Remote In-Building Motion Detection using Single Frequency Technique

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Introduction

- Through-wall-sensing Applications:
  - Military & Law enforcement
  - Search and rescue

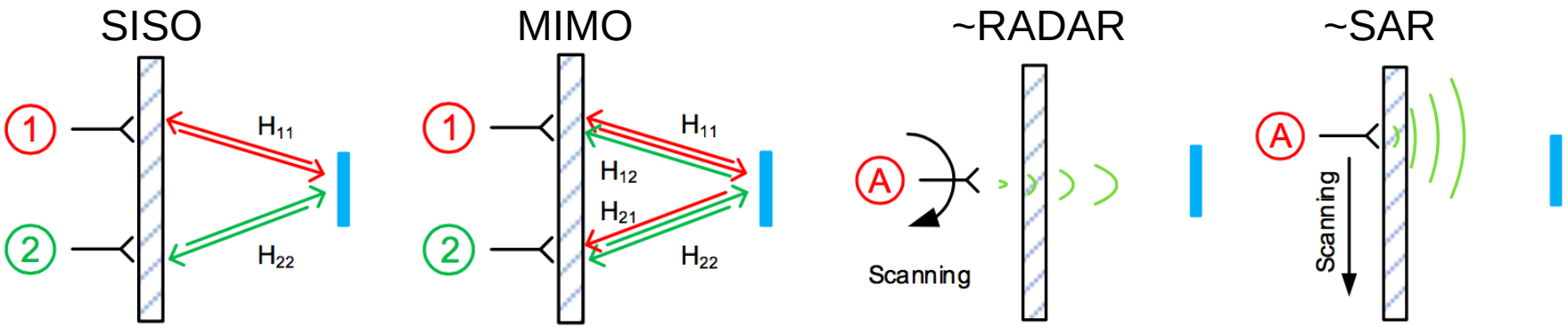
(www.extremetech.com, 2012)

www.bbc.com, 2015

➢ But which TTWS implementation is best for presence detection ?

Introduction

- Over the past years, we worked on
  - Active Sensing
    - Multi-static systems
    - Mono-static Systems



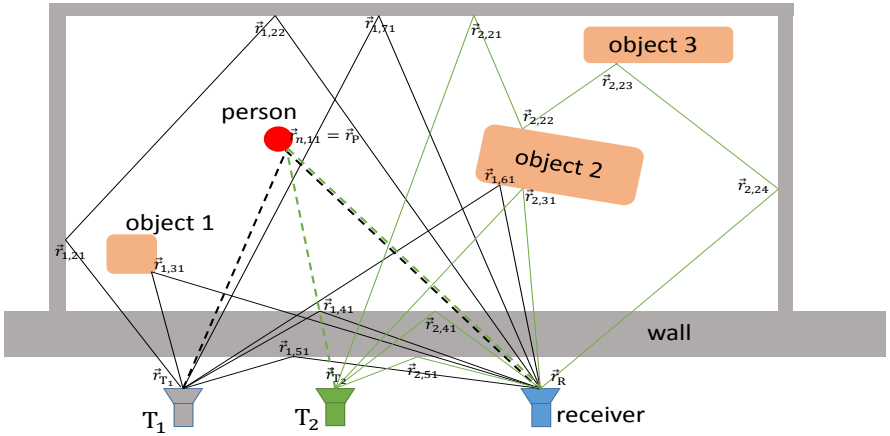
  - Passive Sensing
    - Wifi standards
    - Mobile communication (2-4G) standards

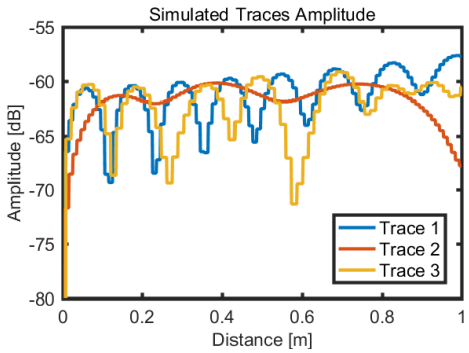
➢ These systems provided very good results, but are rather complex…

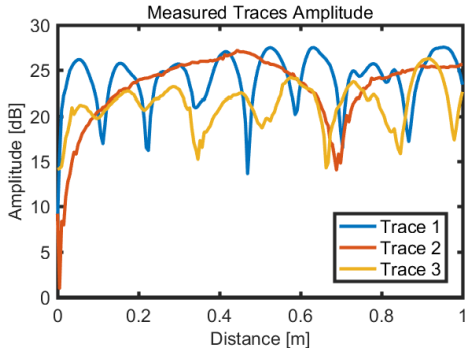
➢ What can we do to have a simple and robust motion detection sensor?

Content

- Introduction
- Single Frequency Sensing
  - Theoretical Background
  - Calibration (nulling)
- Simulation Results
- Experimental Results
- Conclusion

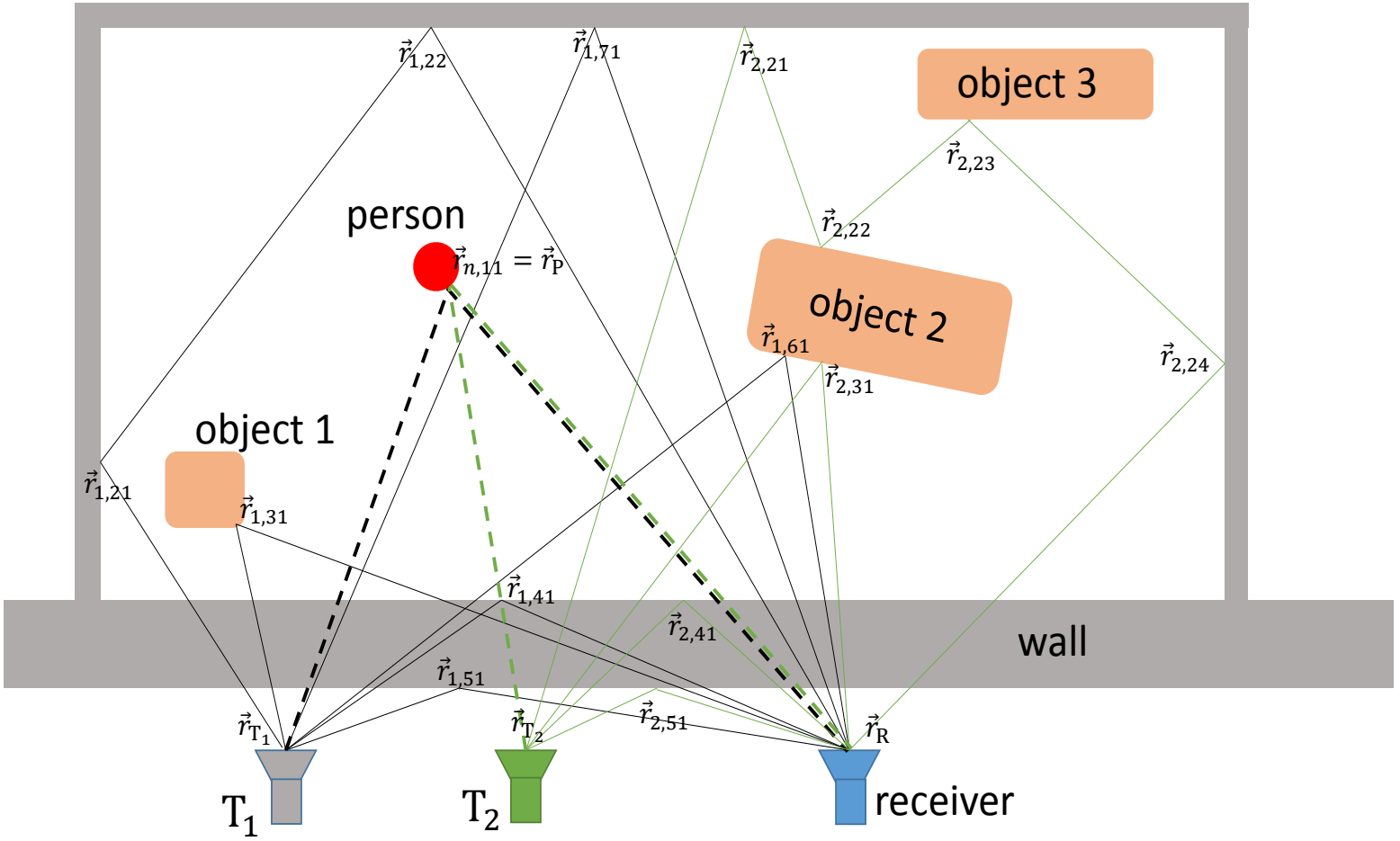




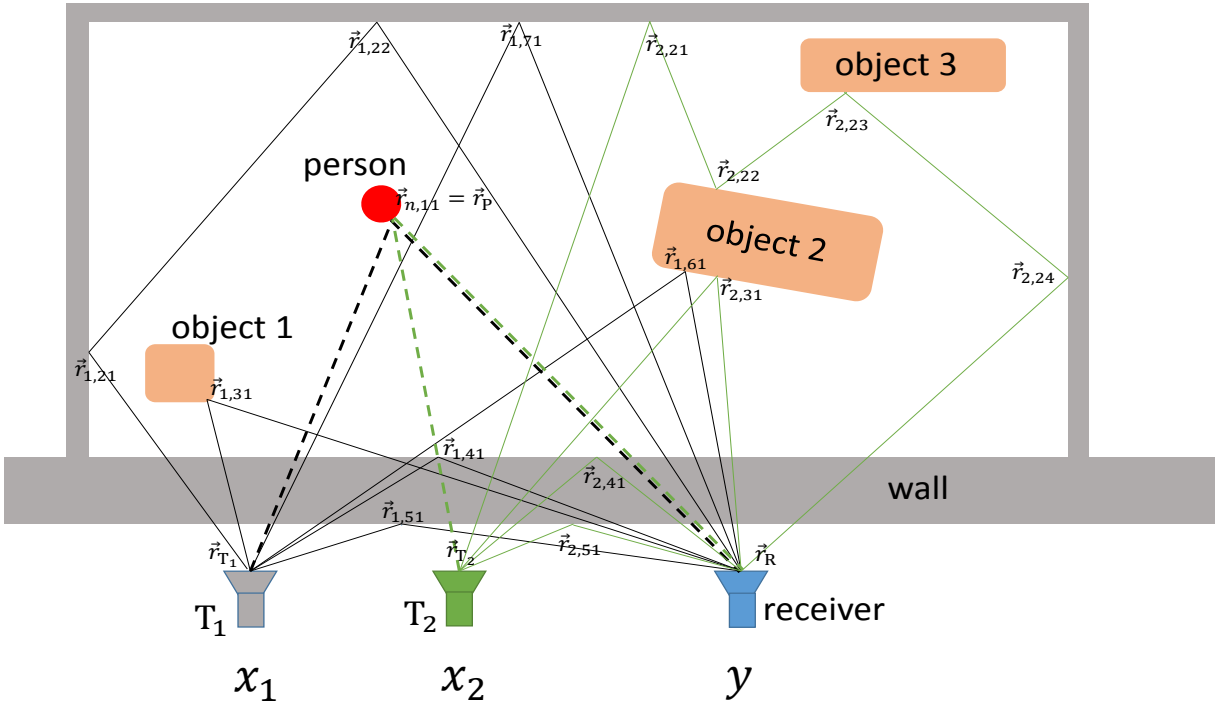


Single Frequency Sensing

- Two transmitters creates destructive interferences on the receiver



Single Frequency Sensing - Theory



- Received signal

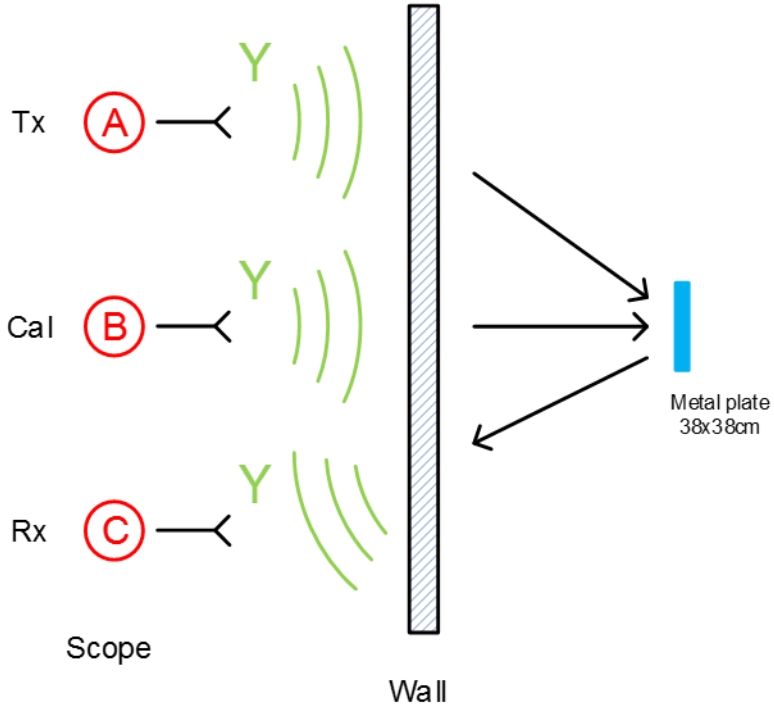
$$y = h_1 x_1 + h_2 x_2 = x_1 \sum_{i\text{th path}} h_{1i} + x_2 \sum_{j\text{th path}} h_{2j}$$

$$y(\vec{r}_P) = (dh_1(\vec{r}_P) - K_0 dh_2(\vec{r}_P)) \cdot x_1$$

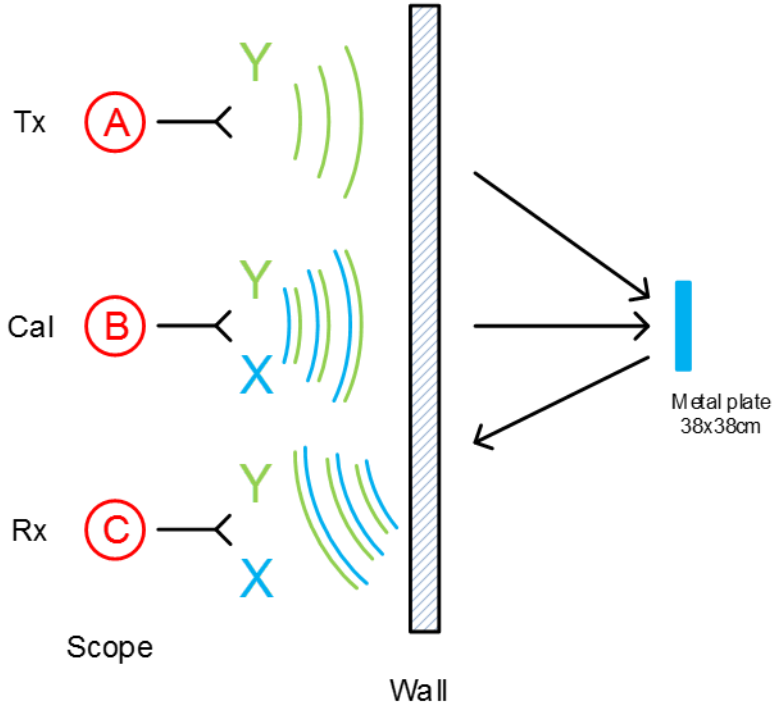
0 if $\vec{r}_P = \vec{r}_{P0}$

Single Frequency Sensing - Calibration

- Single polarization nulling



- Dual polarization nulling



Single Frequency Sensing - Calibration

- Signal at receiver given by:

$$y = h_1 x_1 + h_2 x_2$$

$$Y = \begin{bmatrix} Y_x \\ Y_y \end{bmatrix} = M_1 \mathrm{X}_1 + M_2 X_2 = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} X_{1_x} \\ X_{1_y} \end{bmatrix} + \begin{bmatrix} e & f \\ g & h \end{bmatrix} \begin{bmatrix} X_{2_x} \\ X_{2_y} \end{bmatrix}$$

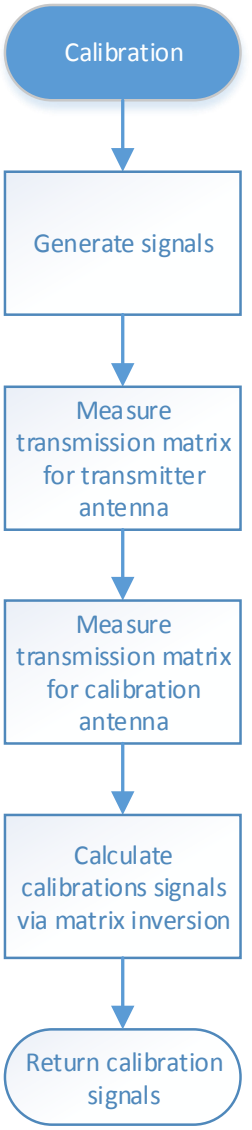
- At calibration:

$$M_1 \mathrm{X}_1 + M_2 X_2 = 0$$

$$X_2 = -M_2^{-1} M_1 X_1$$

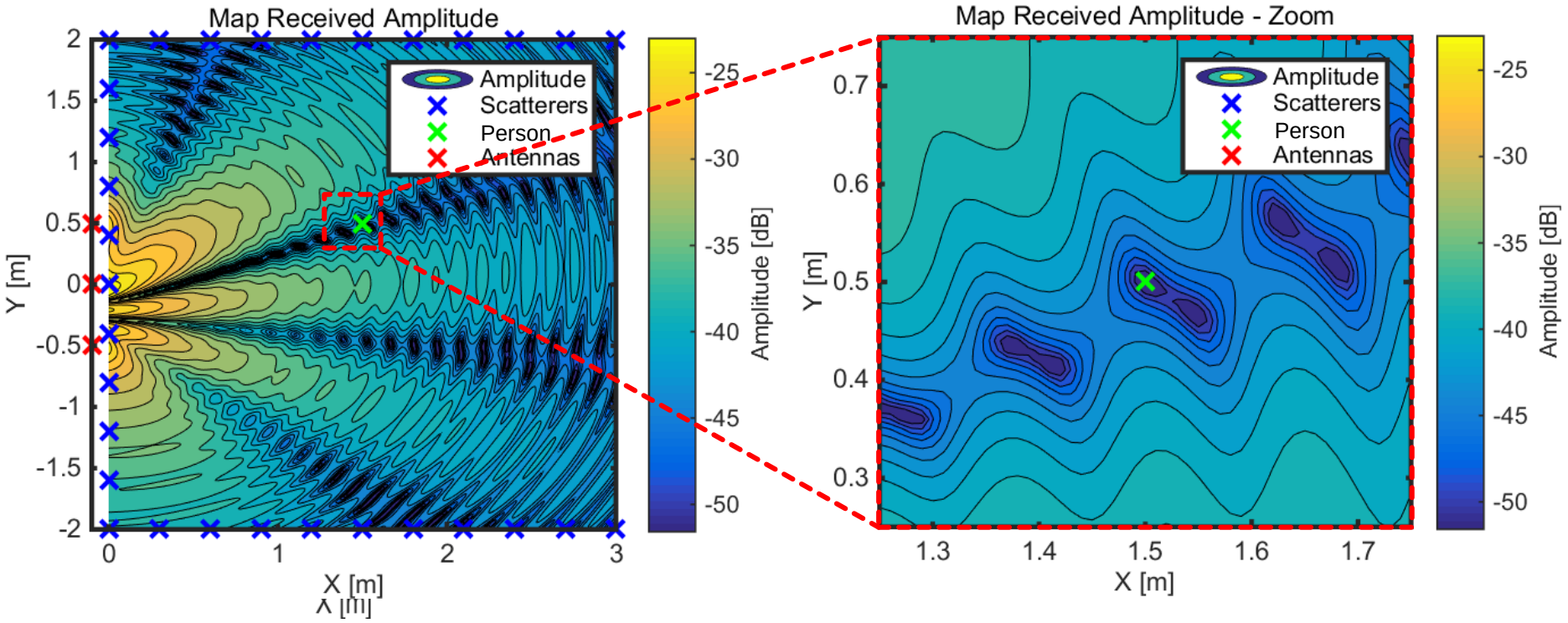
➢ Calibration derived from knowledge of M_1 & M_2

Calibrate using Amplitude, Phase, & Polarization



Single Frequency Sensing - Theory

- Amplitude Map (Matlab)



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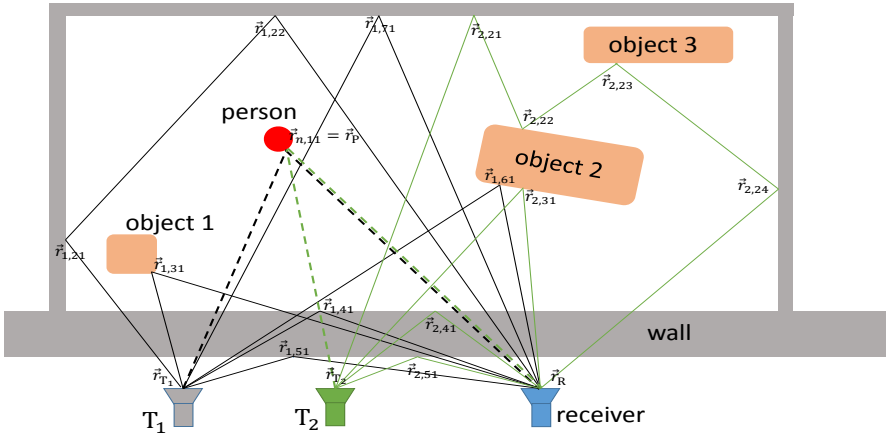
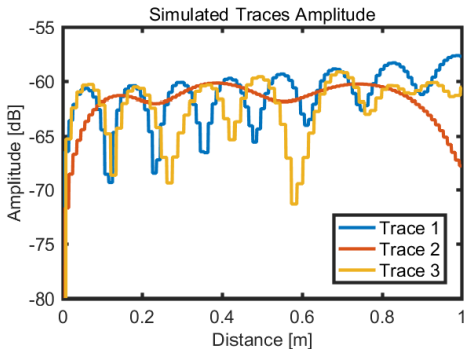
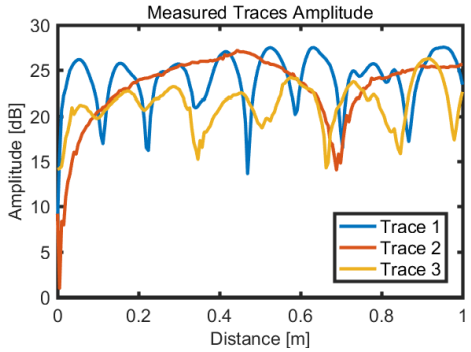
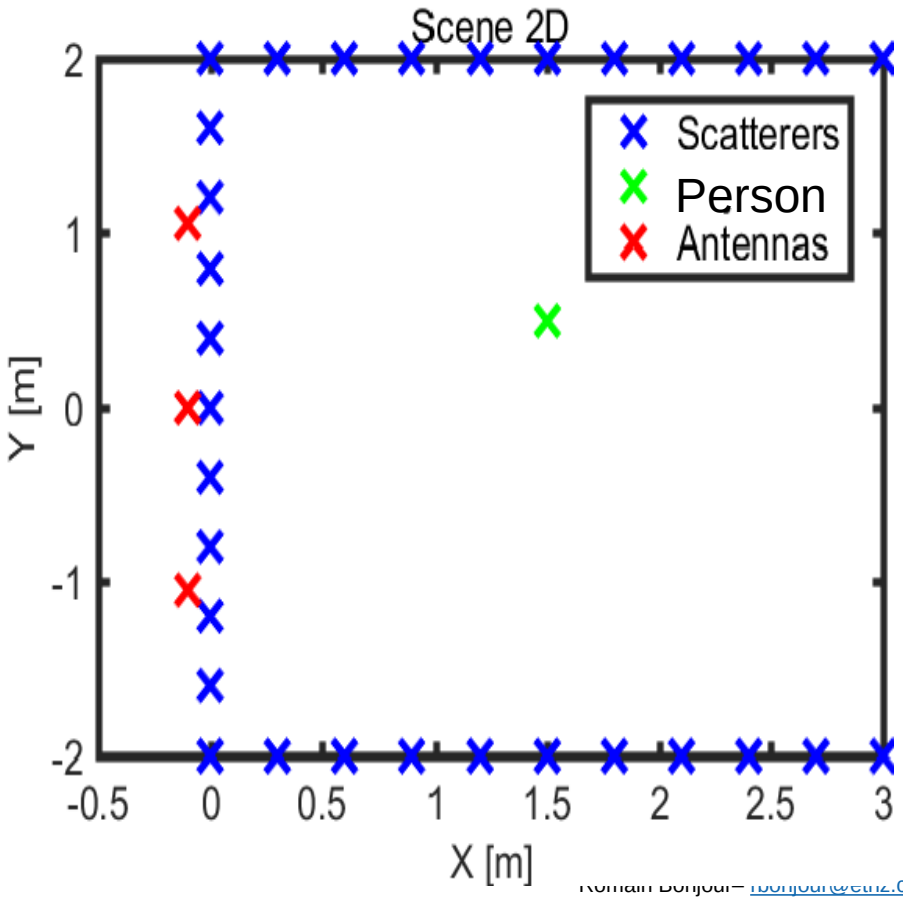






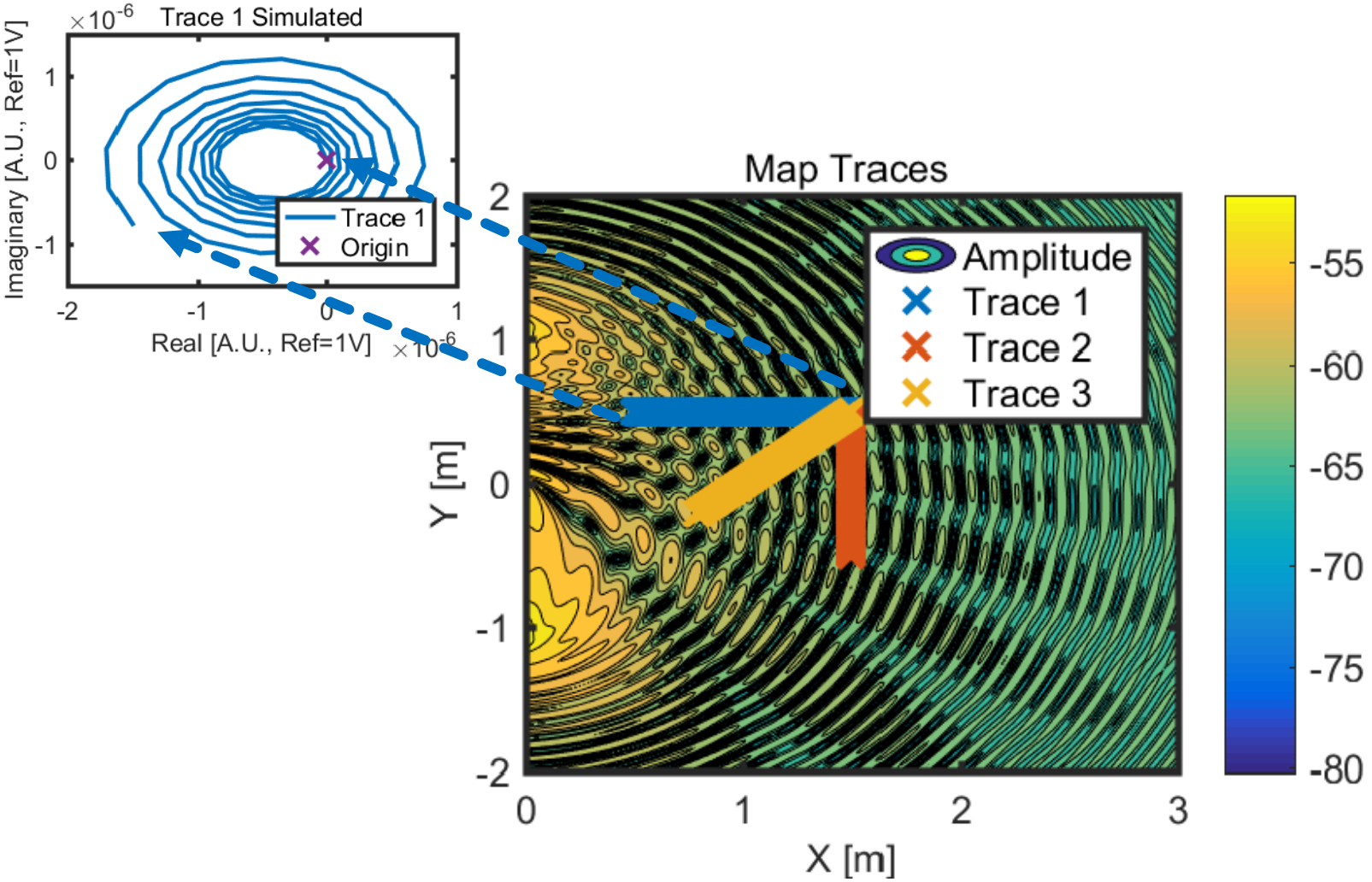
Simulation Results

- Scene under Test



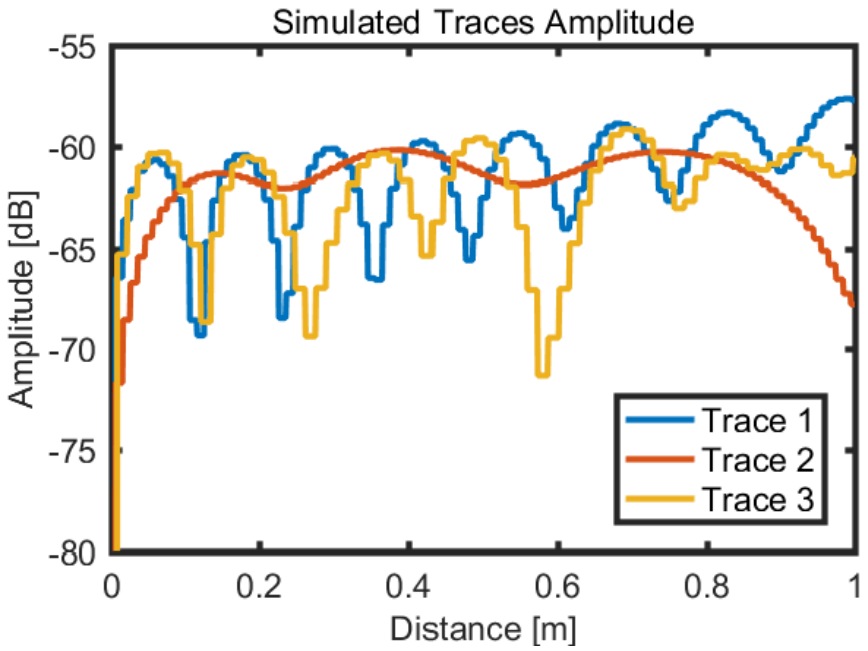
Simulation Results – Amplitude Map

- Amplitude variation along predefined paths

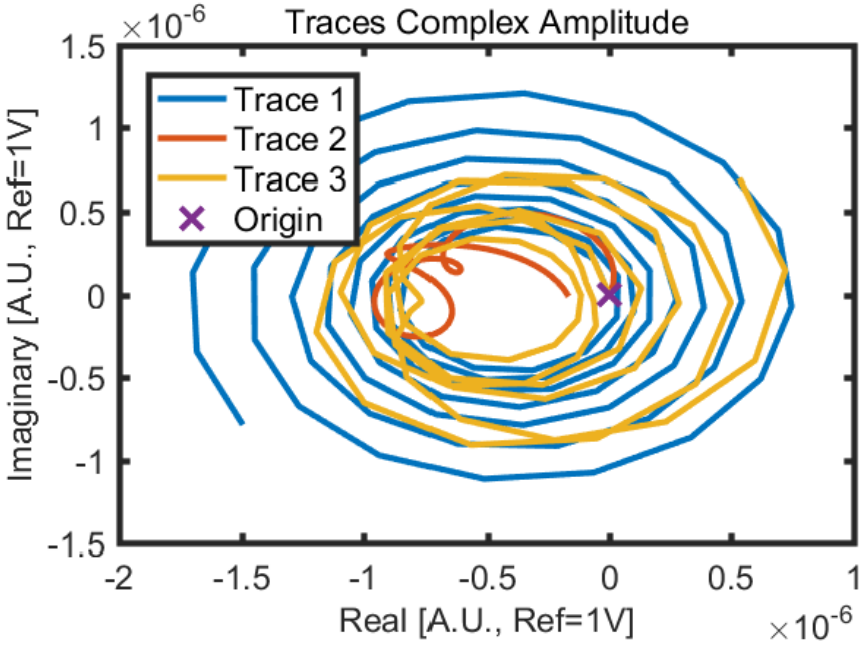


Simulation Results - Traces

- Amplitude Traces



- Complex Traces



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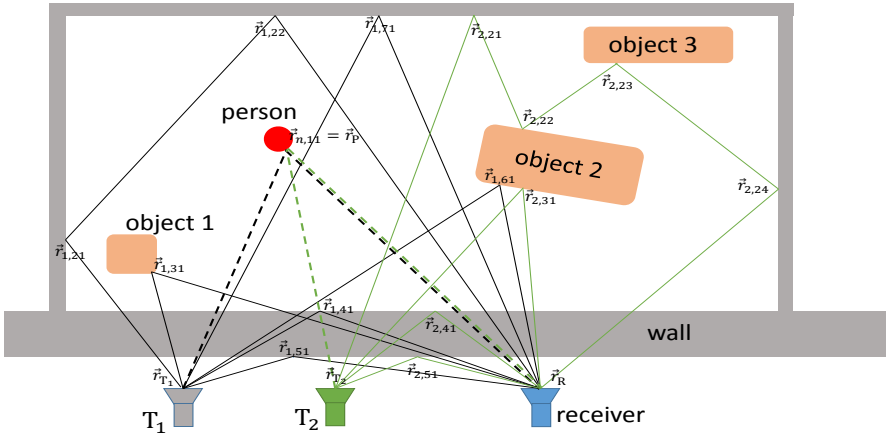
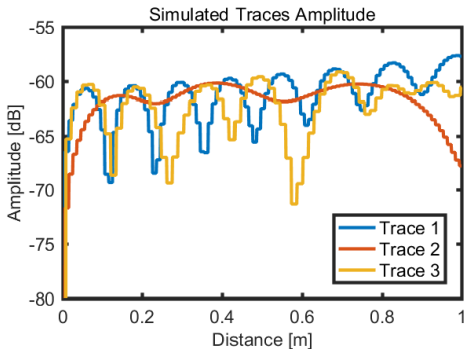
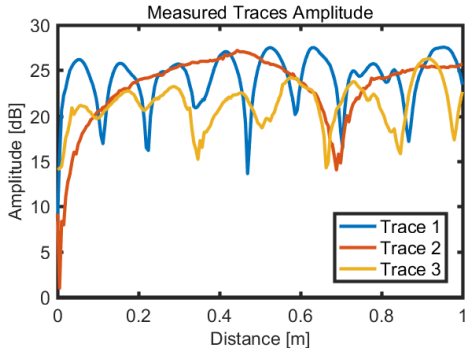
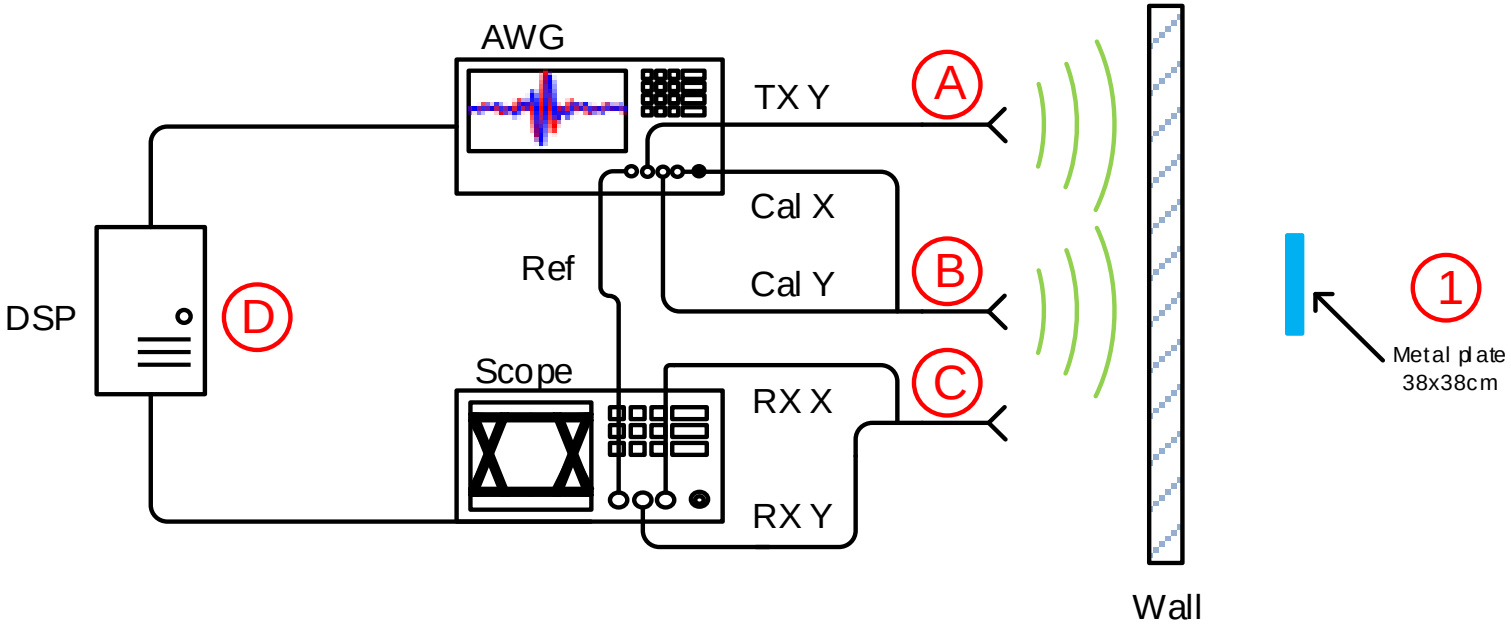


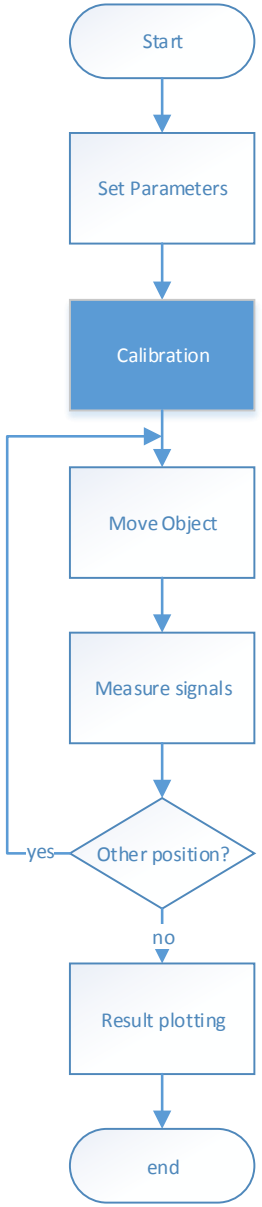




Experimental Results

- Setup

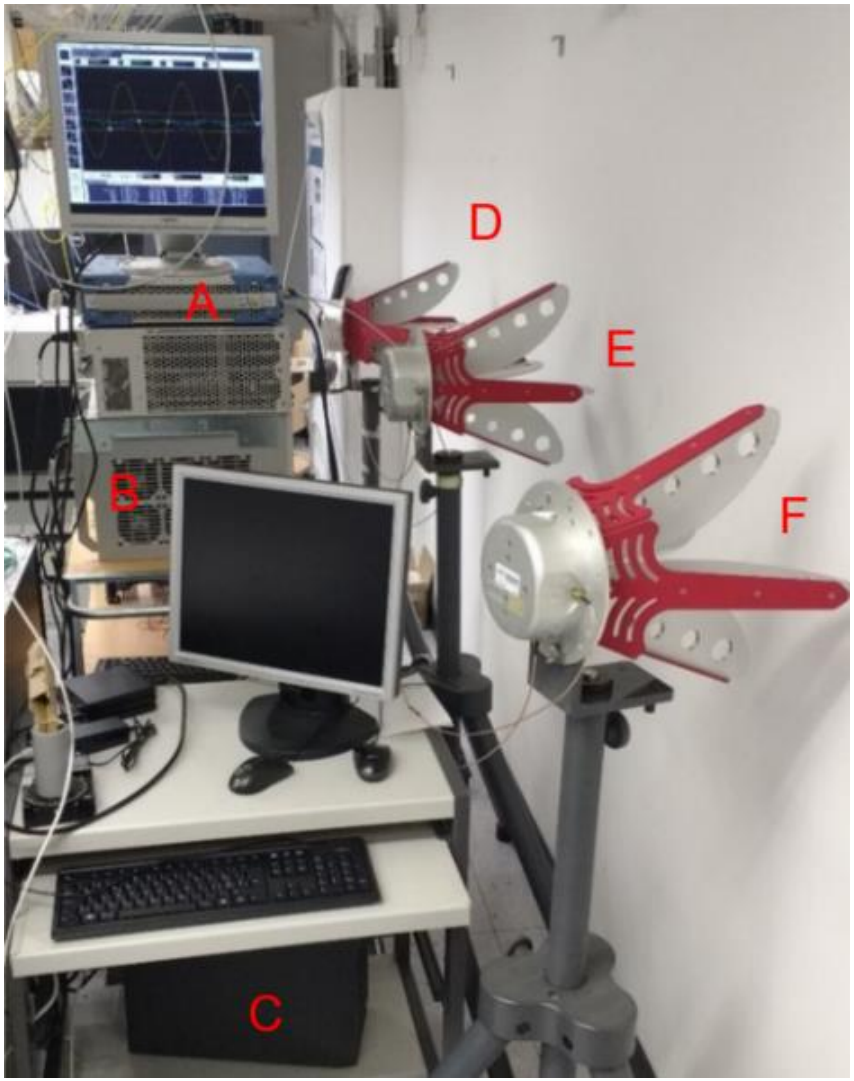




Experimental Results - Setup

- Overview

Experimental Results - Setup



A. Arbitrary waveform generator

B. Oscilloscope

C. Computer

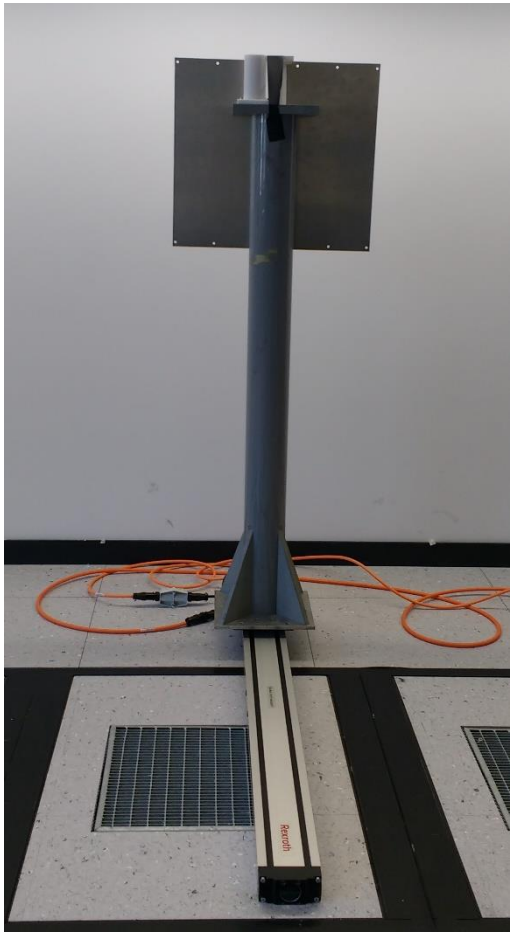
D. Transmitter

E. Calibration Antenna

F. Receiver

Experimental Results - Stage

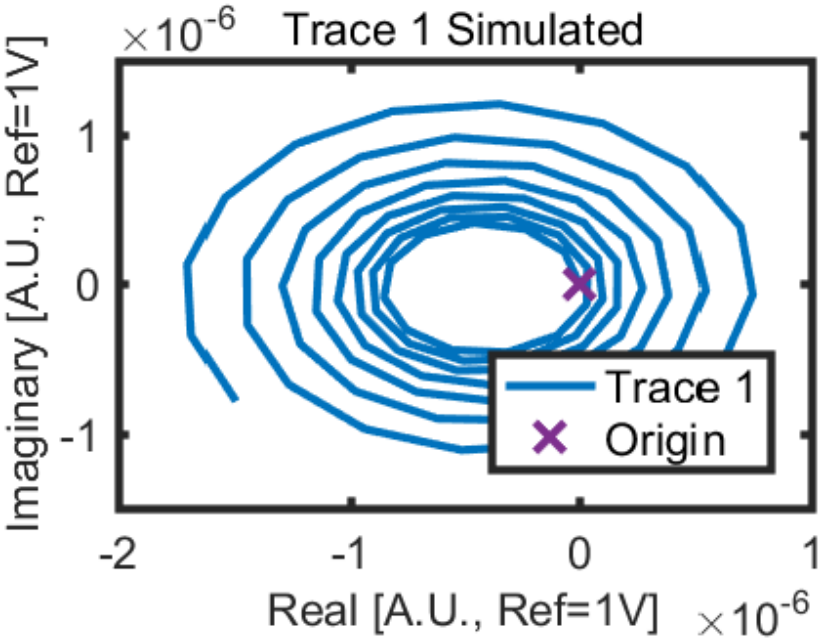
- Linear stage used for traces measurement

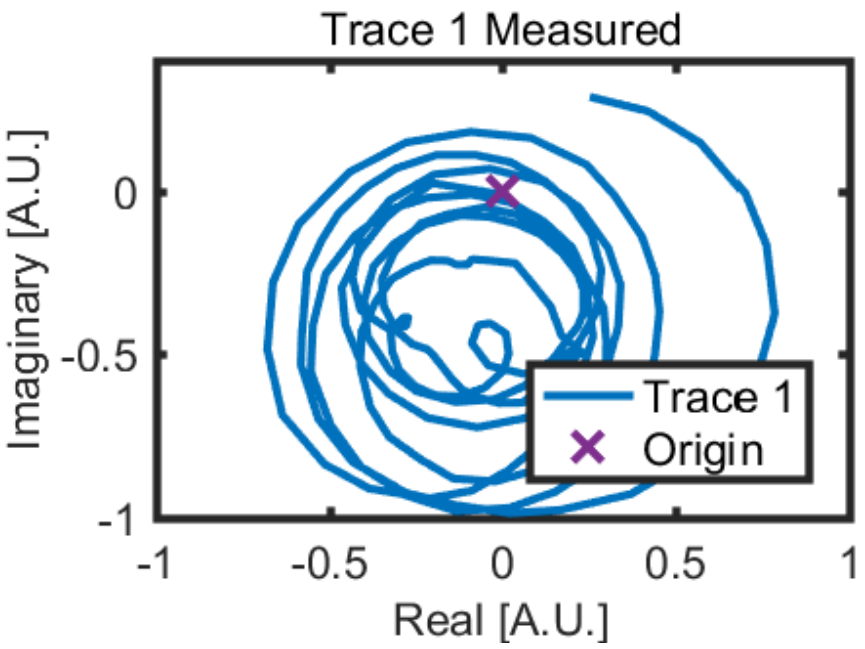


Experimental Results - Traces

- Comparison Simulations / Measurements

  CW @ 1.5GHz, with ~1mW transmitted power





Experimental Results - Traces

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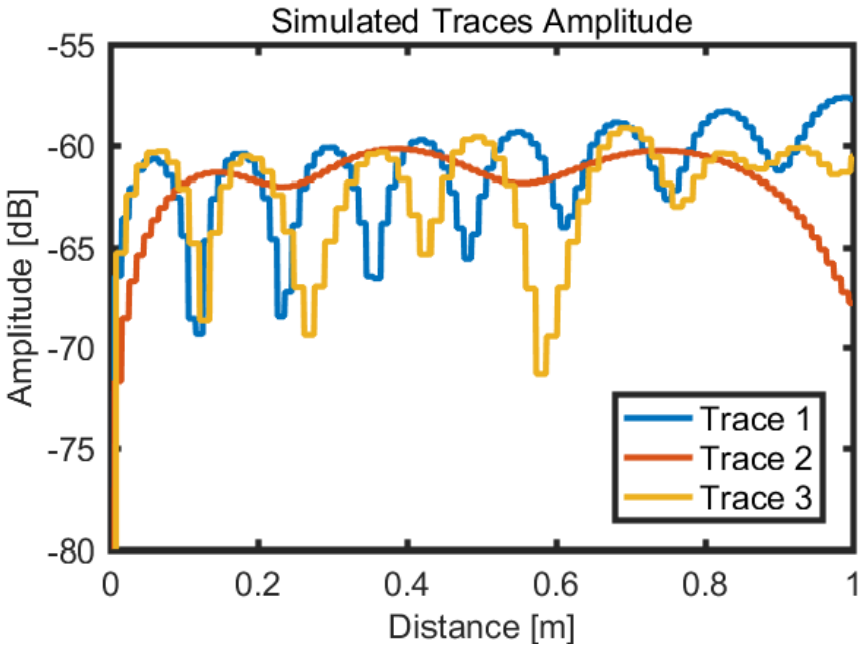
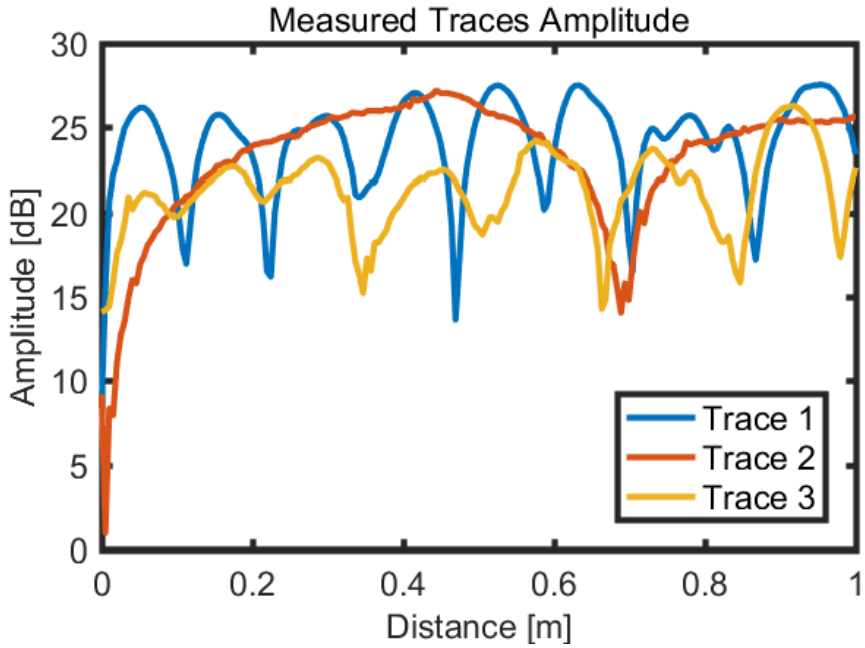
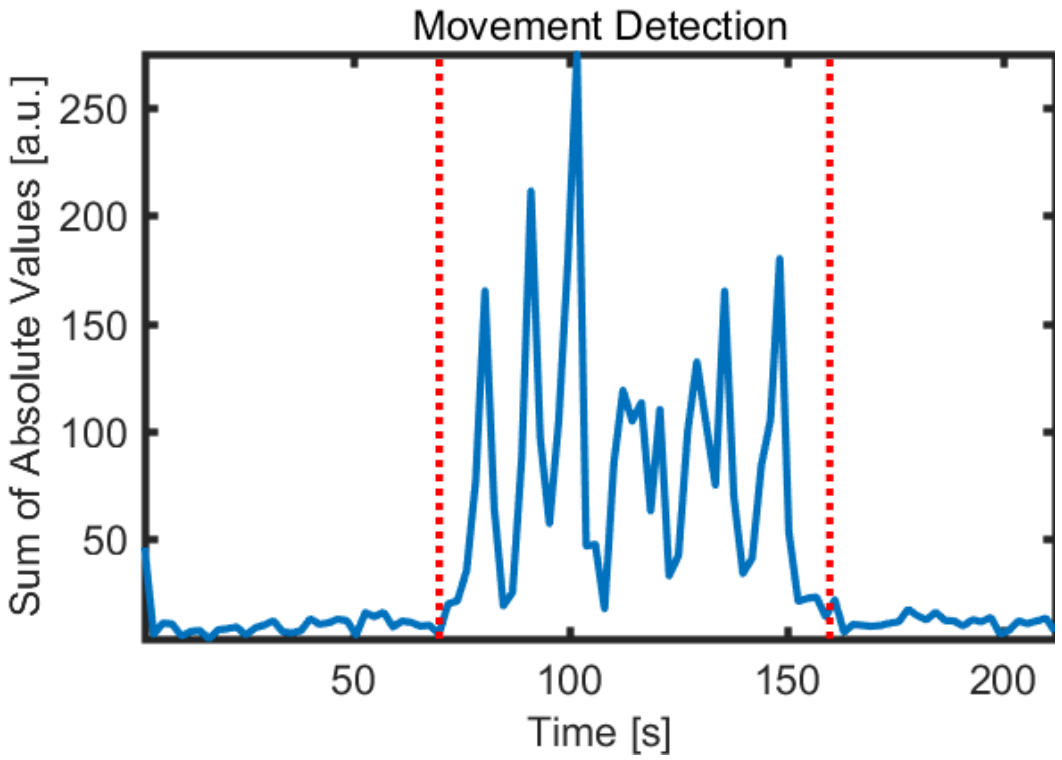




Experimental Results – Movement Detection

- 3 back and forth movement at 2m of the wall

  CW @ 1.5GHz, with ~1mW transmitted power



Conclusion

- Robust concept with
  - High Sensitivity
  - Simple Hardware
- Electronic calibration (~500ms)
- Good match with experiment

- Next Steps:
  - Larger distances from wall
  - Handheld device integration
  - Frequency sweeping
  - Pulsed system ?
  - Nulling of comm. signals