Error Mechanisms in Indoor Positioning Systems without Support from GNSS

W. R. Michalson

Abhijit Navalekar **Hemish Parikh**

10/27/08

Center for Advanced Integrated Radio Navigation

(CAIRN)

ECE-WPI, Worcester, MA

Outline

- Introduction
- Signal Structure
- RF Prototype
- NLOS Positioning Test Setup
- NLOS Positioning Test Results
- Error Sources
- Conclusion

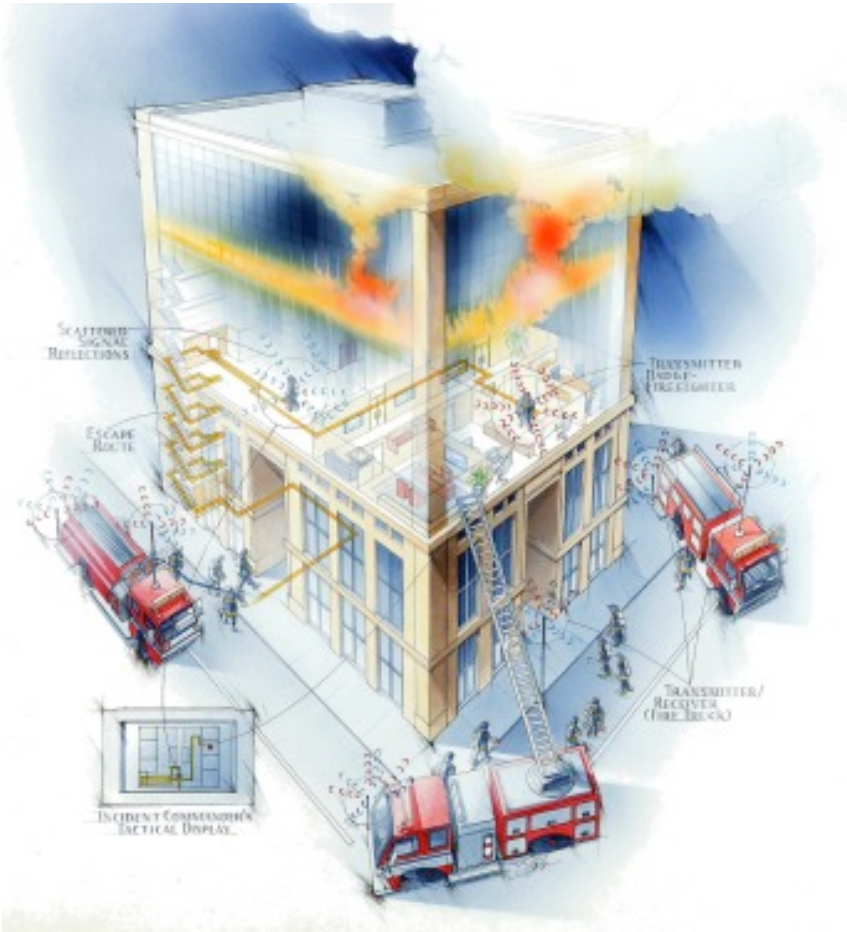
Introduction

Personal Location and Navigation System

The emergency vehicles and personnel carry an ad-hoc transceiver device

The signals received on the receivers installed on the vehicles are used to calculate the relative position of the fire fighters in and around the building

The location of the fire fighter is displayed at a command and control display

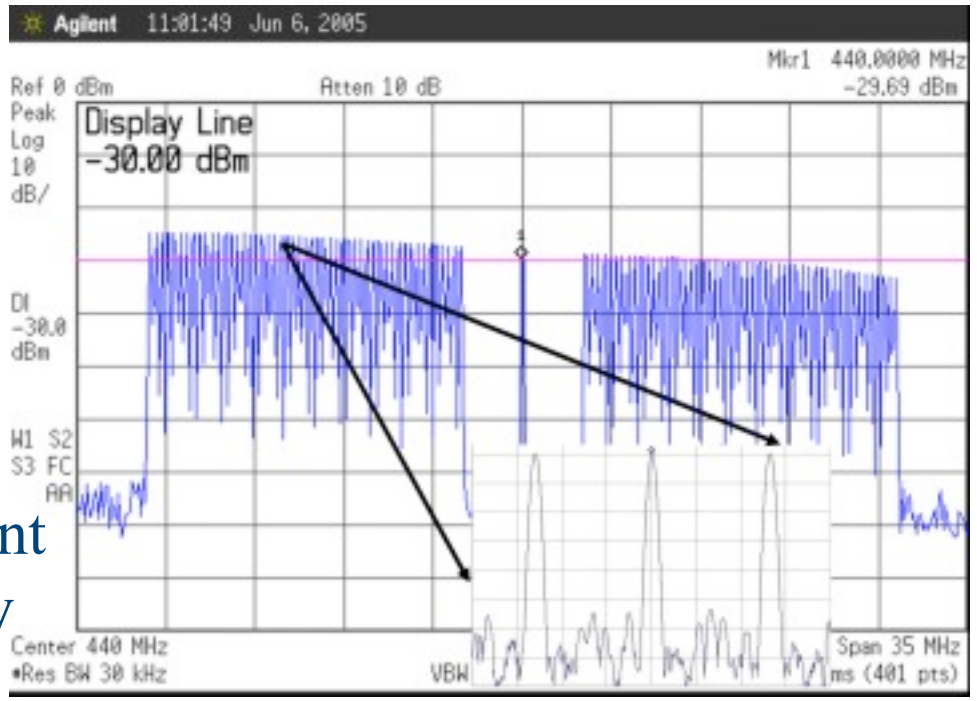


Signal Structure

MC-UWB

MC-UWB Signal:

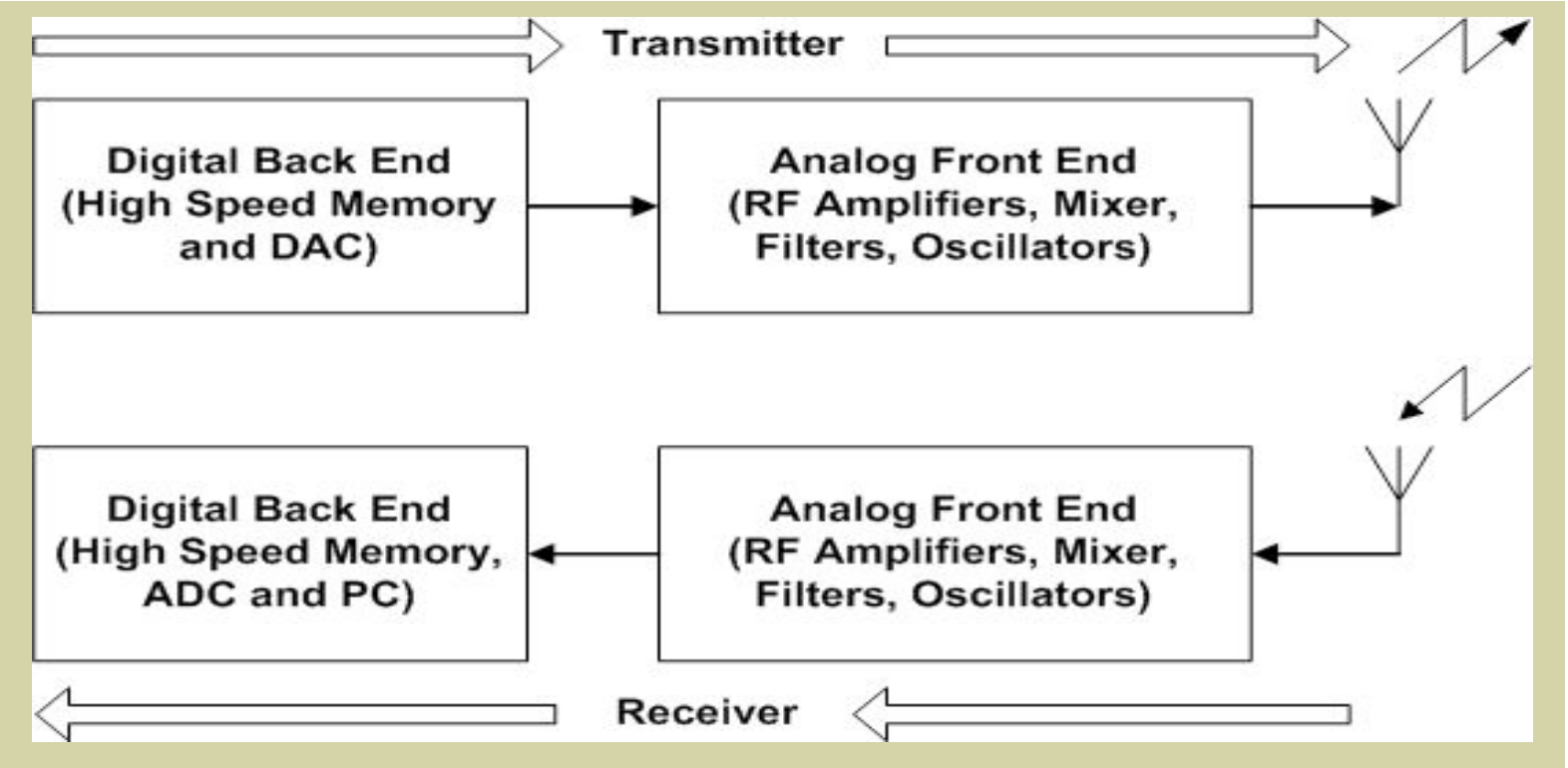
$$s_c(t) = \sum_{m=0}^{M-1} A_c e^{2\pi j(f_o + m\Delta f)t + \phi_m}$$



MC-UWB advantages:

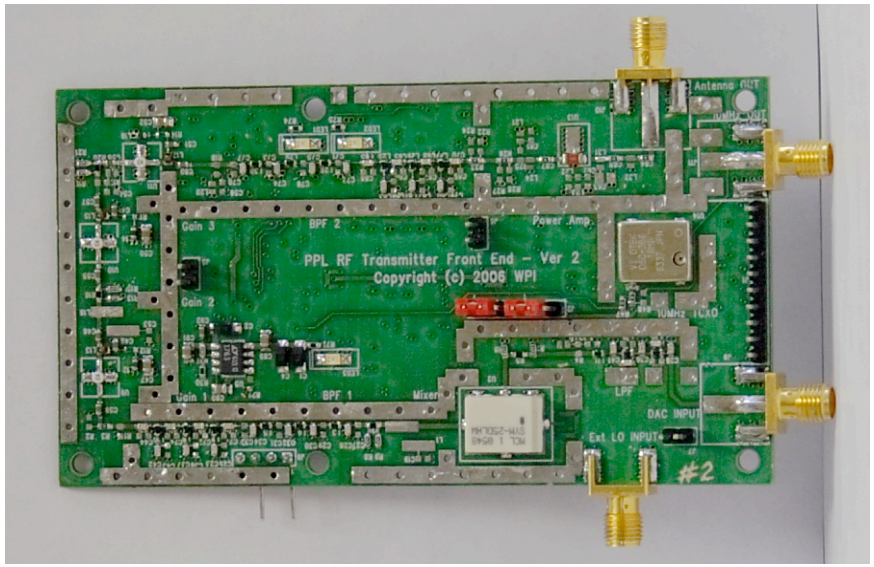
- Robust in fading environment
- Improved spectral efficiency
- High data rate
- Simple signal generation

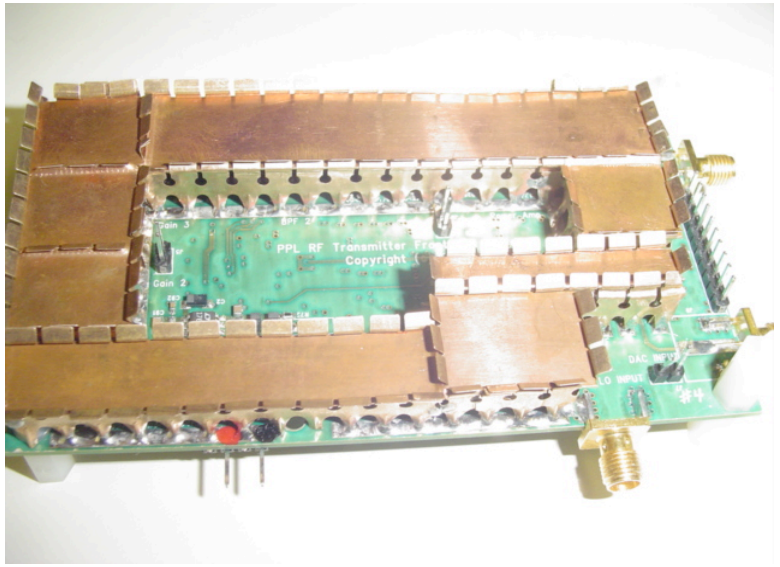
RF Prototype



Custom MC-UWB RF Prototype Design Required

RF Prototype - Transmitter

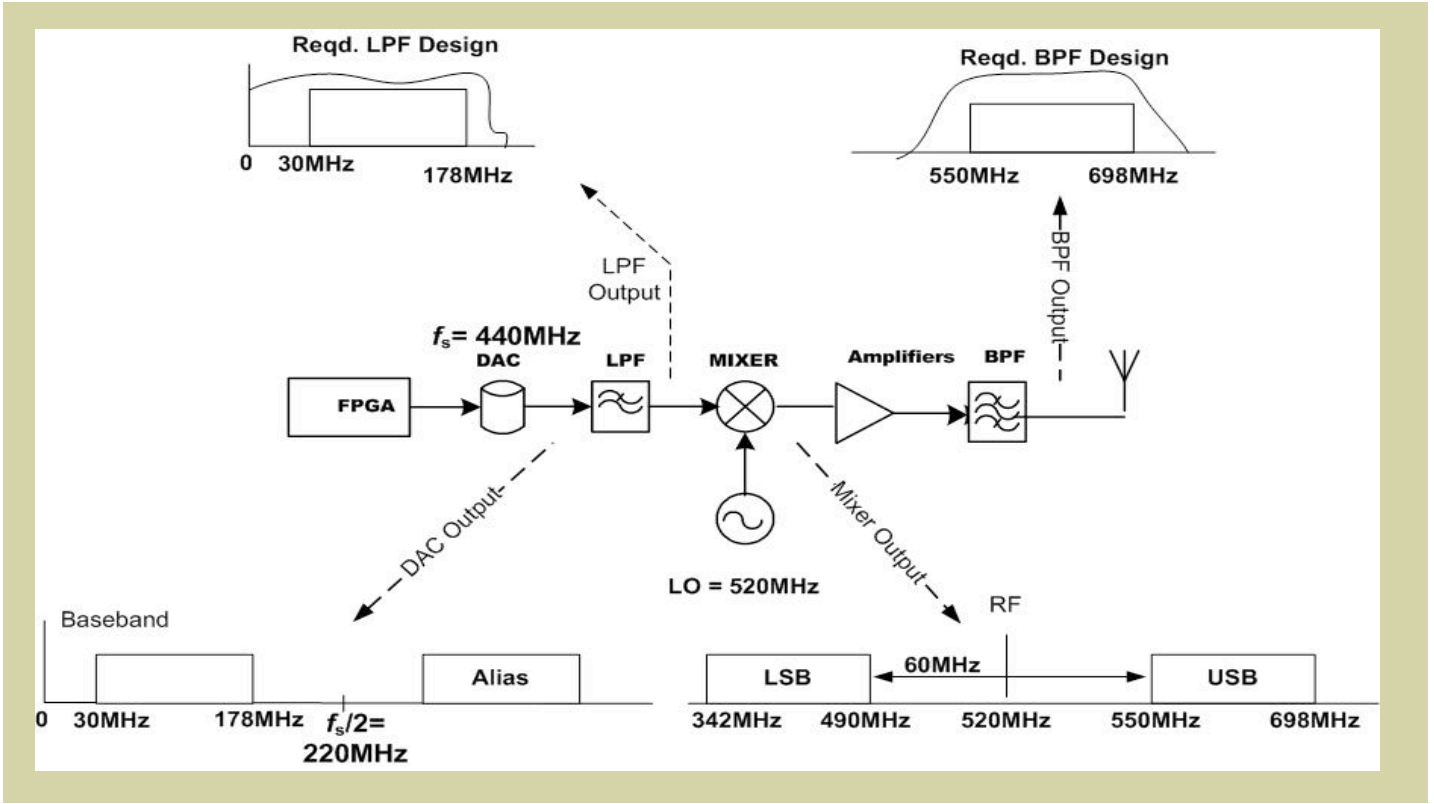




SSB Transmitter Output Frequency Range 550MHz – 698MHz (BW: 148MHz)
Fractional Bandwidth: 24%

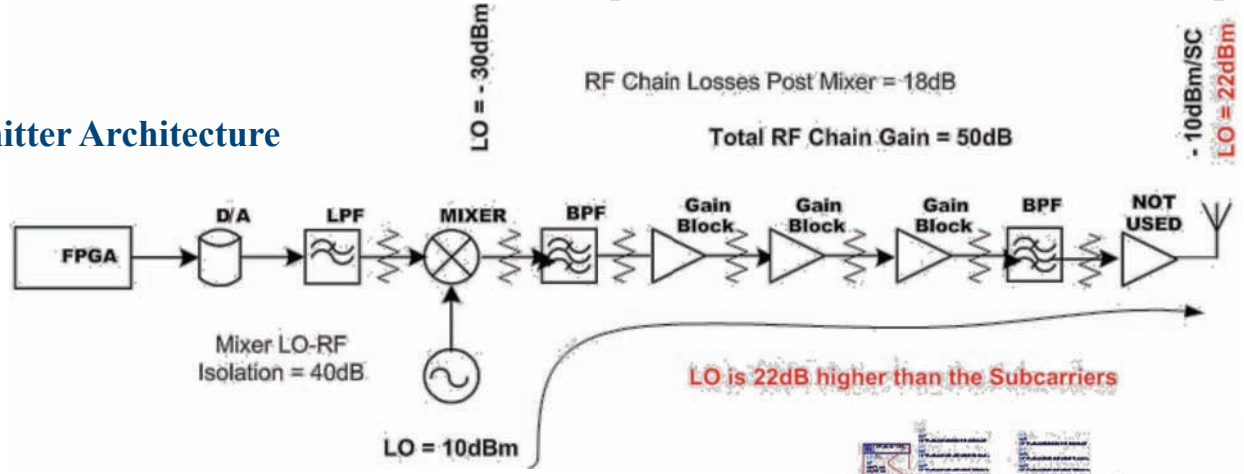
RF Prototype - Transmitter

Transmitter Output = -10dBm/SC

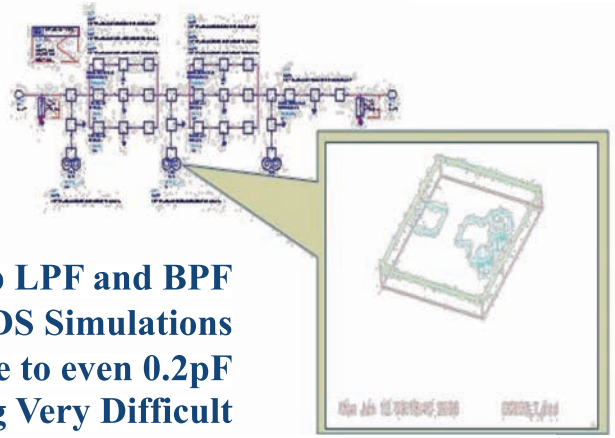


RF Prototype - Transmitter

SSB Transmitter Architecture

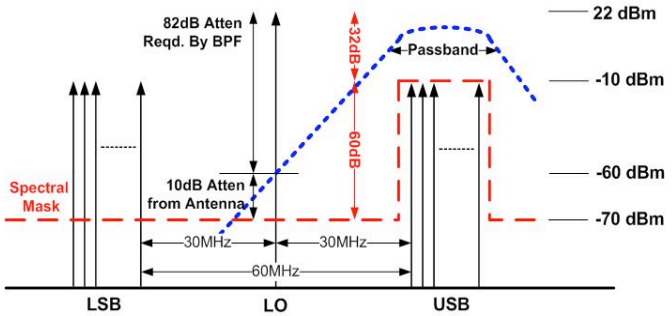


Spurious Emissions at Transmitter Output: LO, LSB

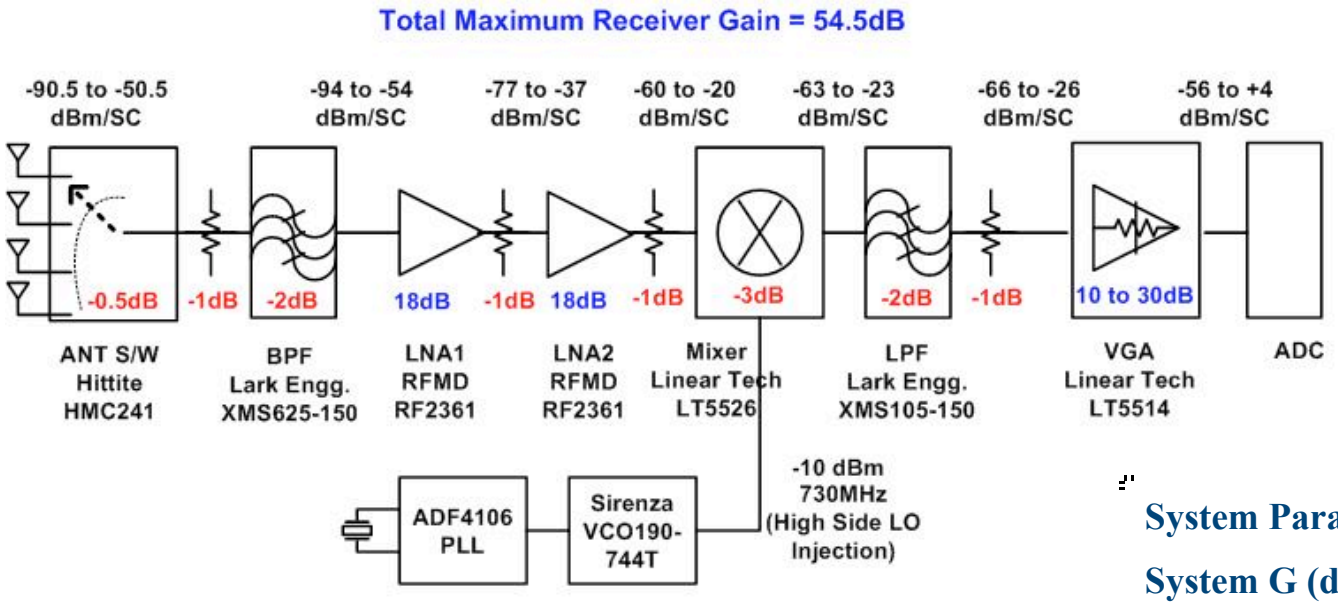


Need very steep LPF and BPF
ADS Simulations
Sensitive to even 0.2pF
Tuning Very Difficult

Spectral Mask



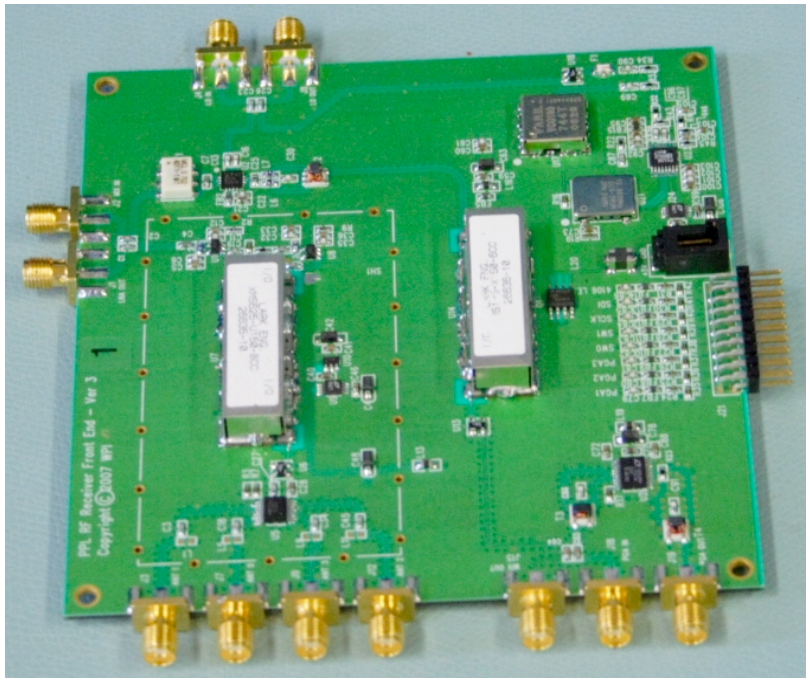
RF Prototype - Receiver



Direct Downconversion Receiver Architecture

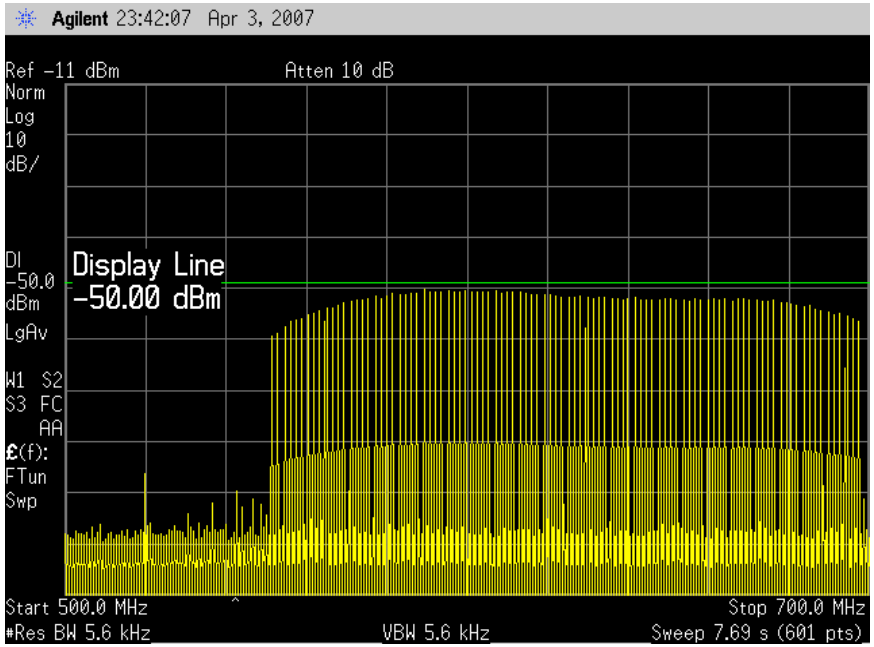
System Parameter	Achieved
System G (dB)	50
System *NF* (dB)	4.5
System *IIP3* (dBm)	-19
Rx. Sensitivity (dBm)	-87
Rx. SFDR (dB)	45.3

RF Prototype - Receiver

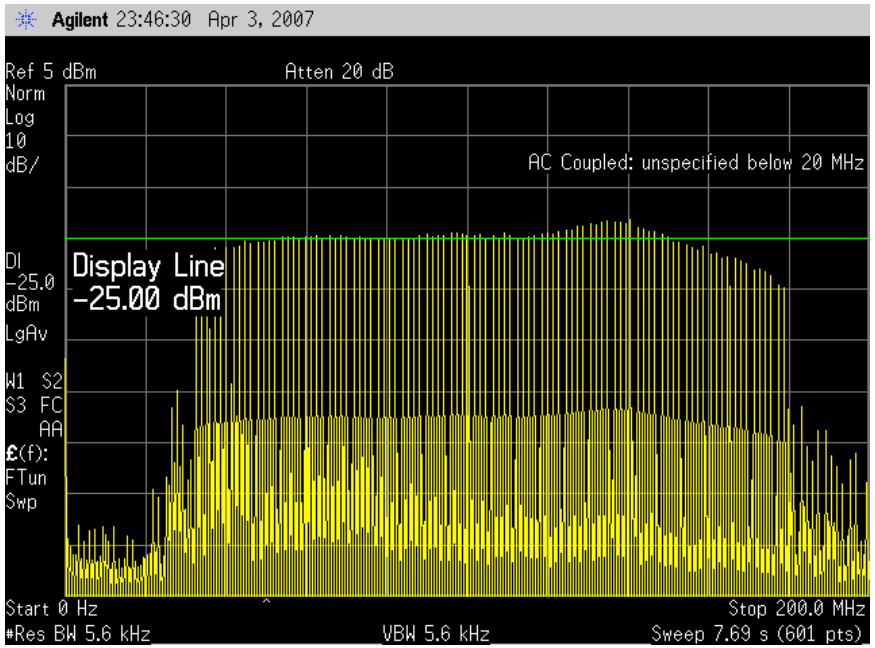


Direct Downconversion Receiver Output Frequency Range
30MHz – 178MHz (BW: 148MHz)
Fractional Bandwidth: 24%

NLOS Positioning Test Setup



148MHz RF System
Transmitter Output



148MHz RF System
Receiver Output

NLOS Positioning Test Setup

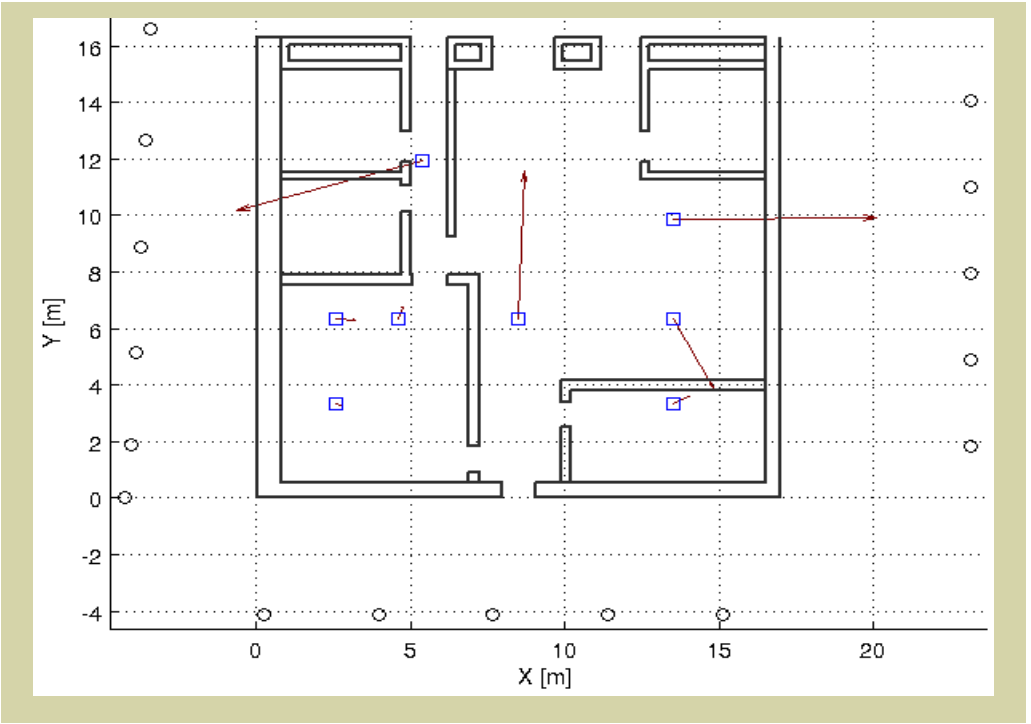
Test Setup:

- 20mx20m brick building
- 1 Transmitter inside
- 16 Receiving antennas outside, covering 3 sides

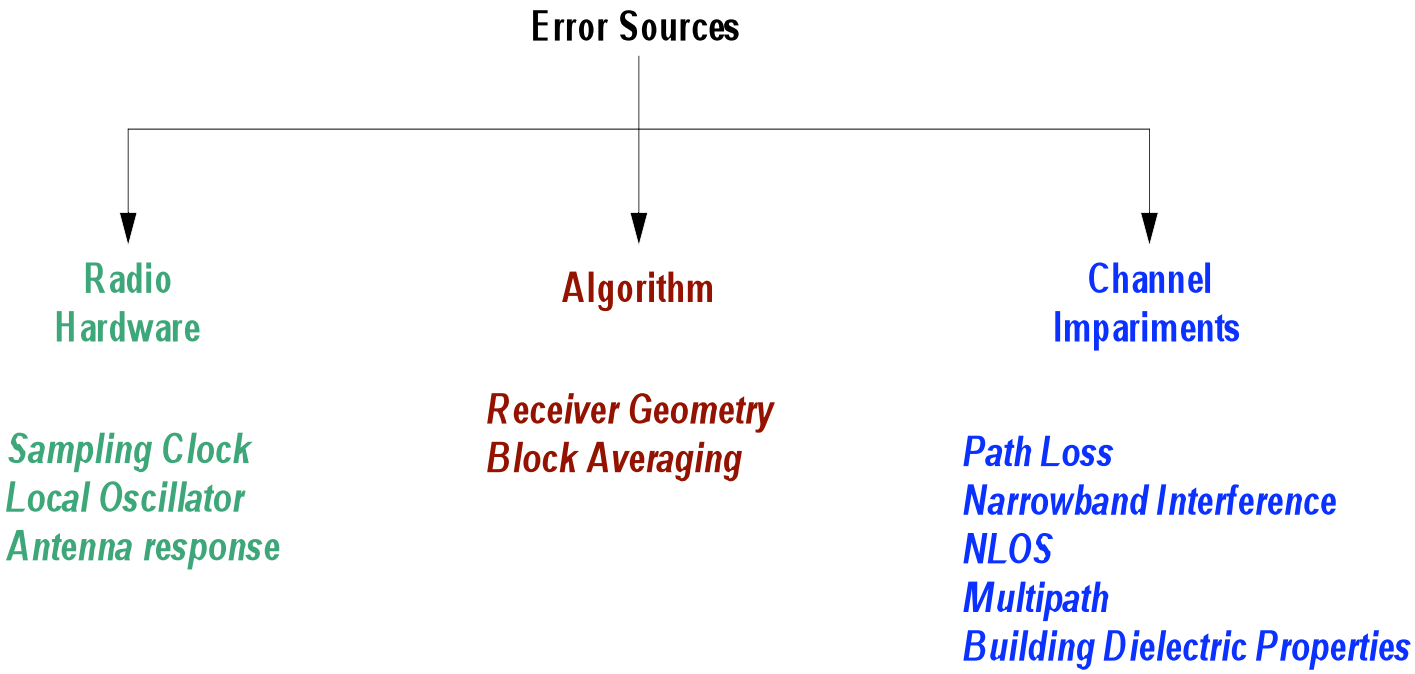
NLOS Positioning Test Results

Test Results:

- Min Error: 0.22m
- Max Error: 6.6m
- Mean Error: 2.84m



NLOS Positioning Error Sources

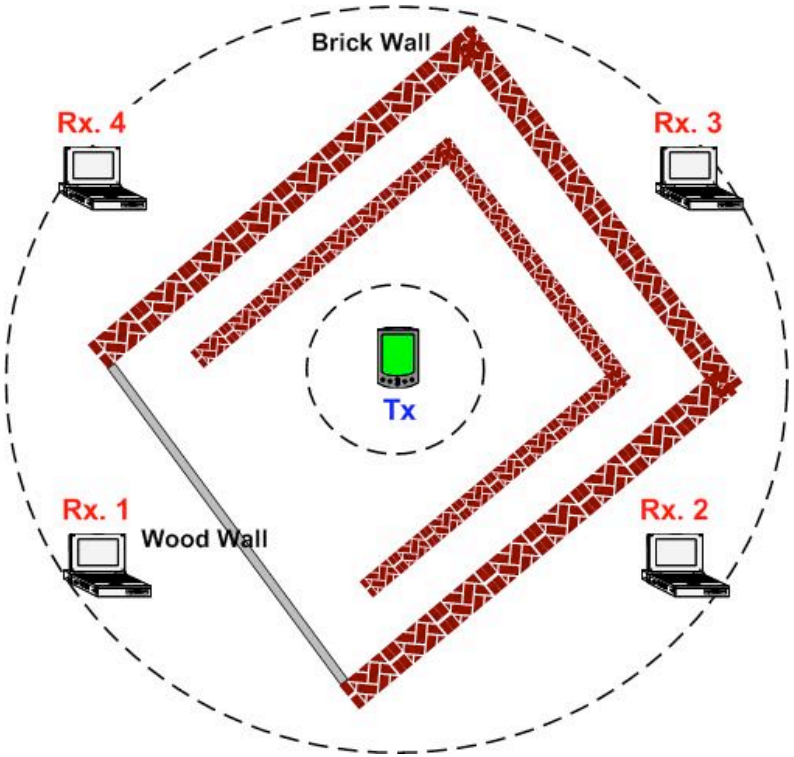


NLOS Positioning Error Sources

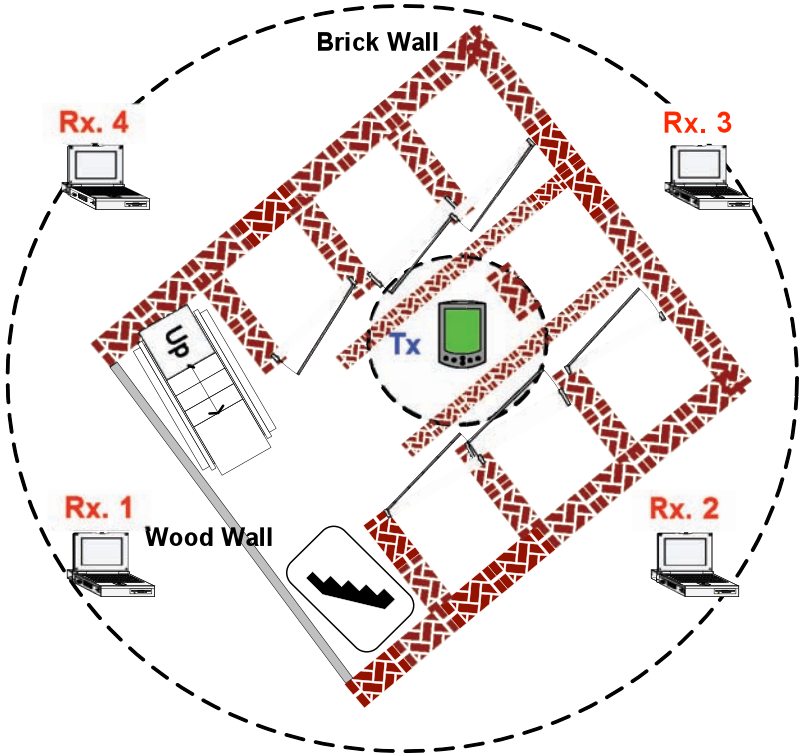
Error Source	Error (meter)	Design Constraints / Comments
Sampling CLK Shift	0.003	< 10 ppm: Sampling CLK frequency error
Sampling CLKDrift	0.003	< 10 ppm: Sampling CLK frequency error
Local Oscillator Shift	0.010	< 2.5 ppm: Local oscillator frequency error
Local Oscillator Drift	0.010	< 2.5 ppm: Local oscillator frequency error
Receiver Geometry	0.30	Optimum receiver geometry very important
Antenna Type	0.30	Need to use directional antennas at receivers
Software Processing	0.10	Optimum selection of the useful spectrum
Path Loss / Shadow Fading	0.10	AGC implementation at the transmitter and receiver
Narrowband Interference	0.30	Optimum selection of the useful spectrum
NLOS	0.50	Better geometry, antenna, transmit power required
Multipath	0.50	Need for channel models specific to indoor positioning
Building Dielectric Properties	???	Characterize delays induced by various building materials
Total RSS Error	???	

NLOS Positioning Error Sources

No Multipath, Effect of Dielectric Properties Only



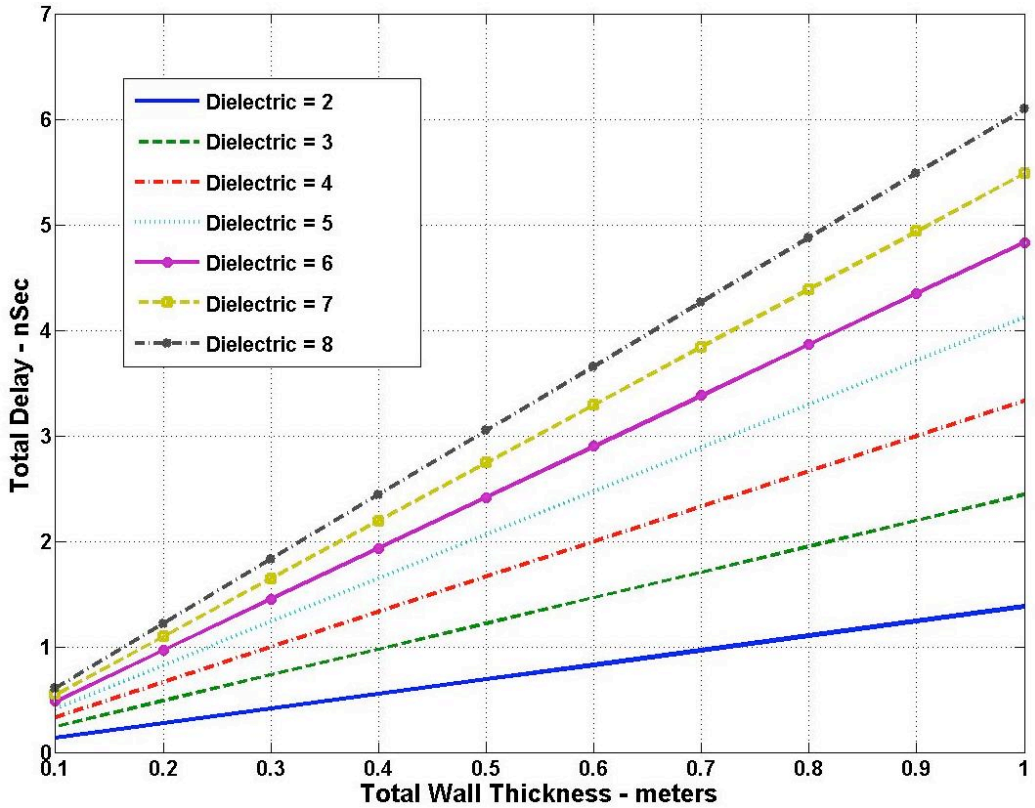
Error = 0.93m



Error = 3.48m

NLOS Positioning Error Sources

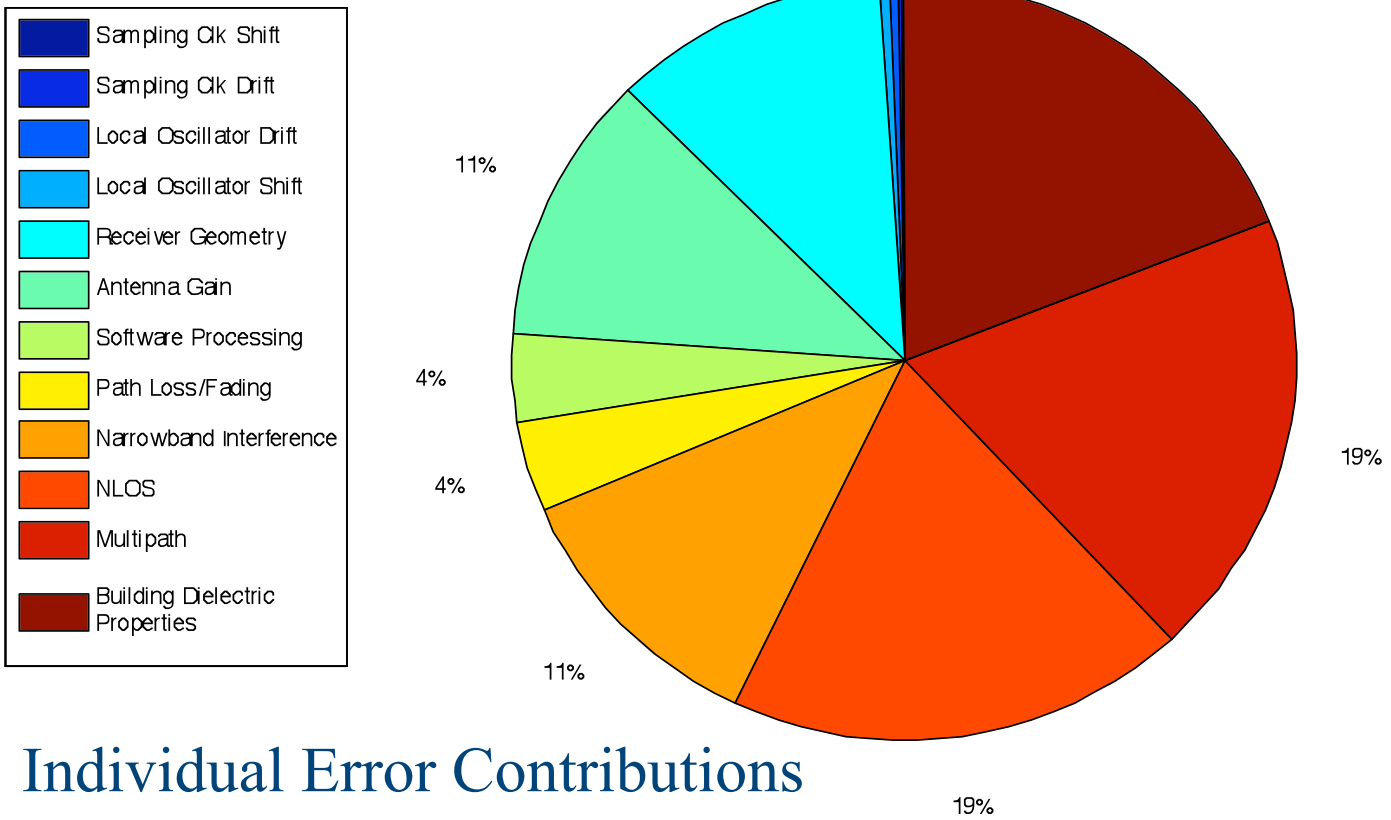
Total Wall Thickness vs. Total Signal Delay / Total Error



NLOS Positioning Error Sources

Error Source	Error (meter)	Design Constraints / Comments
Sampling CLK Shift	0.003	< 10 ppm: Sampling CLK frequency error
Sampling CLKDrift	0.003	< 10 ppm: Sampling CLK frequency error
Local Oscillator Shift	0.010	< 2.5 ppm: Local oscillator frequency error
Local Oscillator Drift	0.010	< 2.5 ppm: Local oscillator frequency error
Receiver Geometry	0.30	Optimum receiver geometryVery important
Antenna Type	0.30	Need to use directional antennas at receivers
Software Processing	0.10	Optimum selection of the useful spectrum
Path Loss / Shadow Fading	0.10	AGC implementation at the transmitter and receiver
Narrowband Interference	0.30	Optimum selection of the useful spectrum
NLOS	0.50	Better geometry, antenna,transmit power required
Multipath	0.50	Need for channel modelsspecific to indoor positioning
Building Dielectric Properties	> 0.5	Characterize delays induced by various building materials
Total RSS Error	> 2.626	

NLOS Positioning Error



Individual Error Contributions

Conclusion

- Dielectric properties of the building materials add to the positioning error.
- The indoor environment typically has more than two walls and this could lead to indoor positioning errors of the order of 2 to 3m.
- This not so well characterized source of error needs to be considered independently in indoor positioning systems
- There is a need to calibrate the positioning system thus minimizing the errors due to building dielectric material properties

?????


cairn
Center for Advanced
Integrated Radio Navigation


WORCESTER POLYTECHNIC INSTITUTE
1865
WPI