ORBIT Room Radio Propagation Measurements

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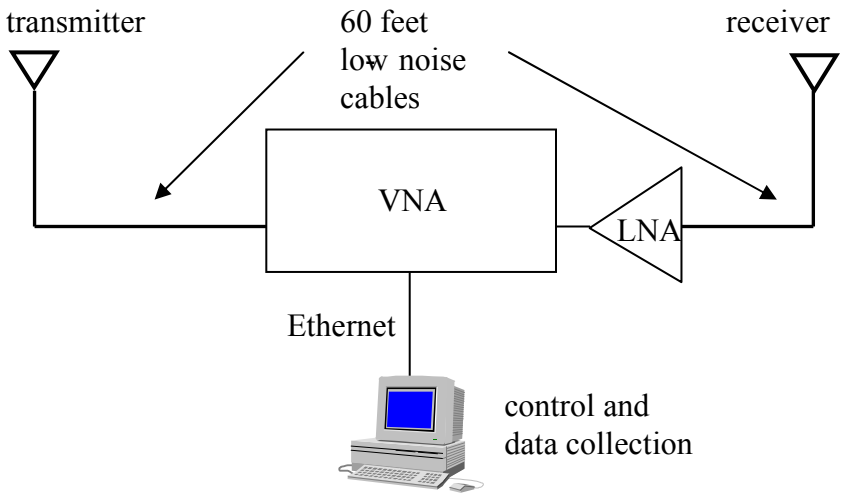
Outline

- Measurements setup
  - network analyzer
  - signal generator and spectrum analyzer
- Measurements background
  - path loss
  - impulse response (multipath intensity profile)
- Two case studies
  - 15 measurements diagonally across the room
  - 66 measurements for two transmitter positions
  - impulse response compared to WISE prediction

Vector Network Analyzer

- measures s-parameters
- J=1601 tones in bandwidth
  - ISM/UNII 100 MHz bands
    - 2.4 to 2.5 GHz
    - 5.15 to 5.25 GHz
    - 5.25 to 5.35 GHz
    - 5.725 to 5.825 GHz
  - wide bandwidth W (coarse)
    - 0.4 to 6 GHz
    - maximum delay
    - multipath resolution

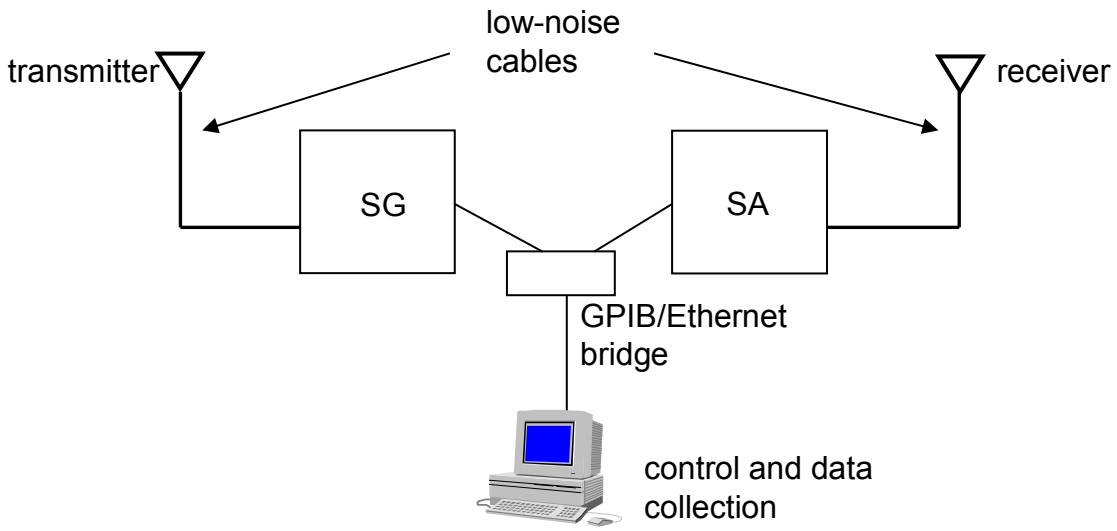


$$\tau_{\max} = \frac{J-1}{W} = \frac{1600}{(6-0.4)\cdot 10^9} = 286ns \Rightarrow 85.7m$$

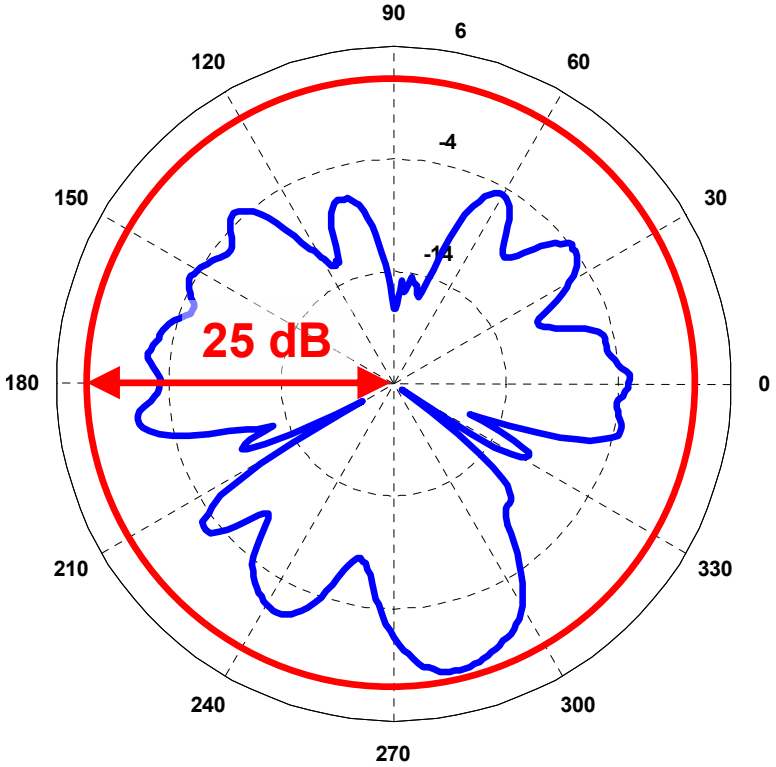
$$\Delta\tau = \frac{1}{W} = \frac{1}{(6-0.4)\cdot 10^9} = 179\,ps \Rightarrow 5.36cm$$

Signal generator and spectrum analyzer

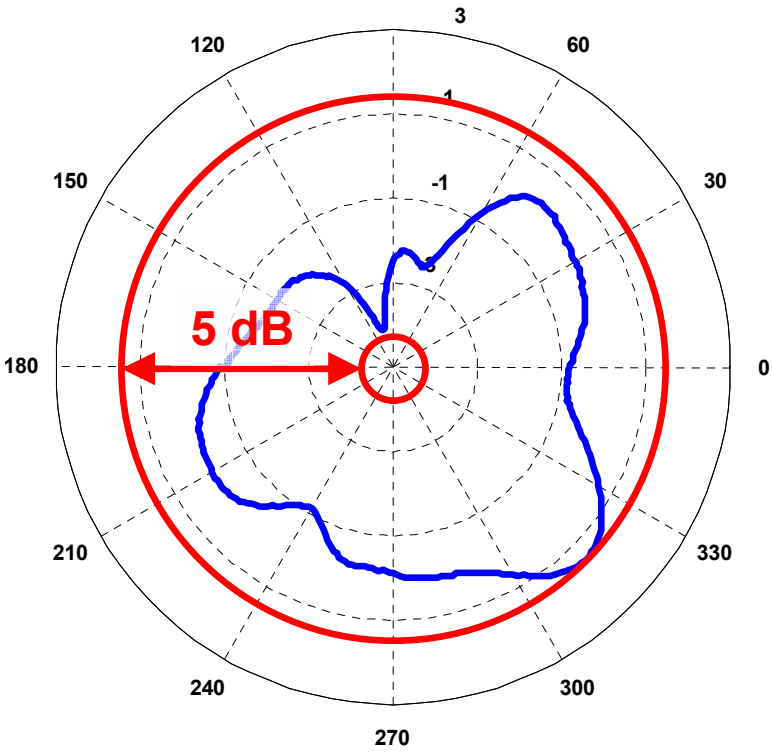
- measure power loss
- send J=51 tones across four ISM/UNII 100 MHz bands
- compare to and verify VNA measurements



Antenna patterns*



elevation



azimuth

* Thanks to Ilya Korisch from Lucent in Holmdel

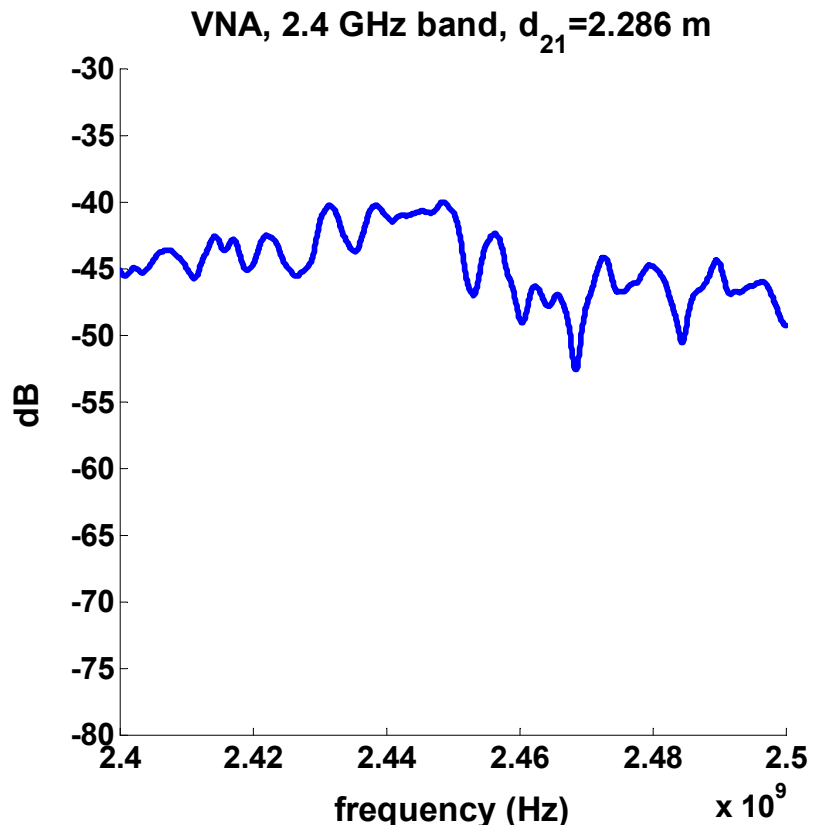
Path loss measurements reduction

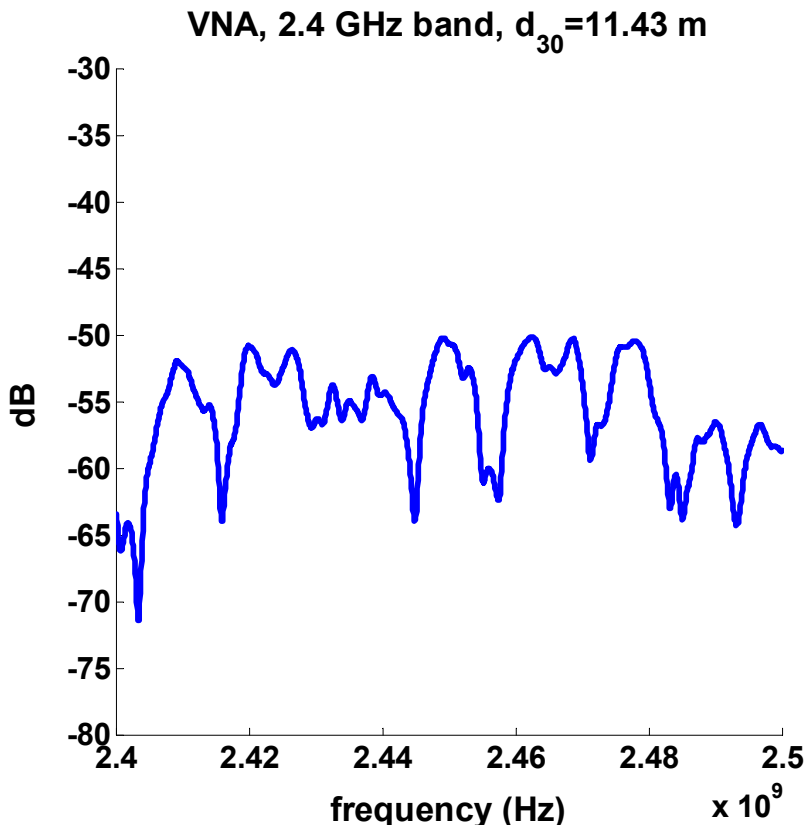
- Channel response $H(f_j,d_k)$ (Ghassemzadeh et al. '03)
  - at frequency f_j j=0,1,..,J-1
  - at distance d_k k=1,2,…,K
  - average of ten measurements taken over two-minutes period

- Path loss at distance d_k averaged over J frequencies
  - J=1601 for VNA and J=51 for SG/SA

$$PL(d_k) = -10\log_{10}\left(\frac{1}{J}\sum_{j=0}^{J-1}\left|H(f_j,d_k)\right|^2\right)$$

Examples of channel response $H(f_j,d_k)$





Path loss best fit

- Assume path loss model

$$PL_{fit}(d) = PL_1 + 10\gamma \log_{10}\left(\frac{d}{d_1}\right)$$

- Perform nonlinear least squares fitting

$$\gamma^*, PL_1^* = \arg\min_{\gamma, PL_1}\left\{\sum_{k=1}^{K}\left(PL(d_k) - PL_{fit}(d_k)\right)^2\right\}$$

Impulse response

- Impulse response (Ghassemzadeh et al. ‘05)

$$g^k(\tau) = \sum_{j=0}^{J-1} a_j{}^k \delta(\tau - \tau_j)$$

$$\tau_j = j \cdot \Delta\tau$$

$$\left\{a_j{}^k\right\} = IDFT\left(H(f_j, d_k)\right)$$

- Path gain

$$G_k = \sum_{j=0}^{J-1} \left| a_j{}^k \right|^2$$

Multipath intensity profile

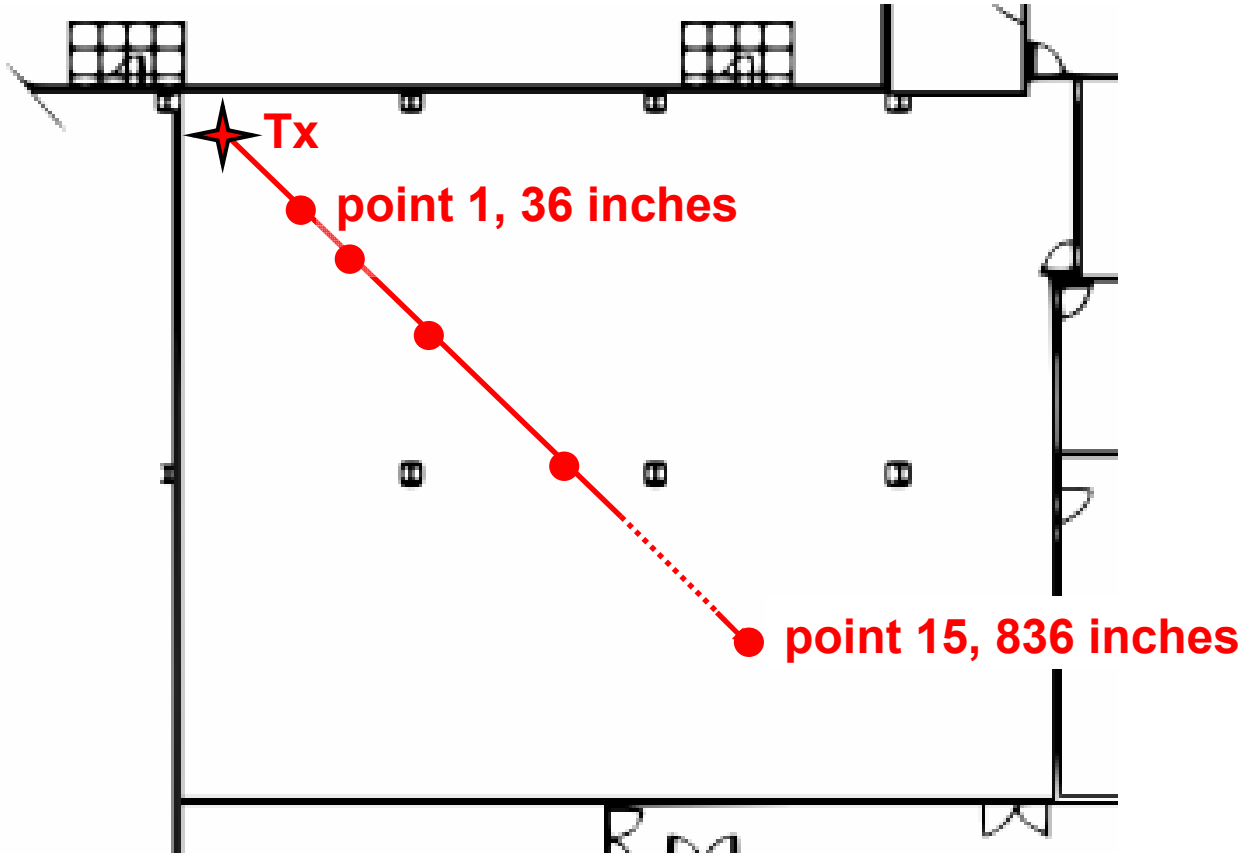
- Delay profile
  - normalized sum of powers of a_j^k

$$p^k(\tau) = \sum_{j=0}^{J-1} p_j{}^k \delta(\tau - \tau_j); \qquad p_j{}^k = \frac{\left| a_j{}^k \right|^2}{G_k}$$

- Power-delay profile (PDP)
  - $p^k(\tau)$ **spatial** average in the radius of a few wavelengths
- Multipath intensity profile (MIP)
  - $p^k(\tau)$ **time** average at a spot k ("local PDP")
  - we measure MIP
    - ORBIT nodes in the room are static
    - ORBIT experiments utilize some amount of time

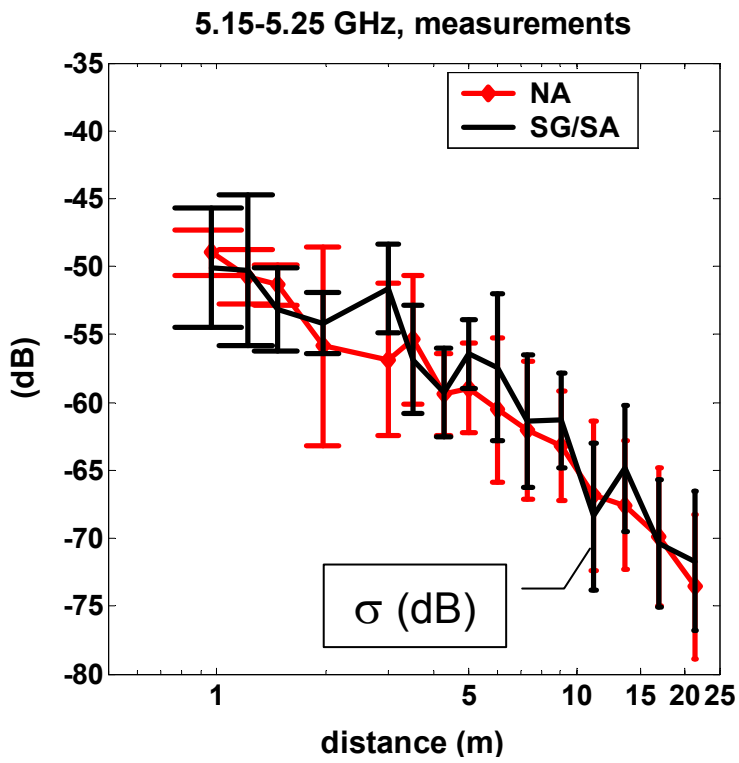
Case study “receiver on a diagonal”

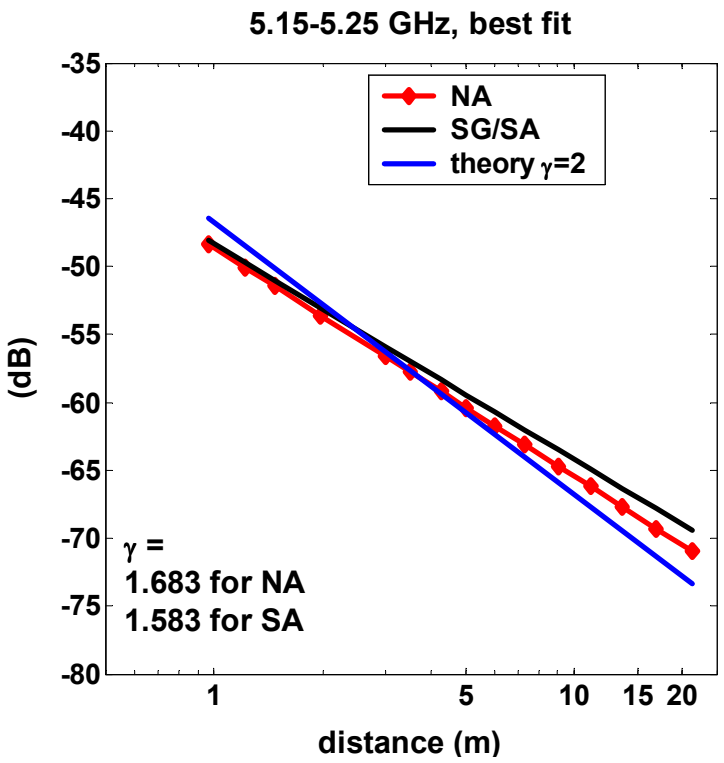
- Logarithmically distributed distances
- Line-of-sight between the antennas



Path loss for receiver on a diagonal

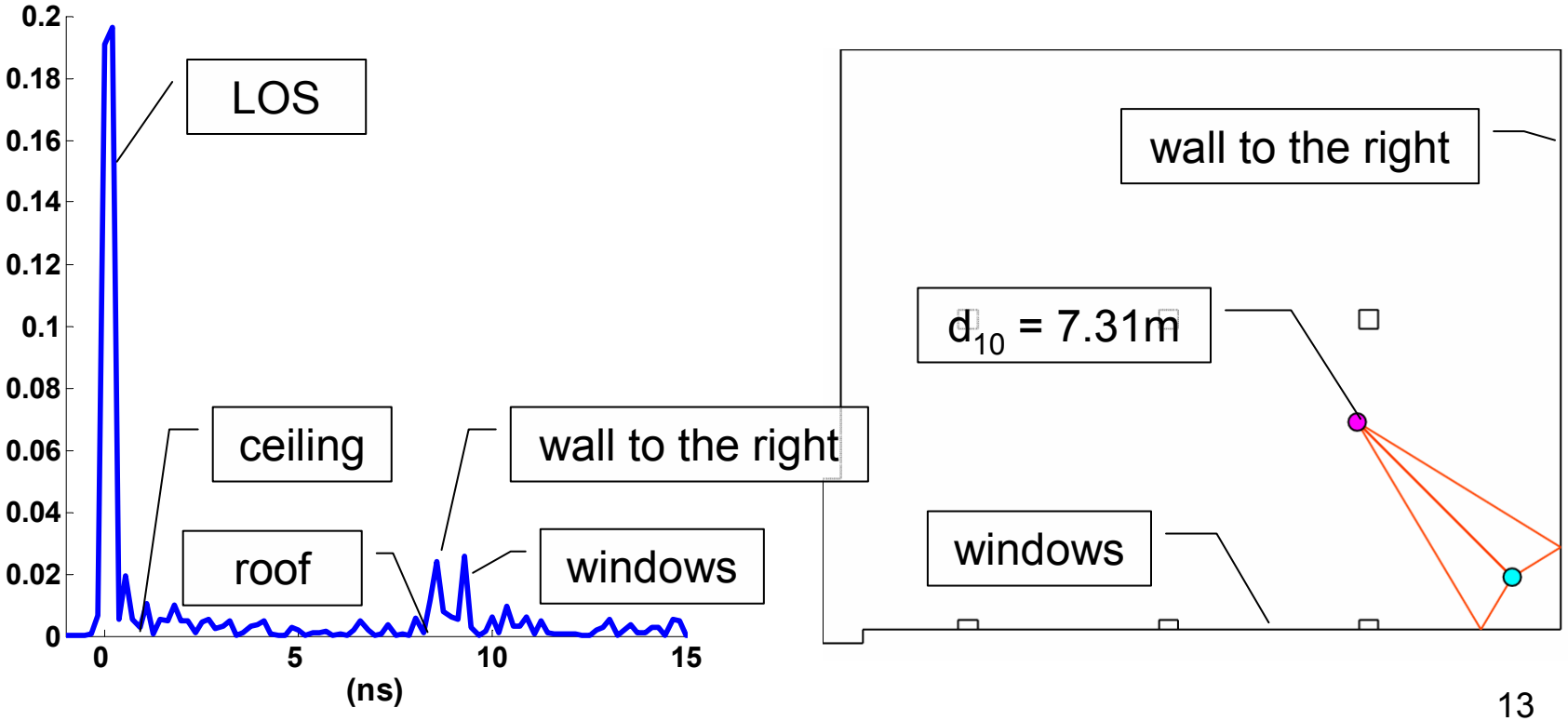
band (GHz)	2.4-2.5	5.15-5.25	5.25-5.35	5.275-5.875	0.4-6
γ^*	1.638	1.683	1.645	**1.162**	1.730
$PL_1{}^*$ (dB)	-44.972	-48.335	-49.116	**-56.017**	-49.592





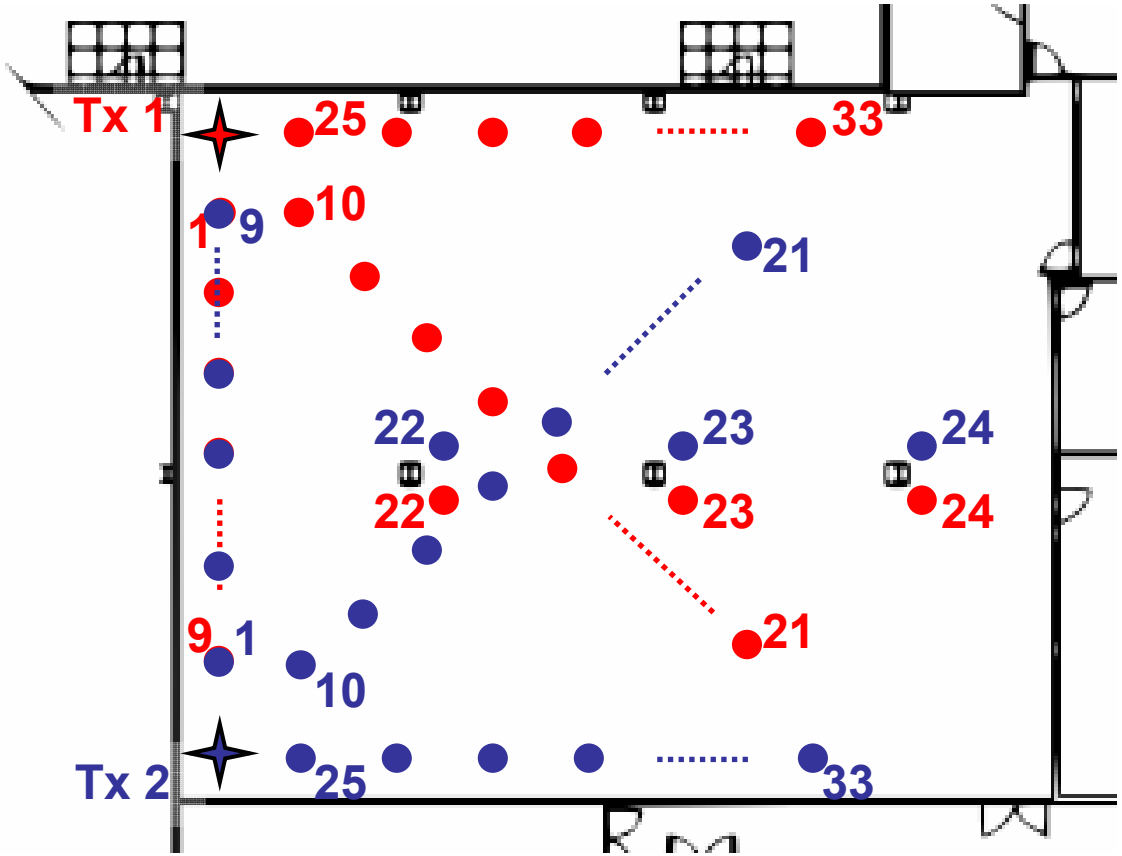
Example of MIP for receiver on a diagonal

- Powers predicted by WISE do not agree with IDFT, but delays do
- Wall, windows significant source of reflections
- Ceiling, roof, floor negligible source of reflections



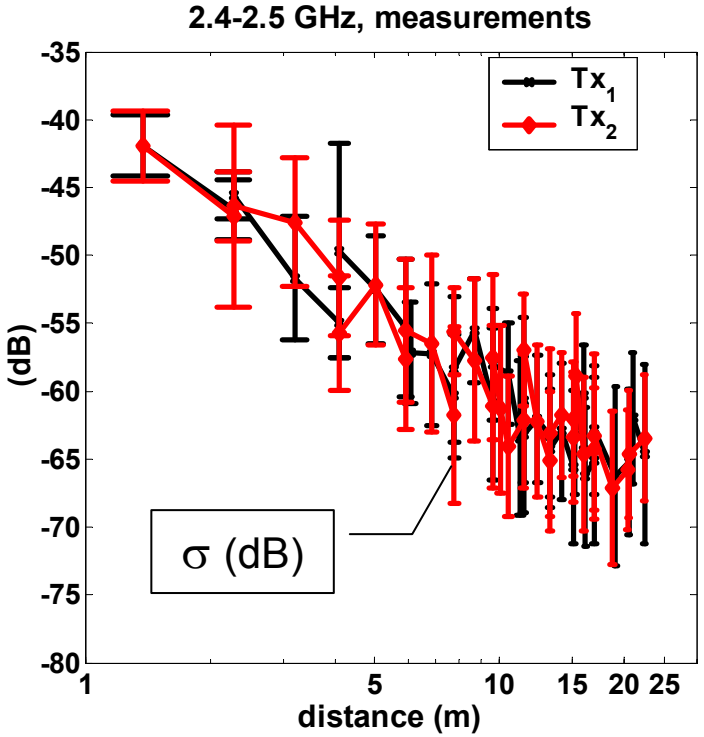
Case study with two transmitter positions

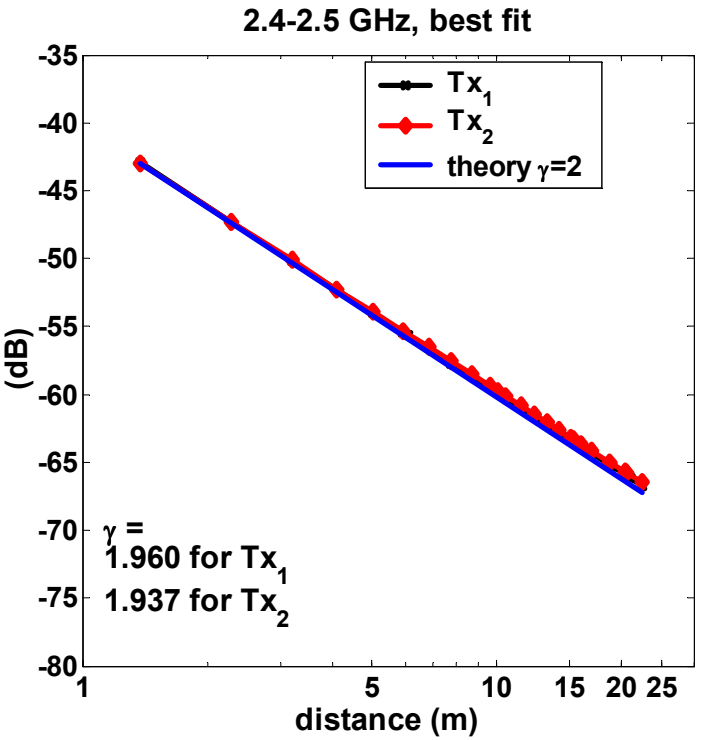
- Distance between measuring points 6 feet
- ORBIT node antennas are obstacles between Tx and Rx



Path loss for two transmitter positions

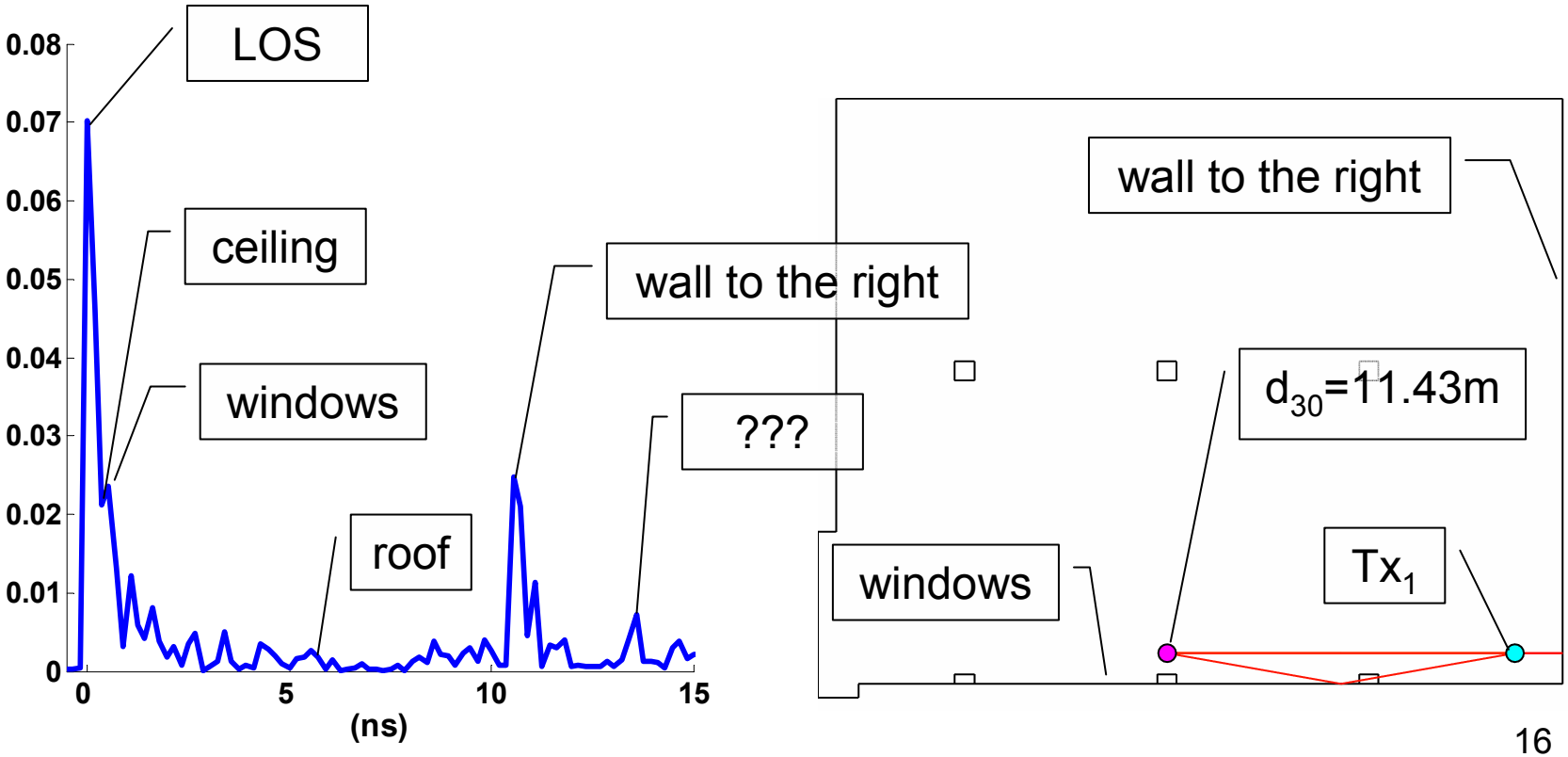
band (GHz)		2.4-2.5	5.15-5.25	5.25-5.35	5.275-5.875	0.4-6
Tx 1	γ^*	1.960	1.660	1.718	**1.732**	**1.821**
	$PL_1{}^*$ (dB)	-42.934	-54.459	-53.411	**-53.398**	-50.623
Tx 2	γ^*	1.937	1.701	1.706	**1.902**	**1.833**
	$PL_1{}^*$ (dB)	-42.993	-53.164	-52.805	**-50.963**	-49.615





Example of MIP for two transmitter positions

- Again, wall, windows significant source of reflections
- Ceiling, roof, floor negligible source of reflections
- Compared to “diagonal” case a lot of weak reflections



Conclusions

- Path loss coefficient close to 1.8
- Walls are significant source of reflections
- Reflections from ceiling, floor, and roof are negligible