Center for Embedded Systems
An NSF Industry/University Cooperative Research Center

Reliable Wireless Communications in Aircraft and Other Challenging Environments

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Project Overview and Description

- **Project Description**
  - ➢ Reducing the complexity of electrical wiring
  - ➢ Improving the operational efficiency

- **Problem**
  - ➢ Propagation model for cabin environment
  - ➢ Assurance of high reliability

Approach

- Signal mapping considering distinct characteristics of cabin environment
- Using beamforming technology to improve efficiency and reliability
- Providing guideline and strategy for deployment of nodes in cabin environment

Project Status

Date	Description
Sept. 16	Introduction to Beamforming
Sept. 25	Smart Antenna based on Beamforming
Oct. 2	Adaptive Beamforming Algorithm
Oct. 9	Path Loss in Aircraft Environment
Oct. 23	Radio Propagation in Aircraft Environment – Path Loss
Oct. 30	Radio Propagation in Aircraft Environment – Shadowing/Fading
Nov. 13	Beamforming Simulation
Nov. 20	Indoor Signal Propagation Simulation
Dec. 2	2-D Cabin Simulation

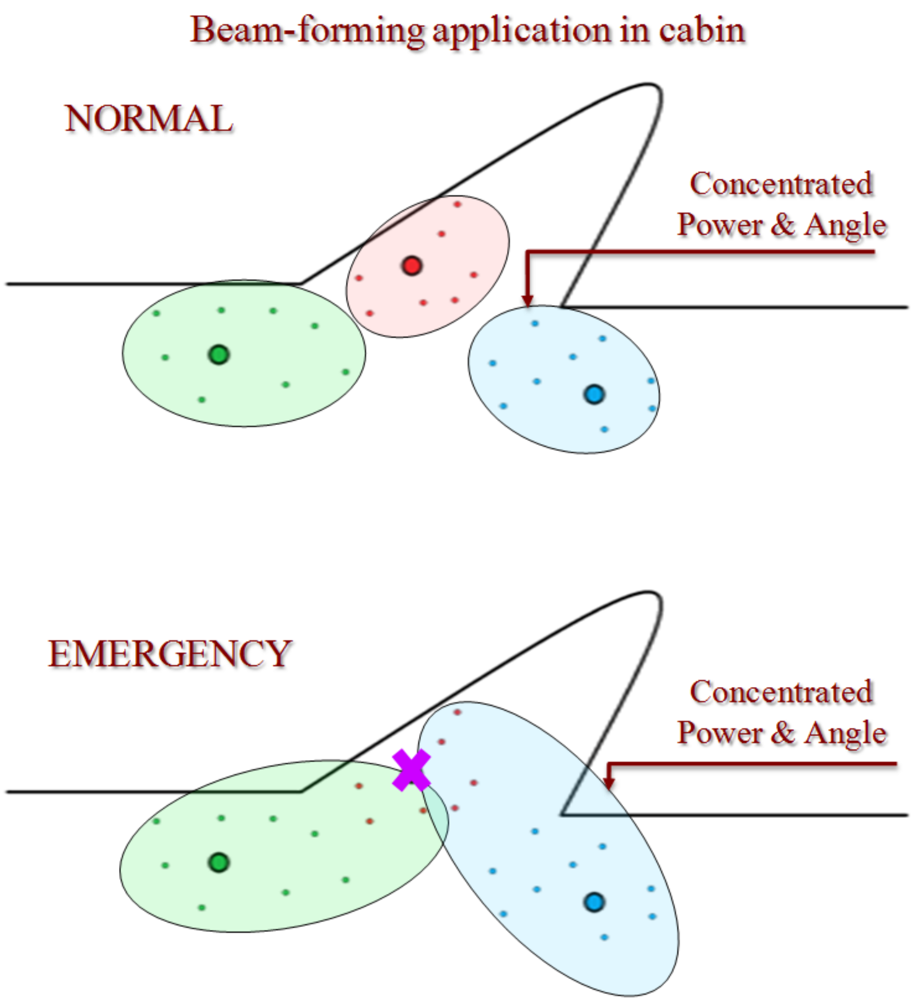
Project Tasks/ Deliverables

	Description	Date	Status
1	Choose beamforming technology to improve efficiency and reliability	Oct. 2	Done
2	Set up wireless signal propagation model for cabin environment	Oct. 30	Done
3	Beamforming simulation with variable antennas and incoming signal directions	Nov. 13	Done
4	2-D aircraft cabin environment simulation using multi-wall method	Nov. 20	Done
5	Path loss simulation in seat, arm & back, and top levels in cabin area with different number of APs	Dec. 2	Done
6	Beamforming simulation combined with signal propagation in cabin environment		To be cont.

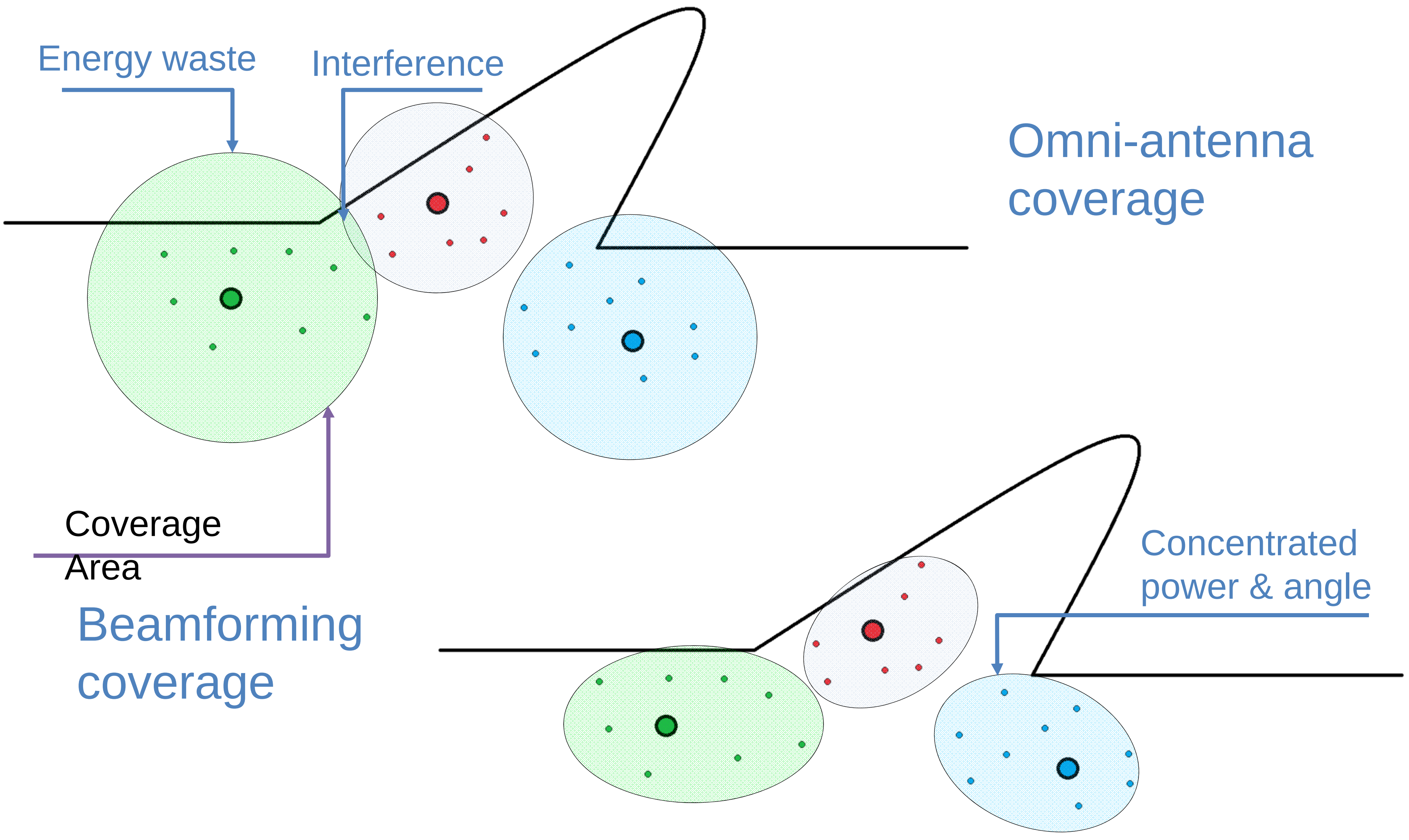
Executive Summary

- **Theoretical preparation**
  – Propagation model
  – Beamforming application

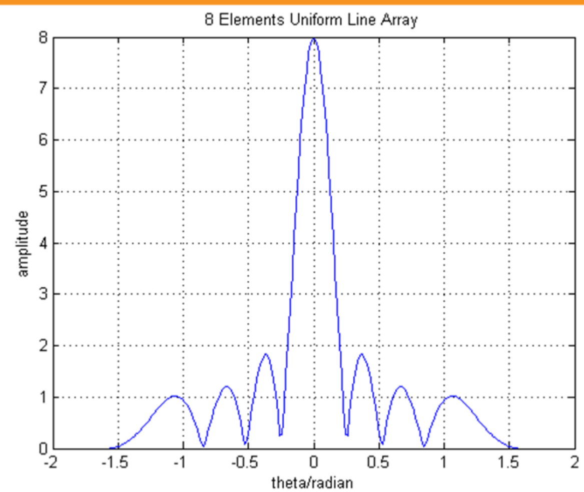
- **Simulation work**
  – Beamforming simulation
  – 2-D cabin environment
  – Path loss simulation in cabin area



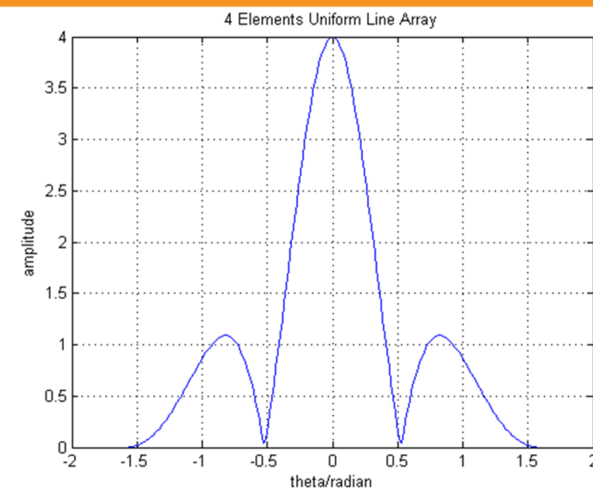
Beamforming Technology



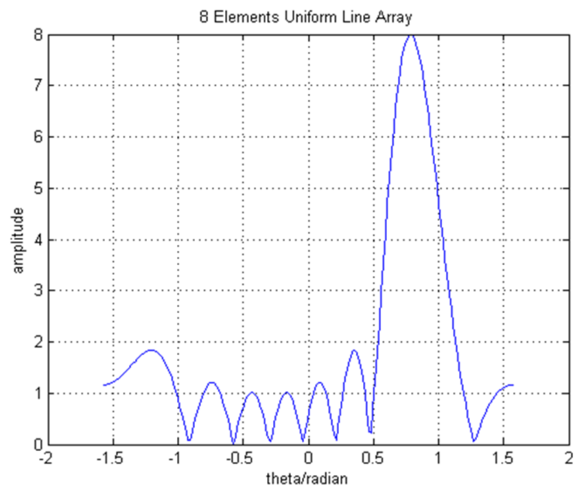
Beamforming Simulation



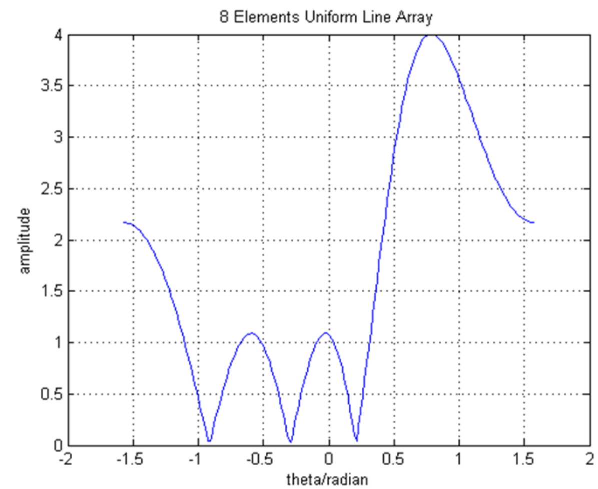
8 elements, uniform line array, incoming signal 0 degree



4 elements, uniform line array, incoming signal 0 degree



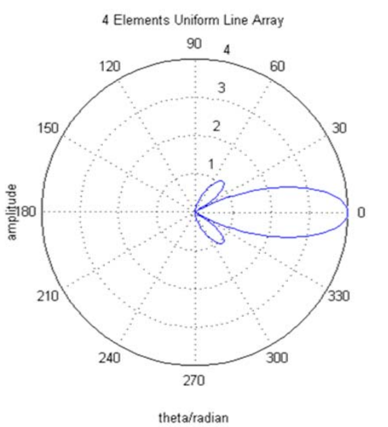
8 elements, uniform line array, incoming signal 45 degree

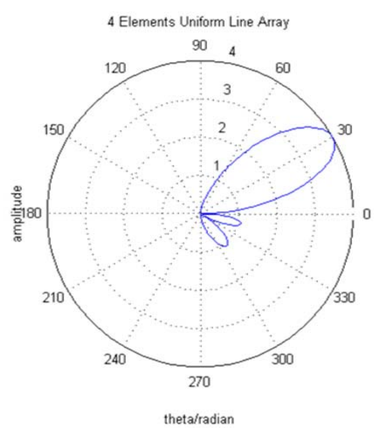


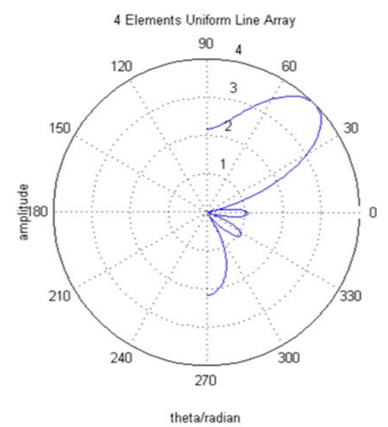
4 elements, uniform line array, incoming signal 45 degree

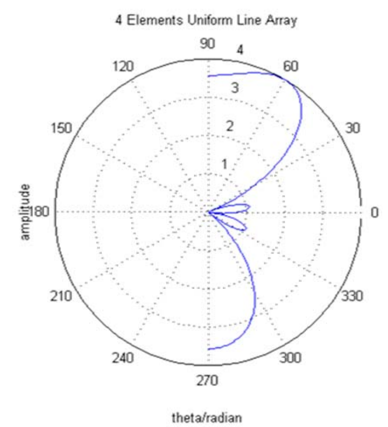
Beamforming Pattern with Variable Antennas and Incoming Signal Directions

4 antennas



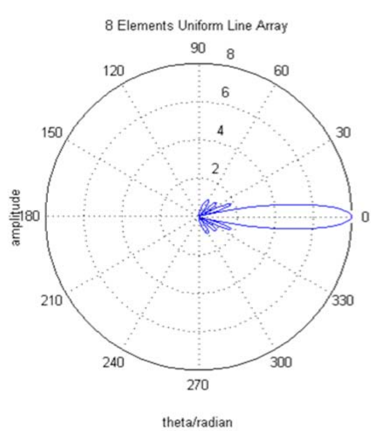


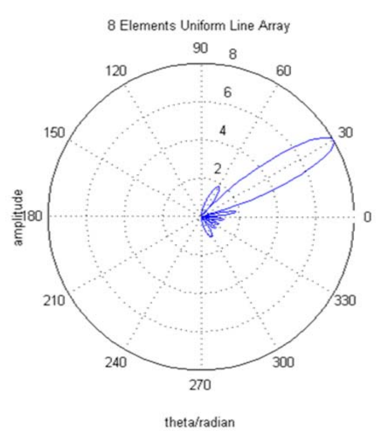


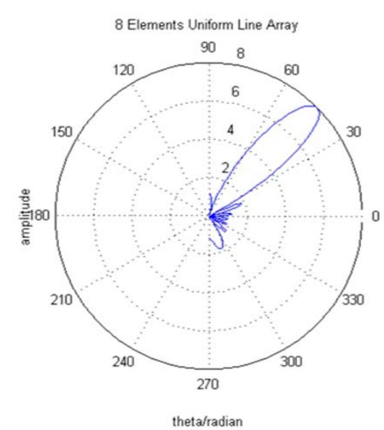


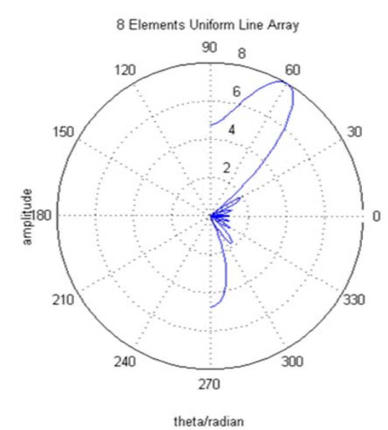
0° 30° 45° 60°

8 antennas

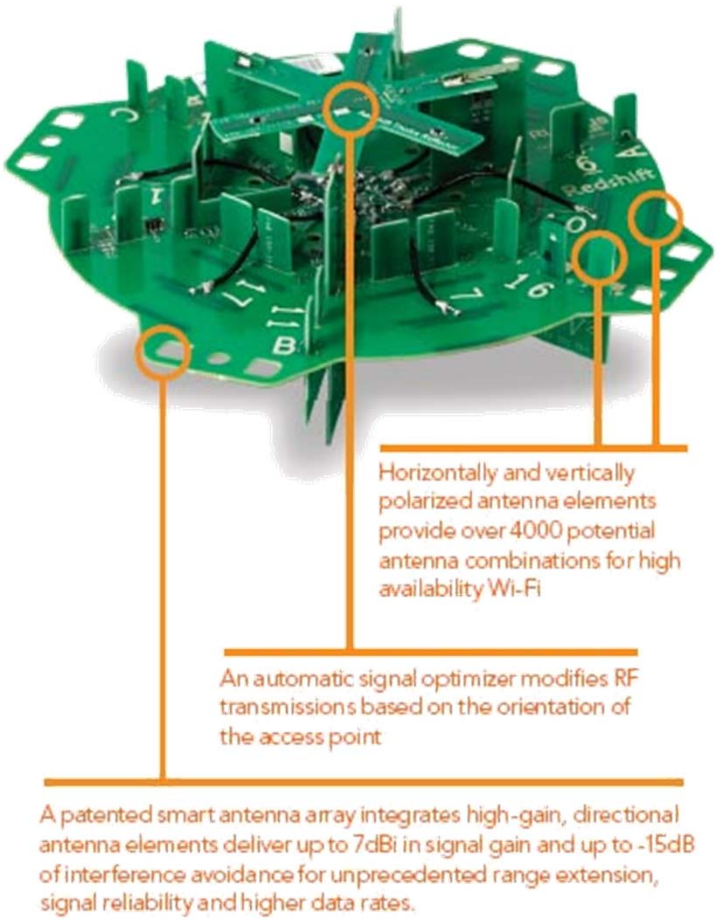








Beamforming Antenna



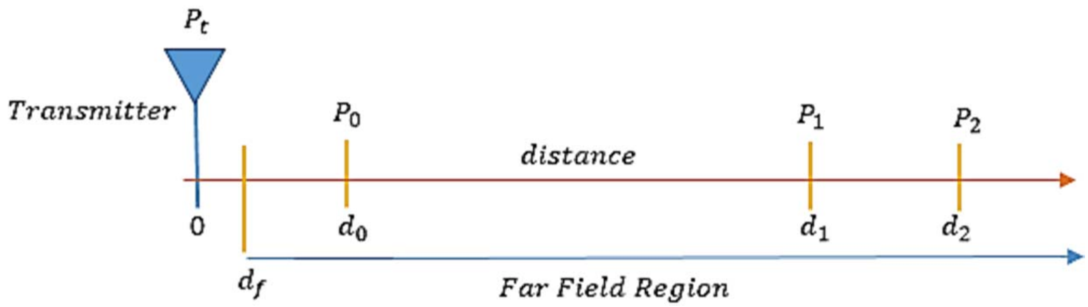
The Ruckus Wireless 7962
(19 antenna elements)

- Over 3X increase in performance and range
- 8X expanded coverage
- Stabilized wireless network performance, for picture-perfect video streaming and crystal-clear voice communications
- Maximized power efficiency
- Interference mitigation
- Unlike omni-directional antennas that radiate signals in all directions, BeamFlex directs transmit energy towards the best path to the receiving device. And unlike fixed-positioned directional antennas, BeamFlex dynamically configures its "beam" on a per-station, per-packet basis, to achieve omni-directional coverage.

- http://www.youtube.com/watch?v=06-81wCkIKM

Log-distance Path Loss Model

- **Log-distance path loss model is a generic model and an extension to Friis Free space model.**
- **It is used to predict the propagation loss for a wide range of environments, whereas, the Friis Free space model is restricted to unobstructed clear path between the transmitter and receiver.**



- **In the far field region of the transmitter ($d \geq d_f$), if $PL(d_0)$ is the path loss measured in dB at a distance d_0 from the transmitter, then the path loss (the loss in signal power measure in dB when moving from distance d_0 to d) at an arbitrary distance $d > d_0$ is given by**

$$\overline{PL}(\mathrm{dB}) = \overline{PL}(d_0) + 10n \log\left(\frac{d}{d_0}\right) + x_\sigma$$

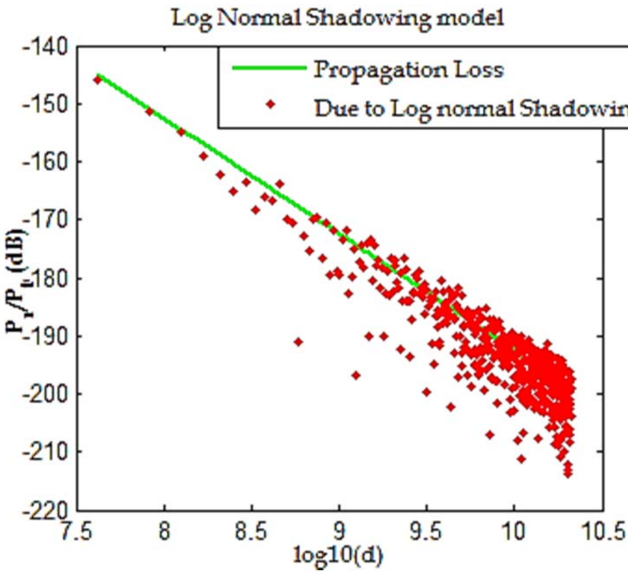
where: *n* is the path loss exponent

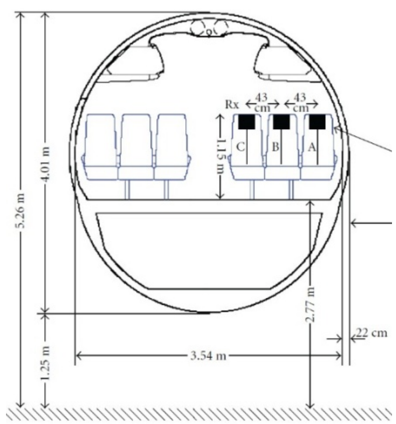
d_0 is the close-in reference distance

d is the T-R separation distance

x_σ is a zero-mean Gaussian distributed random variable (in dB) with standard deviation – σ.

Shadowing





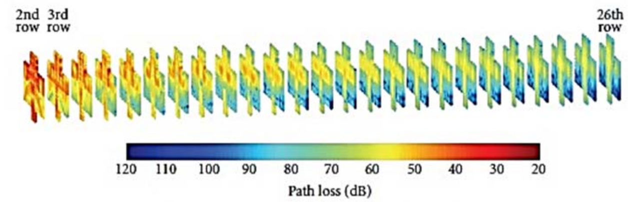


FIGURE 13: Example of PO results (path loss in dB) for all rows.

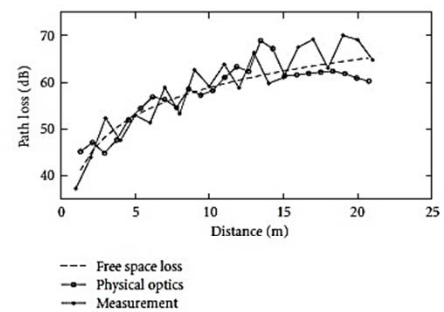


FIGURE 14: Comparison of simulated and measured values, aisle.

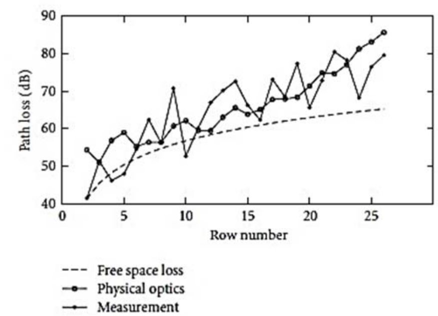


FIGURE 16: Comparison of simulated and measured values, B seat.

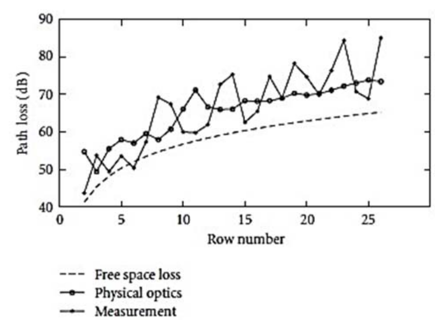


FIGURE 15: Comparison of simulated and measured values, A seat.

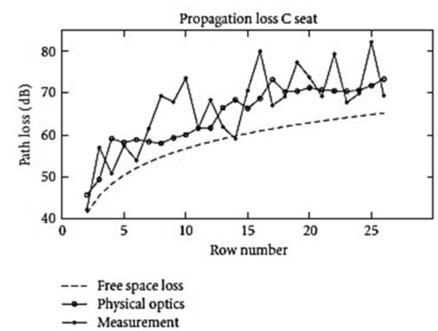
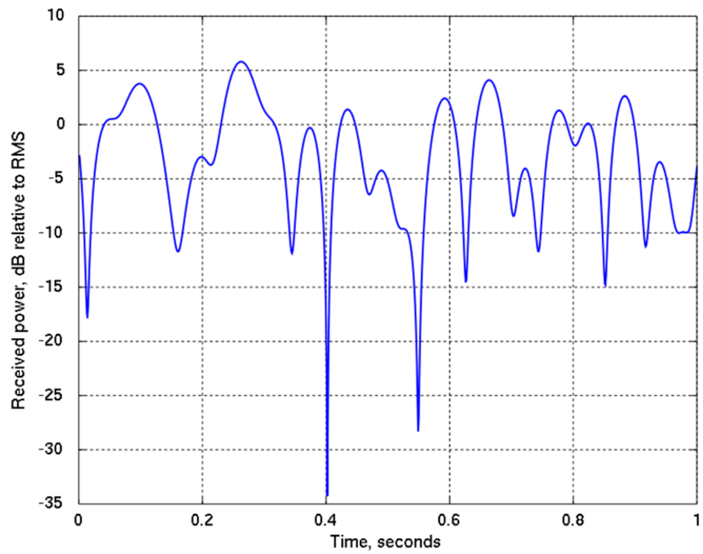


FIGURE 17: Comparison of simulated and measured values, C seat.

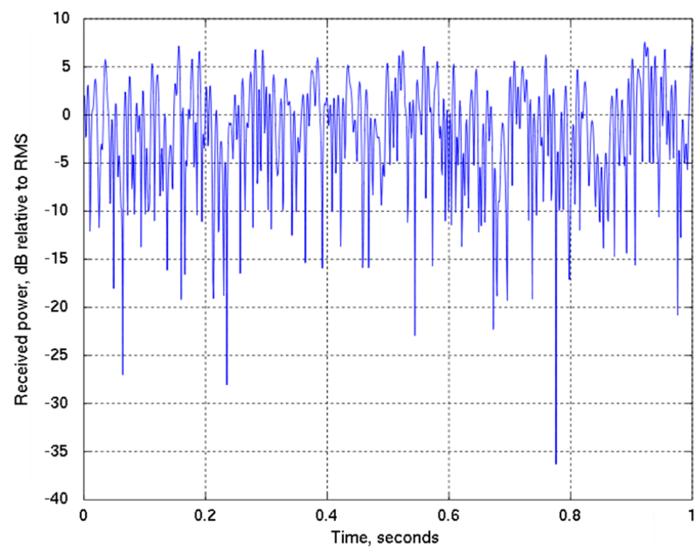
Moraitis, Nektarios, et al. "Propagation measurements and comparison with EM techniques for in-cabin wireless networks," *EURASIP Journal on Wireless Communications and Networking,* 2009.

Rayleigh Fading

- **Rayleigh fading models assume that the magnitude of a signal that has passed through a transmission medium will vary randomly, or fade, according to a Rayleigh distribution — the radial component of the sum of two uncorrelated Gaussian random variables.**



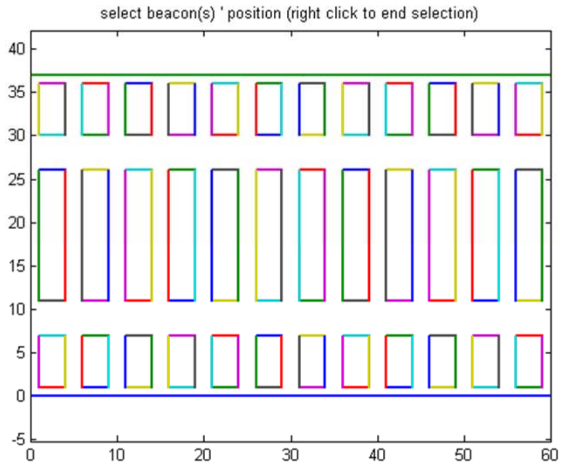
One second of Rayleigh fading with a maximum Doppler shift of 10 Hz
GSM 1800MHz 6km/s



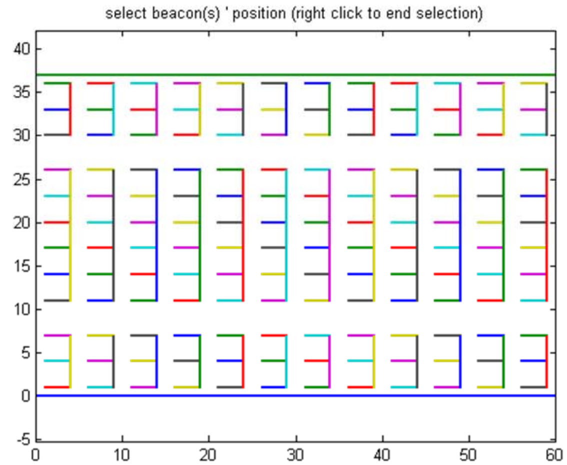
One second of Rayleigh fading with a maximum Doppler shift of 100Hz
GSM 1800MHz 60km/s

Cabin Environment in 2-D

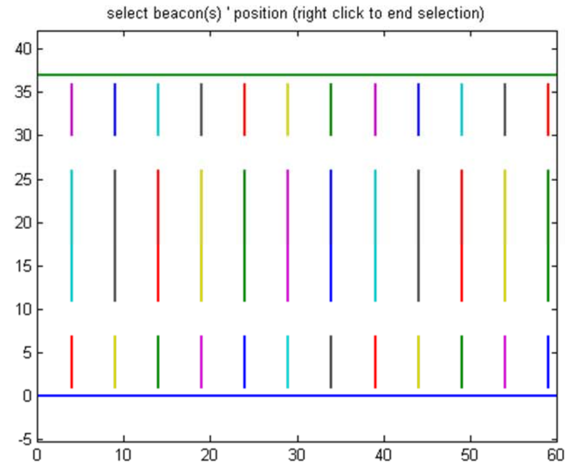
Seat



Arm & Back

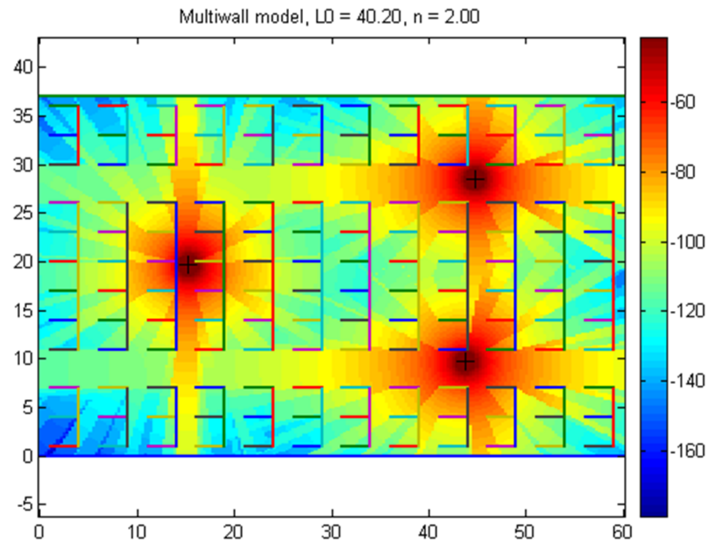


Top

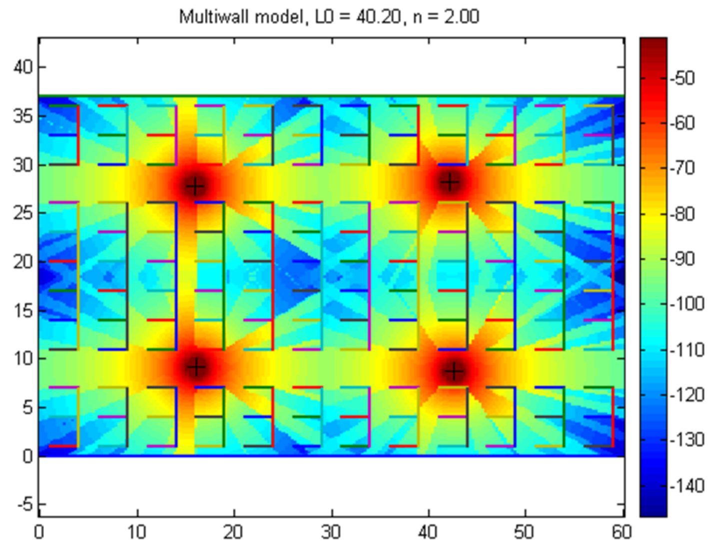


12 Rows
Seat Chart 2-5-2

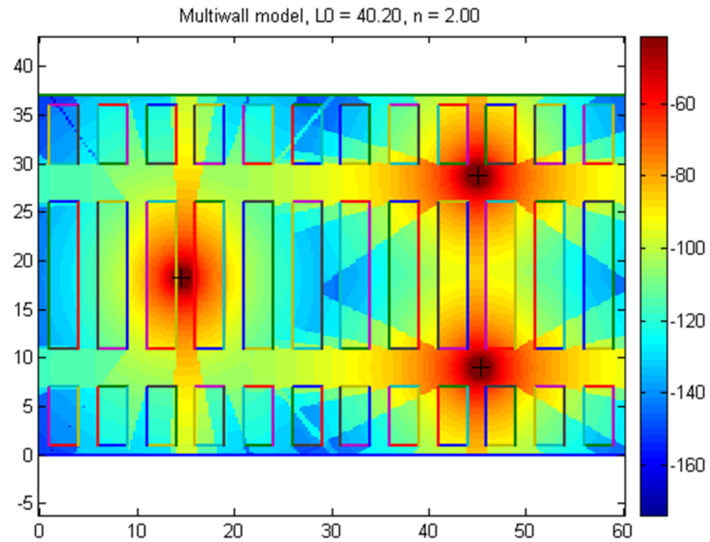
Cabin Simulation in 2-D



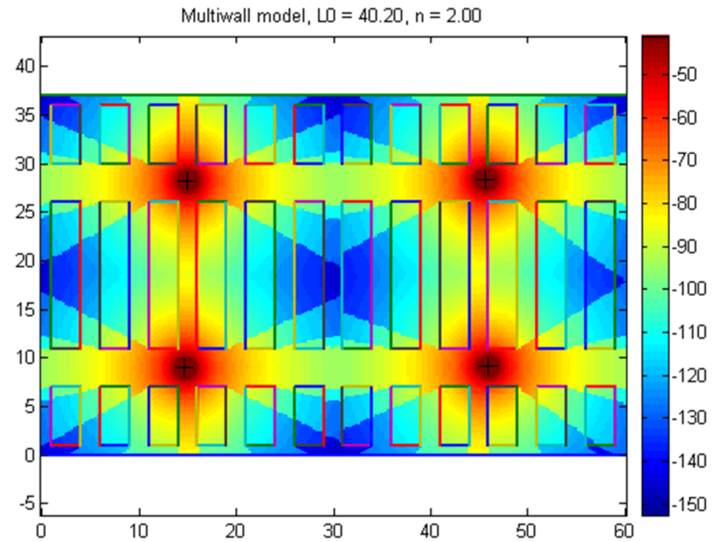
Arm & back, 3 APs



Arm & back, 4 APs

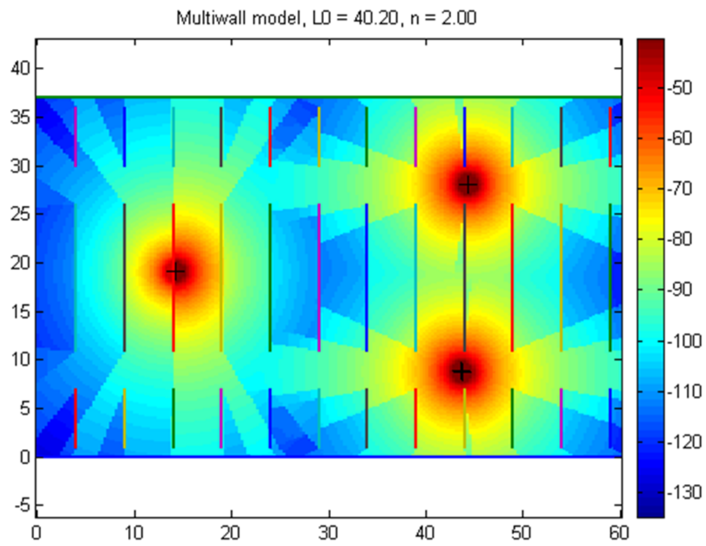


Seat, 3 APs

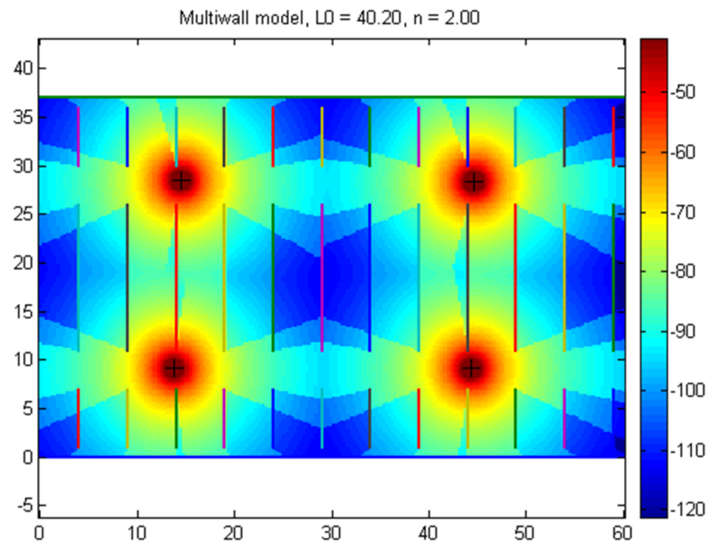


Seat, 4 APs

Cabin Simulation in 2-D (cont.)



Top, 3 APs



Top, 4 APs