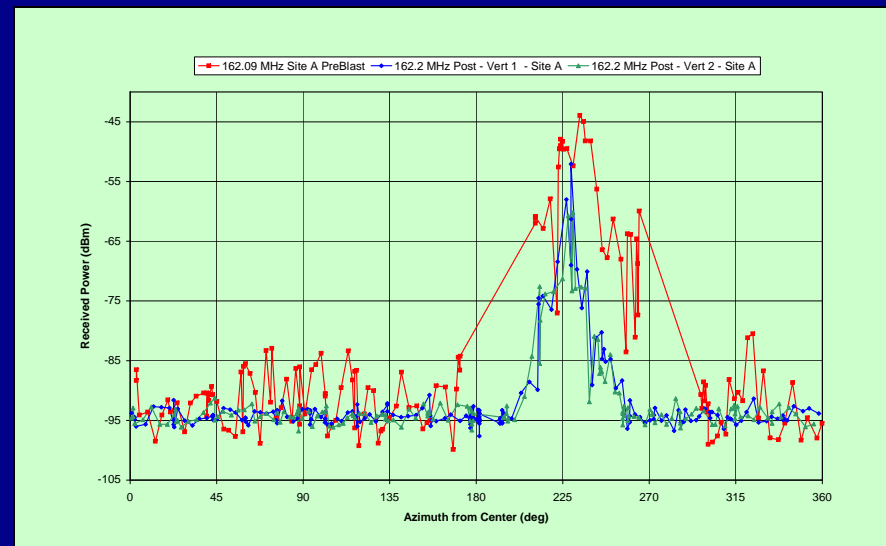

14-story apartment building
New Orleans
January 2004

Old Convention Center
Washington, D.C.
December 2004

Veteran's Stadium
Philadelphia
March 2004

Tests in oil refinery

Difficult radio environment

- Metal surfaces, heavy equipment
- Large footprint
- Mobile machinery and users

- Open structure
- Tunnel-like behavior

Test set-up mimics incident deployment

Base site outside facility:
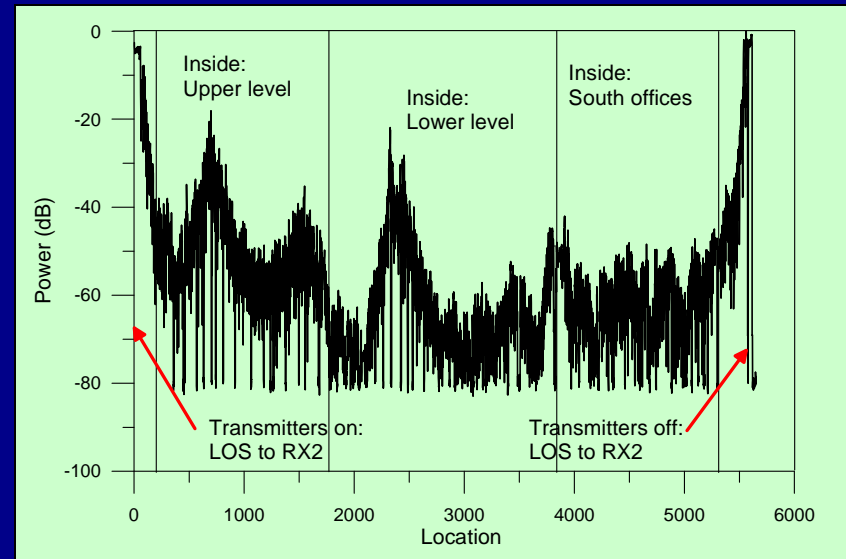- Equipment located in van, fixed location

Responder site moves through facility:
- Single frequency
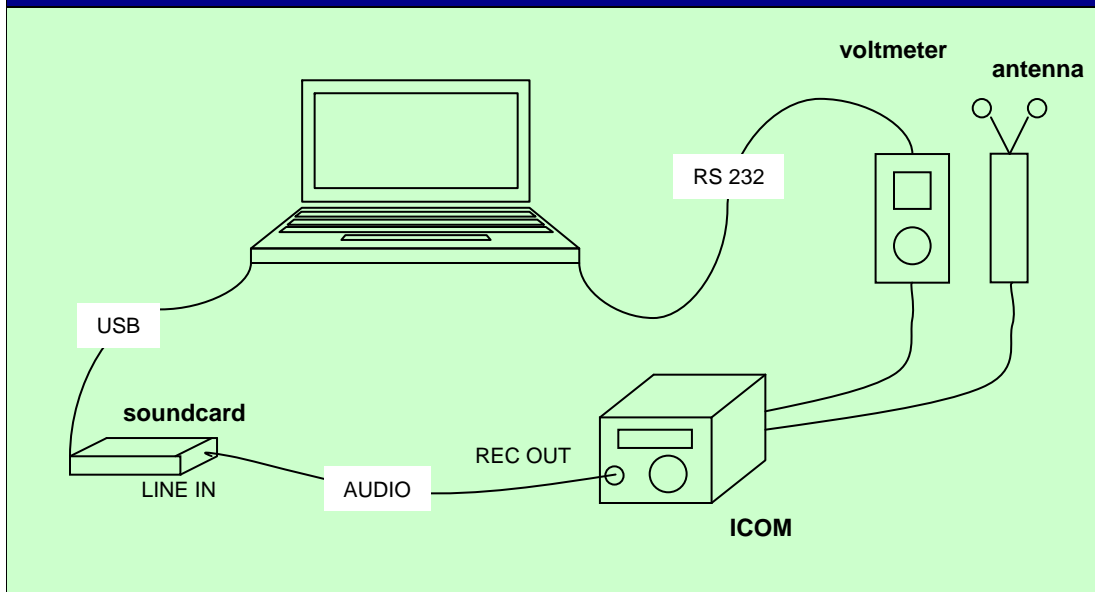- Broadband UWB (synthetic pulse)
- Modulated Signal

Received signal strength measurements

Radios are tuned to public safety frequencies and carried throughout buildings. Data recorded continuously.
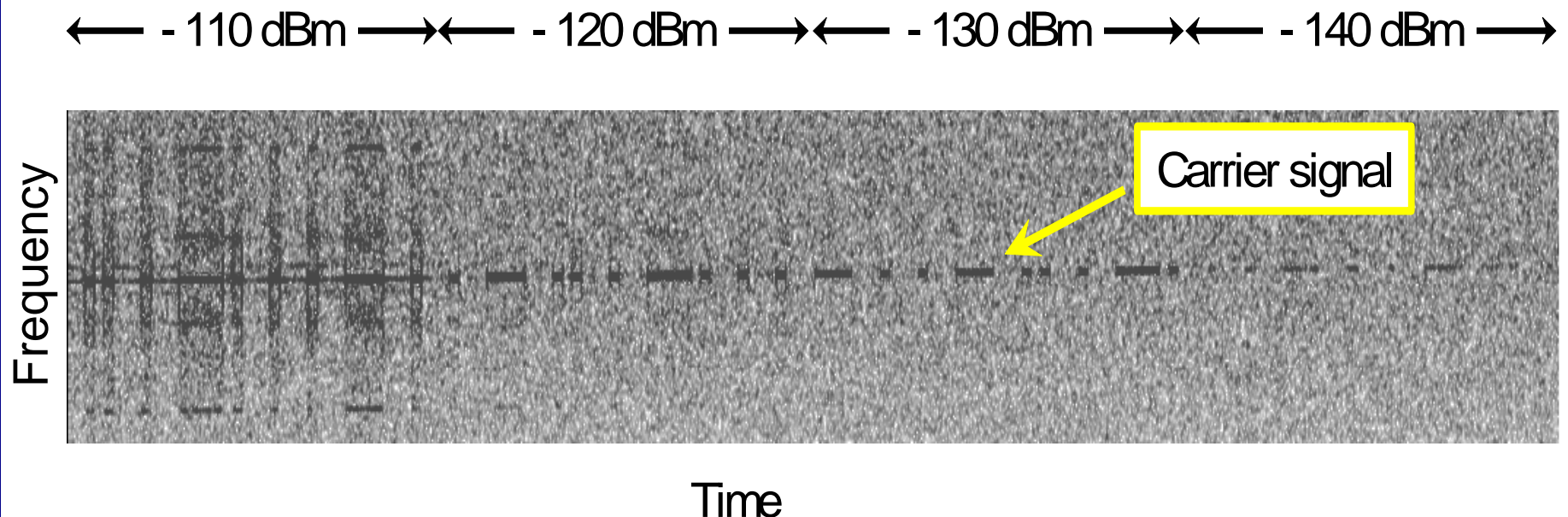

transmitter path
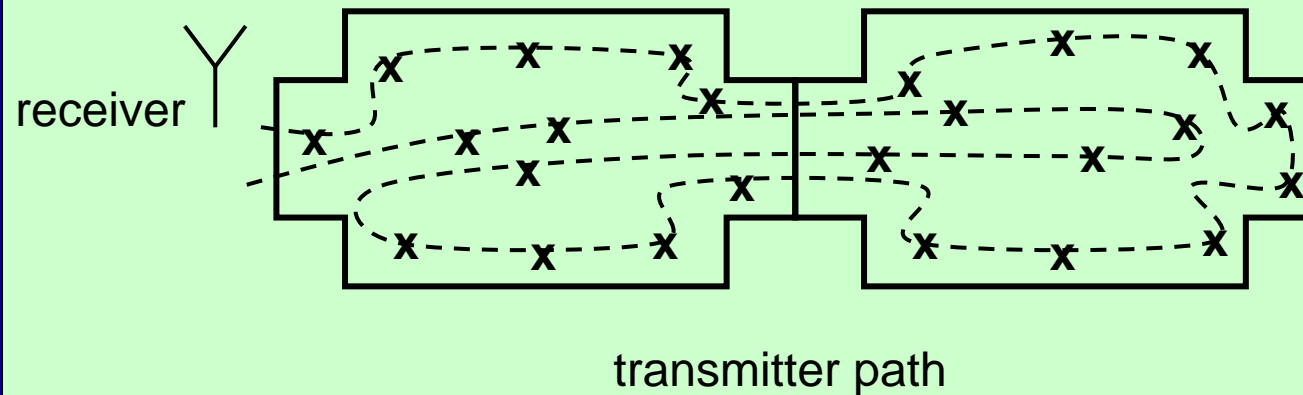
Calibrated receiver system

Allows researchers, emergency responders to study difficult radio environments
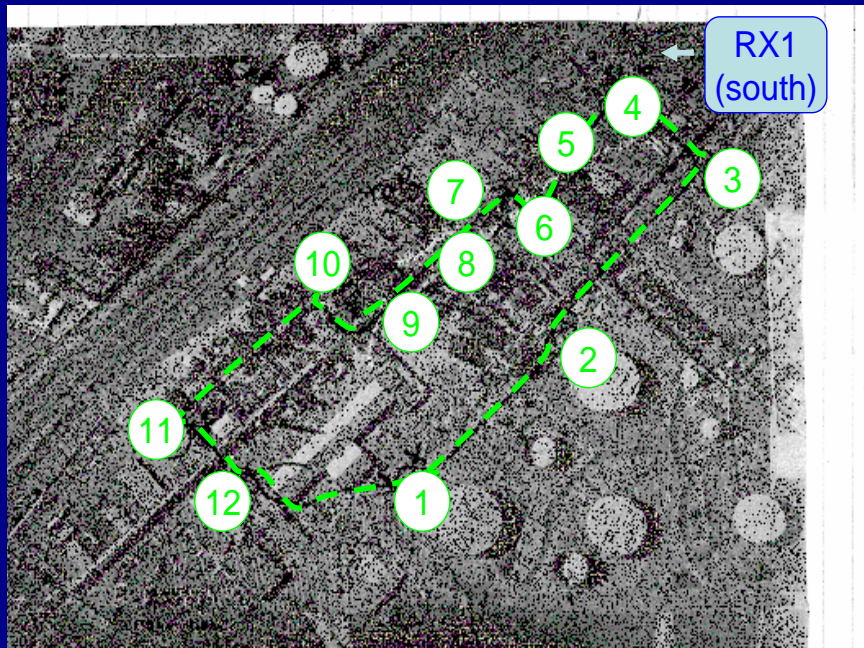

Commercially available receiver and PC sound card are inexpensive and straightforward to use
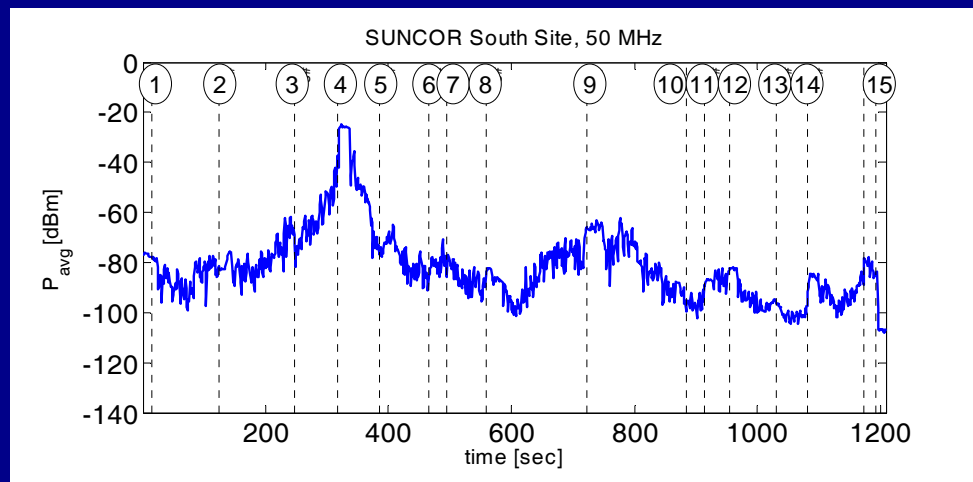
Increased dynamic range

- Morse Code signals illustrate concept

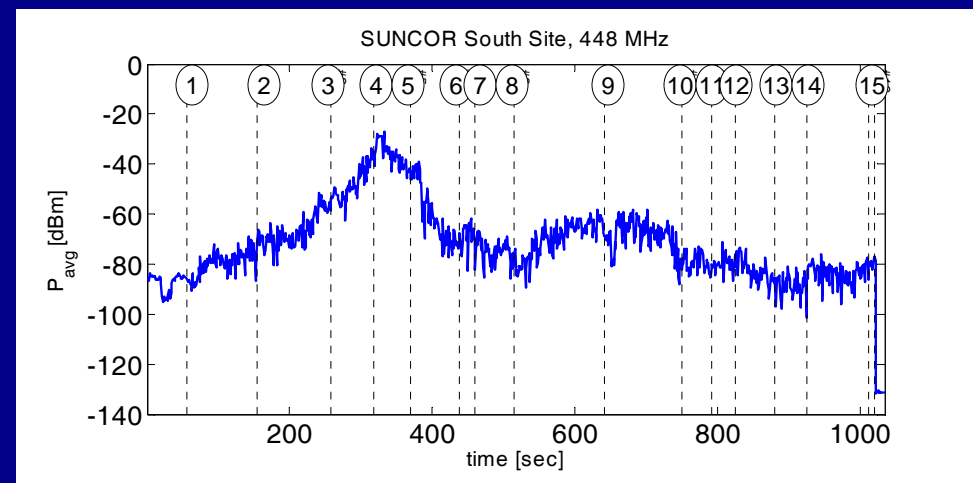- Narrowband detection picks signals out of noise
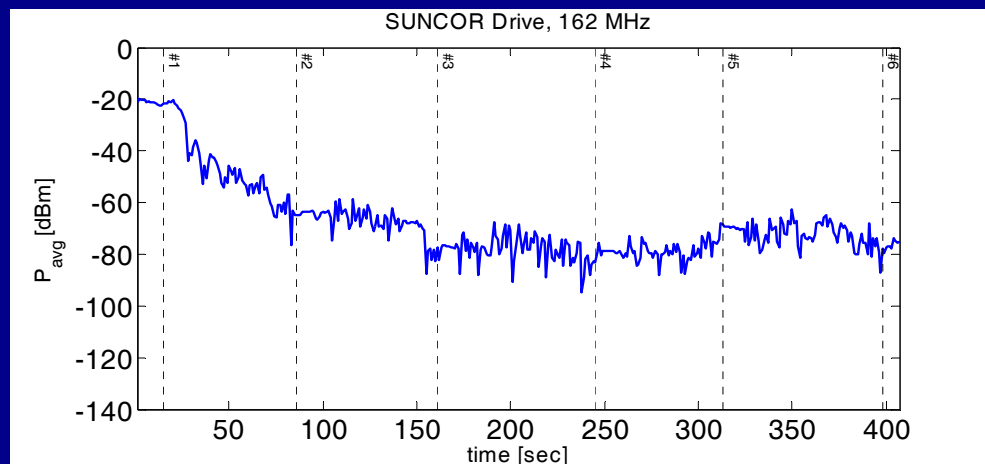
Receiver data

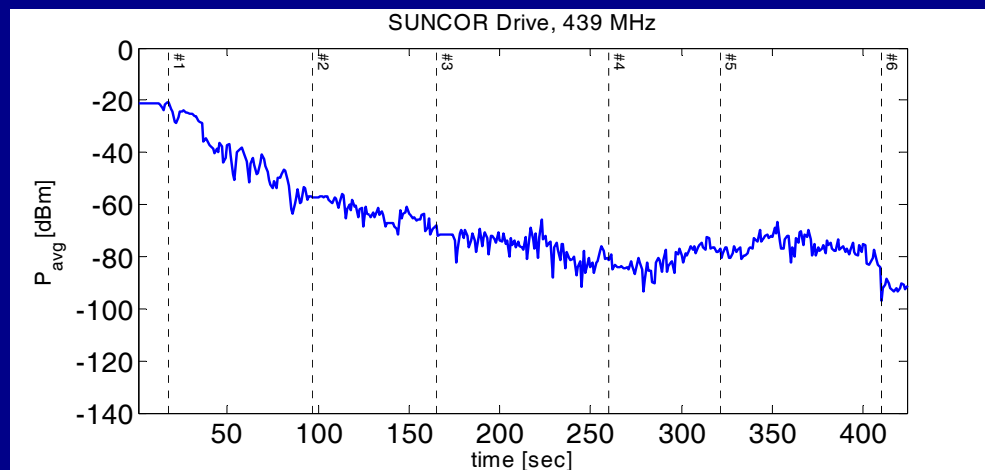Walk Through

50 MHz

448 MHz
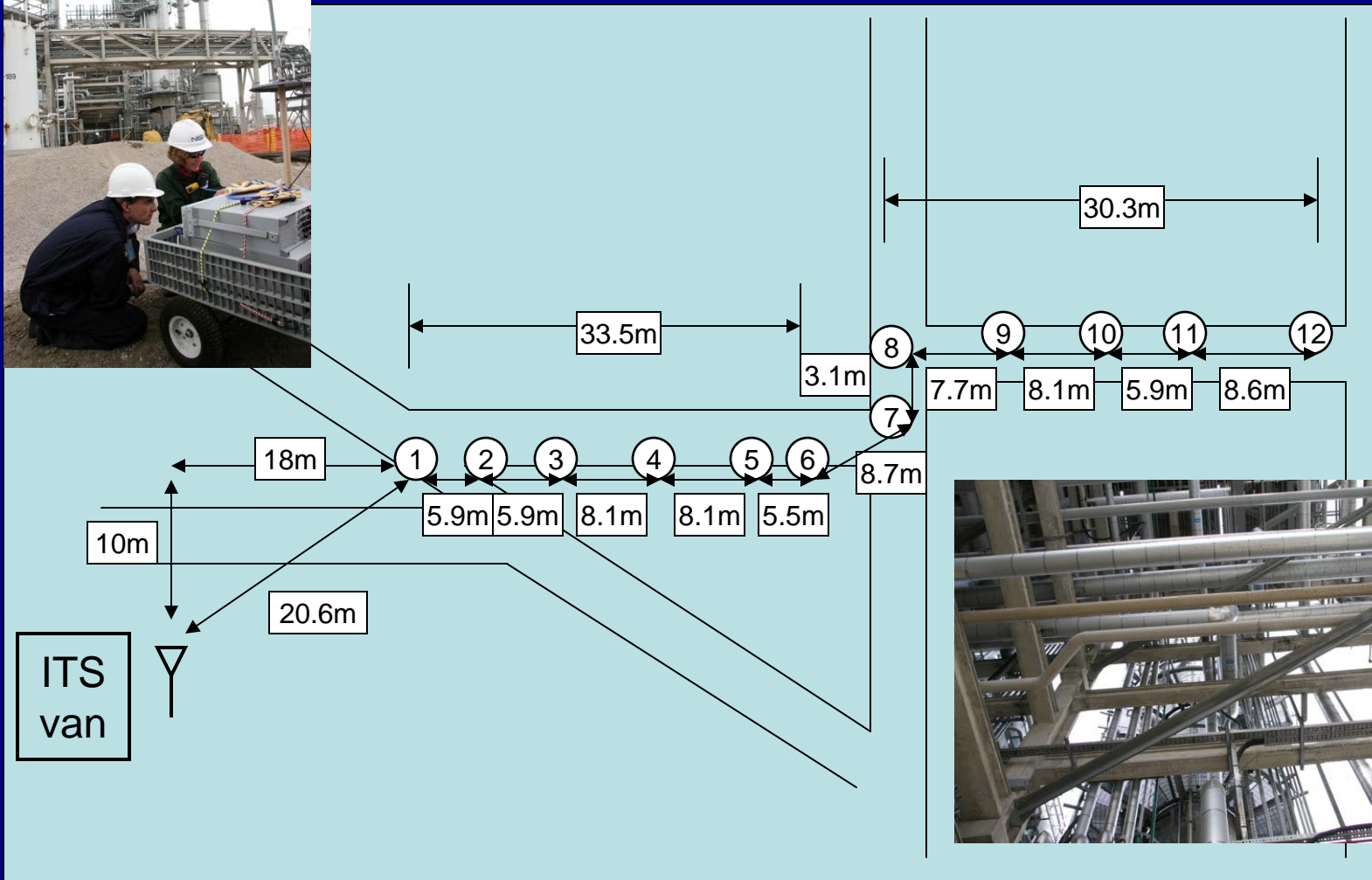
Receiver data

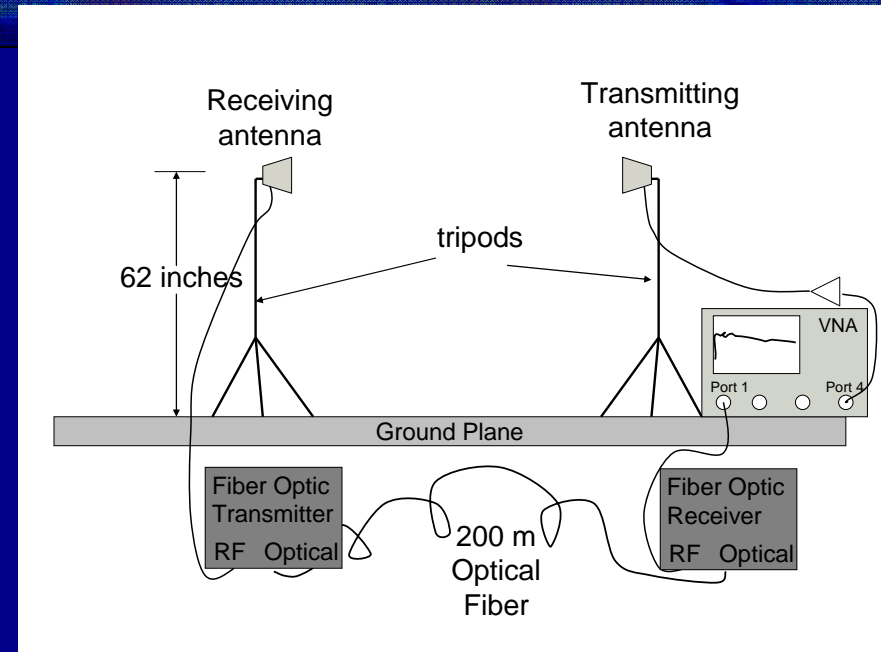Drive around perimeter

162 MHz

439 MHz

Synthetic pulse and modulated-signal
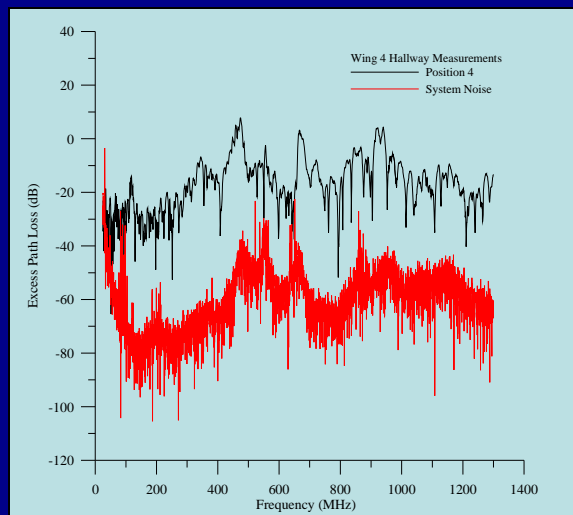
Test point locations
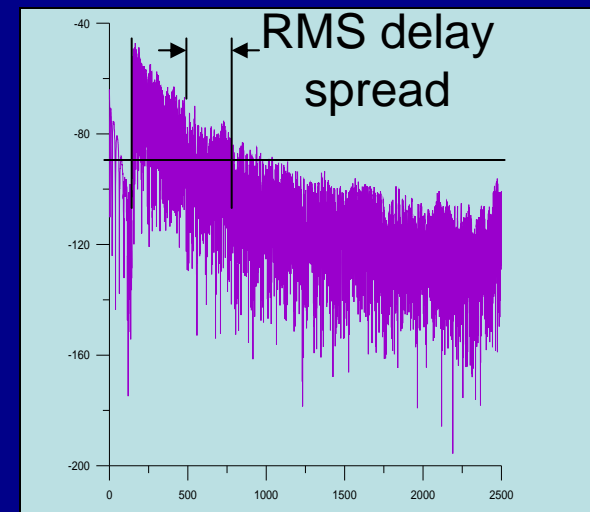
UWB synthetic-pulse measurement system

- Collect data over wide frequency band
- Fourier transform to time domain
- Synchronize using optical fiber
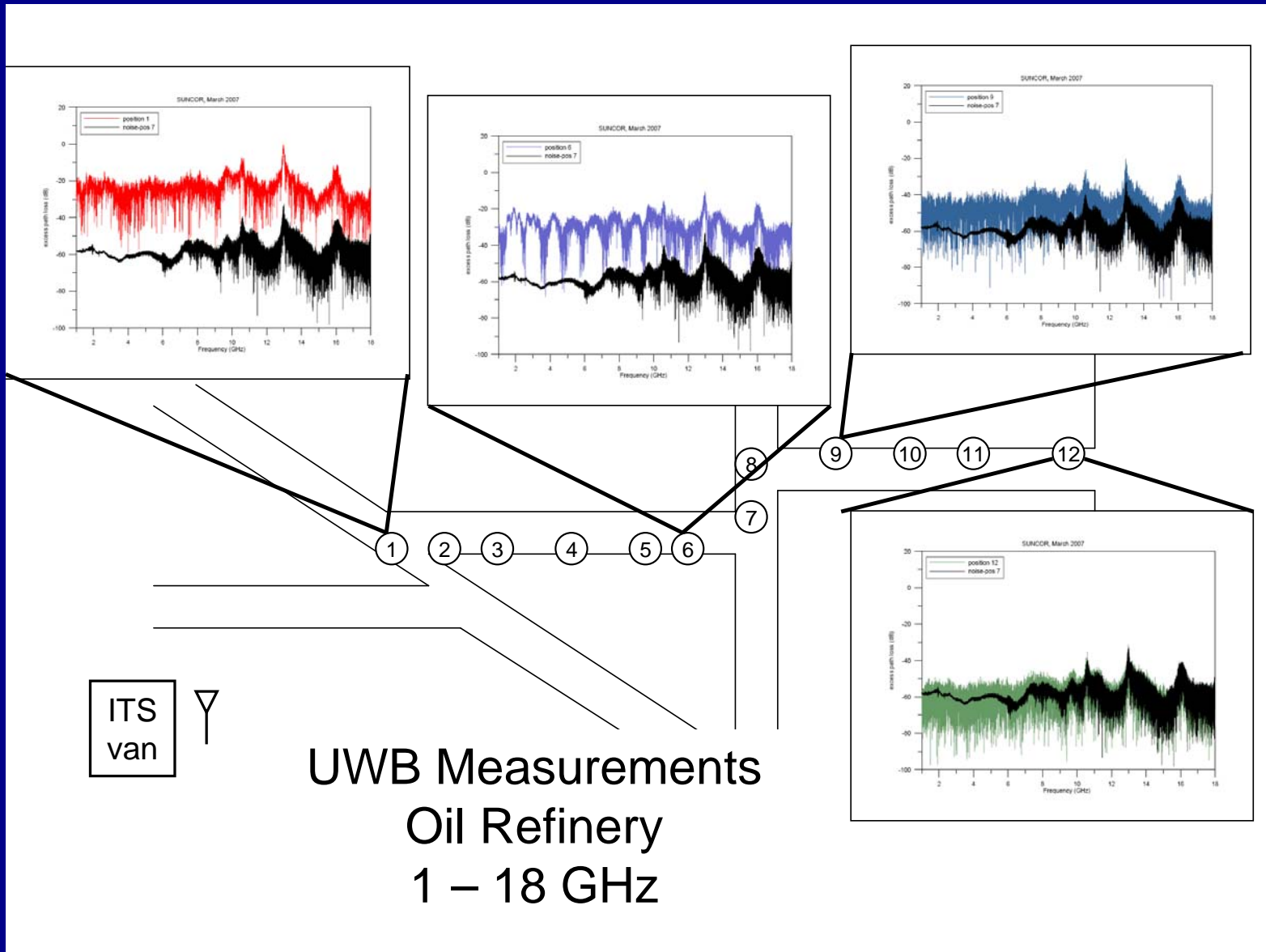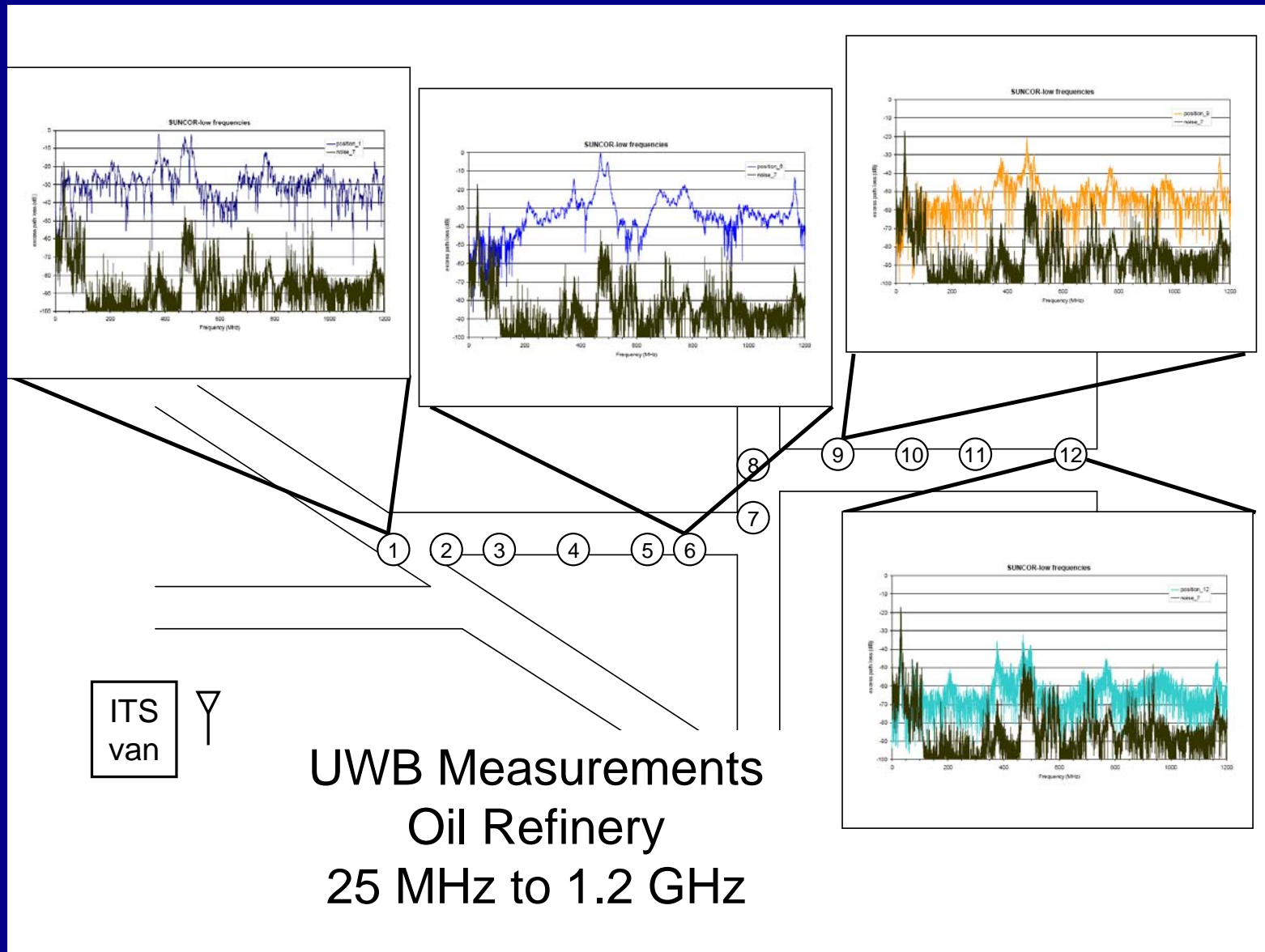- Good for wideband characteristics, RMS delay spread

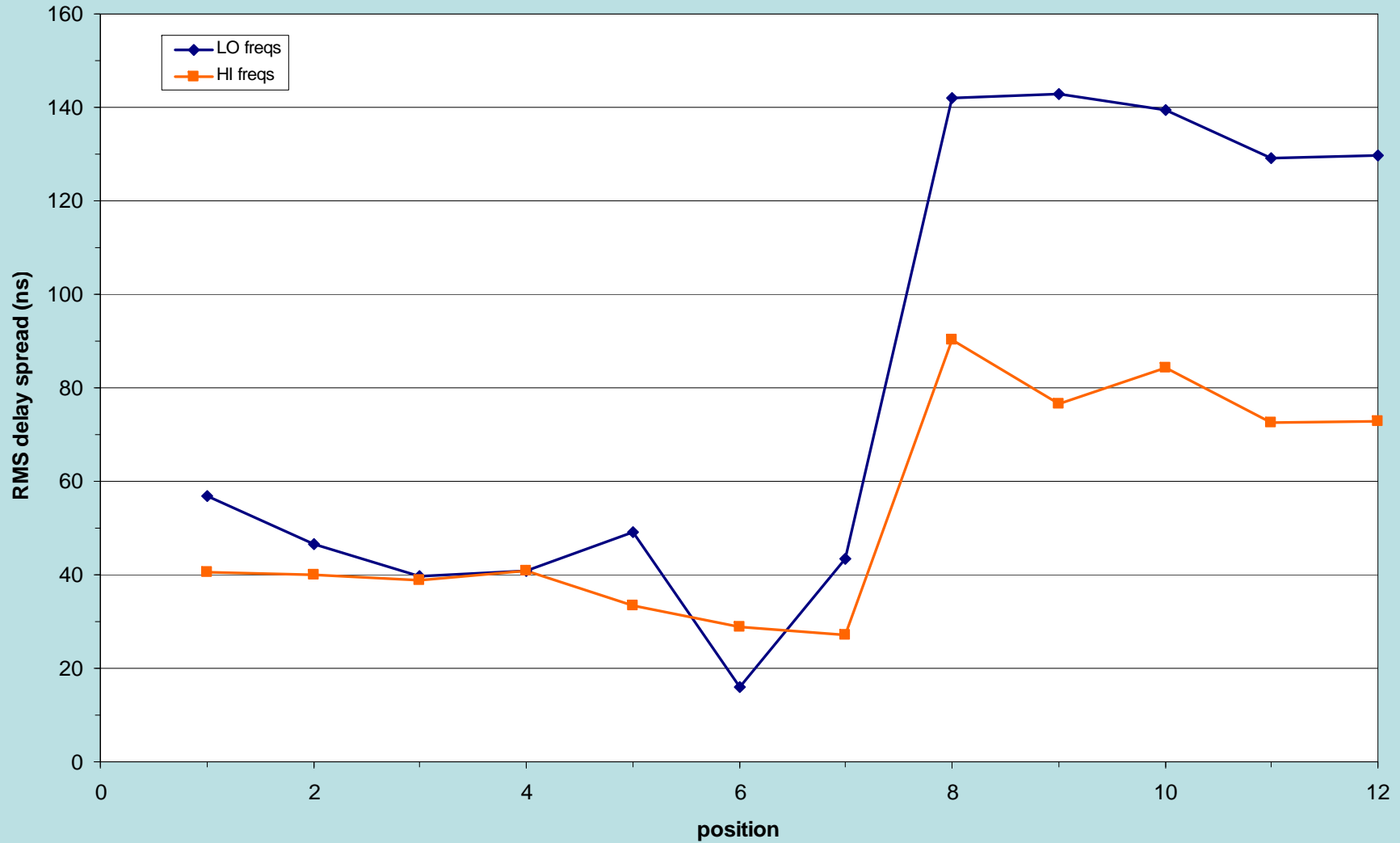Frequency domain response

Time-domain waveform

UWB Measurements
Oil Refinery
1 – 18 GHz

UWB synthetic pulse

UWB Measurements
Oil Refinery
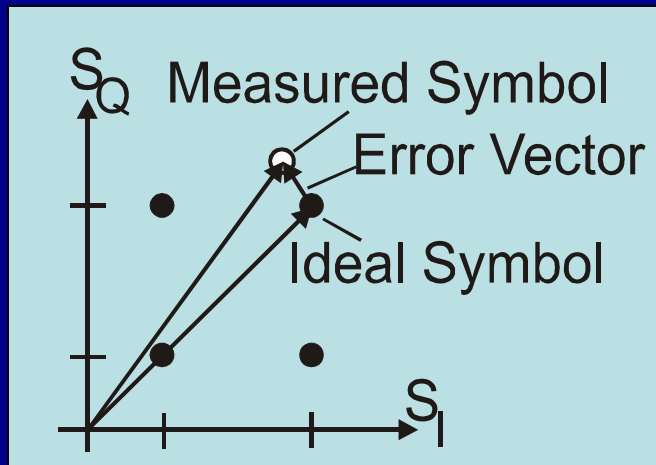25 MHz to 1.2 GHz
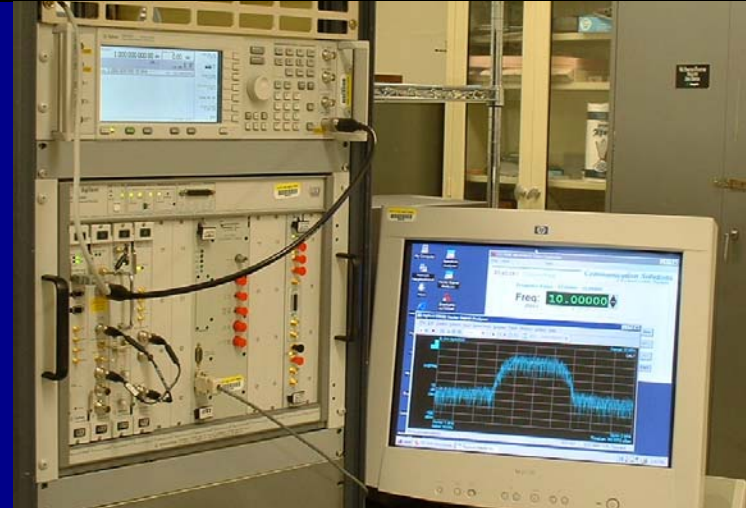
UWB synthetic pulse
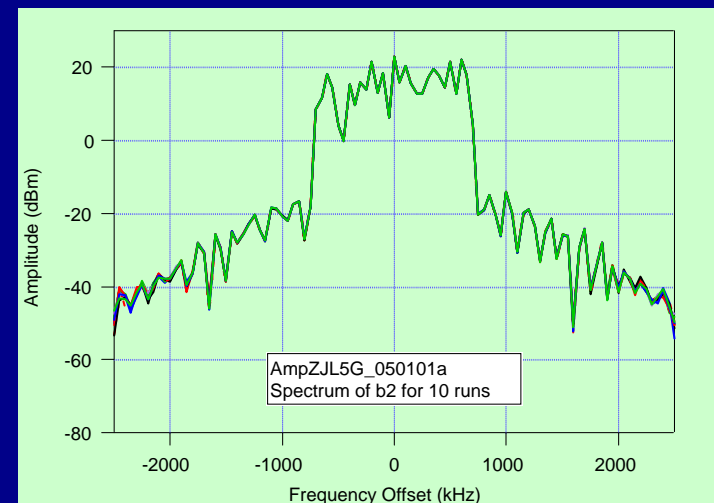

SUNCOR facility (3/9/07)

Digitally modulated signal measurements

Vector signal analyzer (VSA)

- Signal generator creates digital signals
- Detailed measurement around carrier (4.95 GHz, etc.)
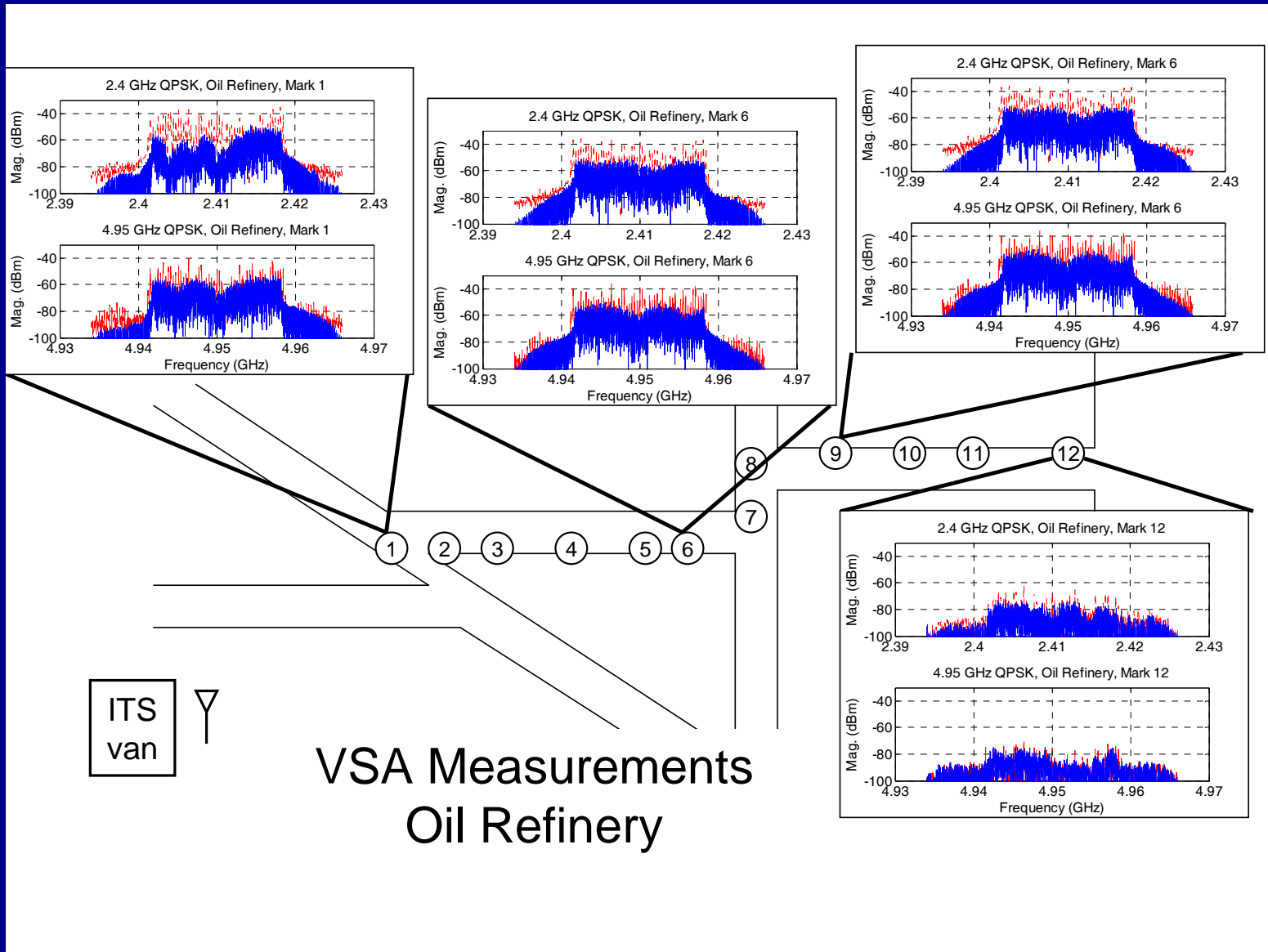- Good for characterization of realistic wideband digital signals

Error Vector Magnitude (EVM)
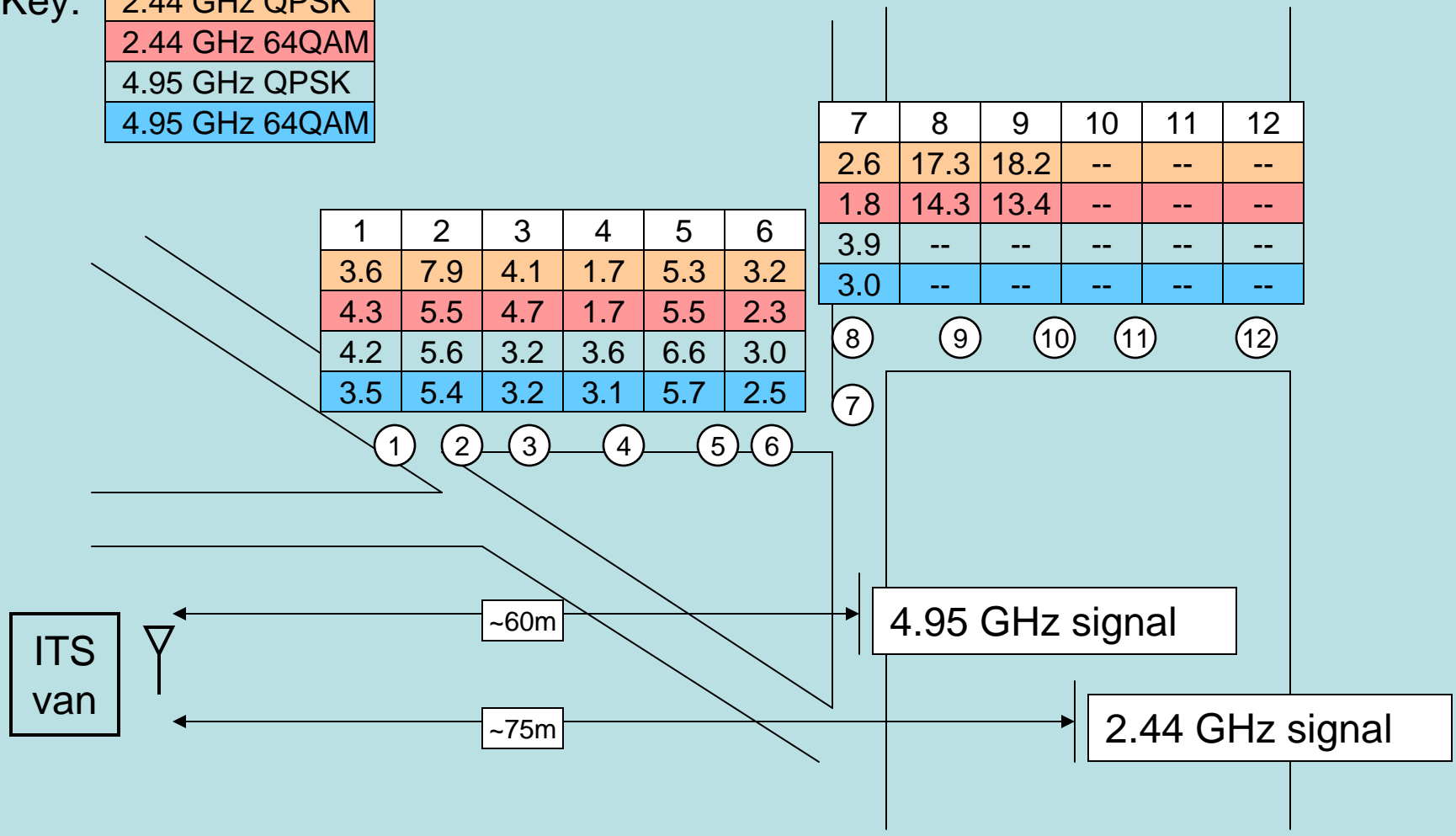

Adjacent channel power ratio (ACPR)

VSA Measurements
Oil Refinery

Comparison of modulation, frequency

EVM for QPSK and 64QAM modulation at 2.44 GHz and 4.95 GHz

Key:

2.44 GHz QPSK	(orange)
2.44 GHz 64QAM	(red)
4.95 GHz QPSK	(white)
4.95 GHz 64QAM	(blue)

7	8	9	10	11	12
2.6	17.3	18.2	--	--	--
1.8	14.3	13.4	--	--	--
3.9	--	--	--	--	--
3.0	--	--	--	--	--

1	2	3	4	5	6
3.6	7.9	4.1	1.7	5.3	3.2
4.3	5.5	4.7	1.7	5.5	2.3
4.2	5.6	3.2	3.6	6.6	3.0
3.5	5.4	3.2	3.1	5.7	2.5

ITS van

~60m

~75m

4.95 GHz signal
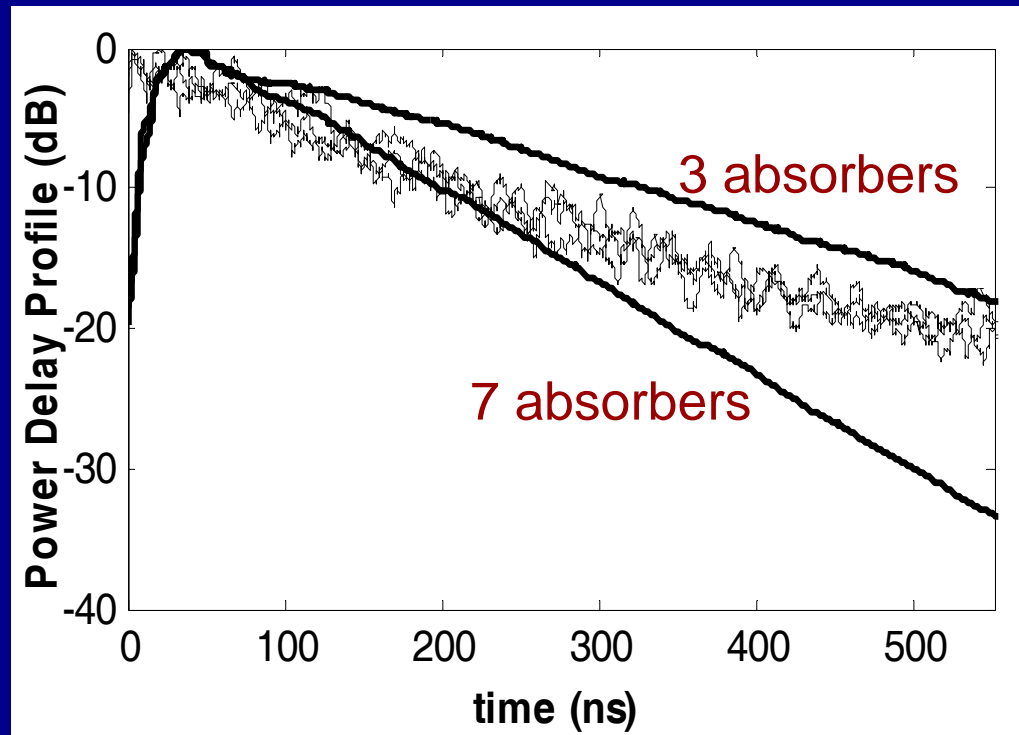
2.44 GHz signal

Reverberation chamber tests

Simulate high multipath environments:
- Repeatable
- Error analysis
- Inexpensive, efficient test facility
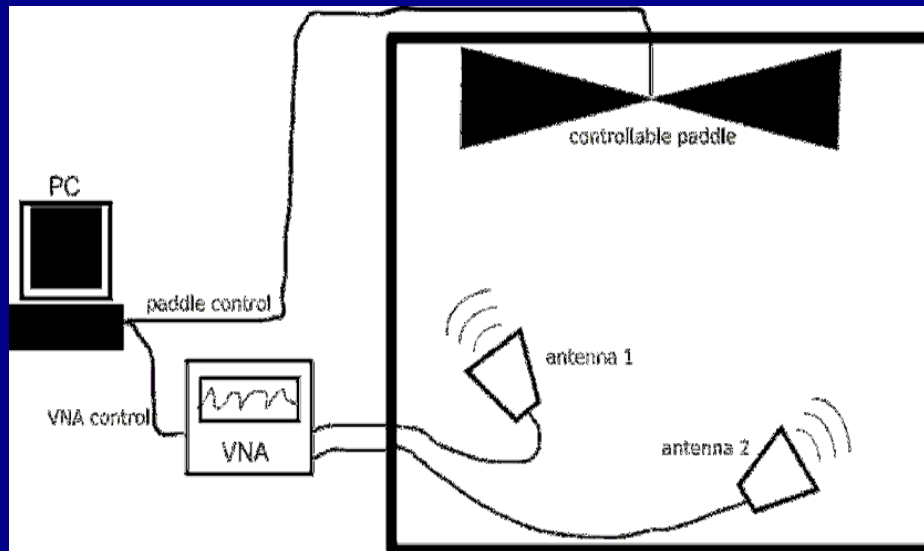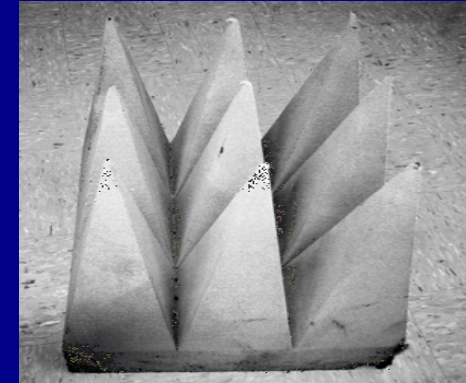
Reverberation Chamber Tests

- Compare time-domain statistics oil refinery (power delay profile, RMS delay spread) to those in the chamber.

- Duration of reflections can be bounded by reverb chamber.


Oil refinery data at one location

Wireless in high multipath locations

- Large body of data in oil refinery:
  - single-frequency
  - wideband, synthetic pulse
  - wideband digitally modulated signal

- Measurements show:
  - Non-line-of-sight, high multipath conditions even though outdoors
  - Low frequencies can experience waveguide-below-cutoff effect
  - 4.95 GHz band fails sooner than 2.4 GHz band

- Reverberation chamber:
  - simulate high multipath environment
  - useful for device qualification

Calibrated Receiver for Weak Signal Detection
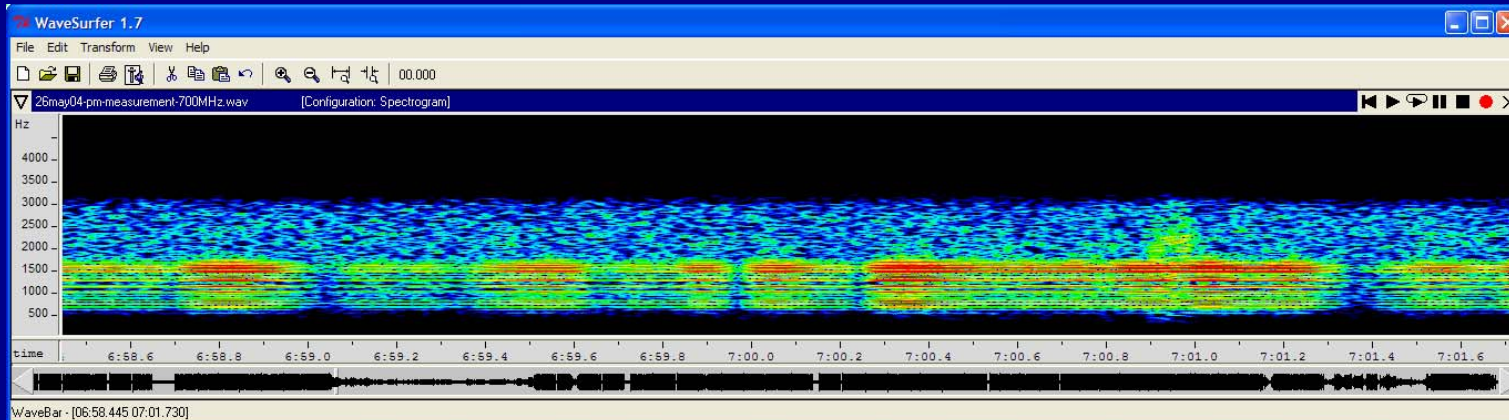
raw
data
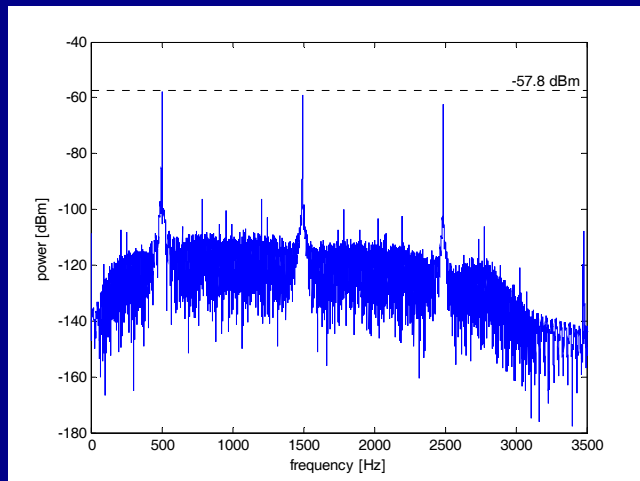
processed spectrum

Narrowband receivers detect signals orders of magnitude weaker than standard equipment