A Coexisting MIMO-Radar MIMO-Communications Hardware Prototype

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MIMO Radar	MIMO Comm
N element transmit and M element receive arrays	N transmit and M receive antennas
Transmit orthogonal waveforms from antennas • $< x_m(t), x_n(t) >= \delta(m-n)$ • $x_n(t)$: FMCW, PMCW, OFDM • Multiplexing in time, frequency, antenna, code	Transmit correlated waveforms • $\boldsymbol{x(t)} = \boldsymbol{f(s(t))}$, $\boldsymbol{s(t)}$: data vector across N antennas • Linear processing : $\boldsymbol{x(t)} = \boldsymbol{F}\, \boldsymbol{s(t)}$
$\boldsymbol{y(t)}$: Received Signal $= \sum_{k=1}^{K} \alpha_k e^{-j\omega_{d,k}t} \boldsymbol{a}_r(\theta_k)\, \boldsymbol{a}_t^H(\theta_k) \boldsymbol{x}(t-\tau_k) + \boldsymbol{c}(t)$ $+ \boldsymbol{\eta}(t)$ $\boldsymbol{c(t)}$: Clutter, K targets $\boldsymbol{a}_r(\theta), \boldsymbol{a}_t(\theta)$: Rx/ Tx steering vectors	$\boldsymbol{y(t)} = \sum_{k=1}^{K} \alpha_k e^{-j\omega_{d,k}t} \boldsymbol{H}_k \boldsymbol{x}(t-\tau_k) + \boldsymbol{\eta}(t)$ K scatterers, $\boldsymbol{H}_k$: Channel Multipath channel
Receiver Processing and Performance Metrics • Matched filtering, Range, Angle and Doppler processing • SINR, MSE, P_D (P_{FA})	Receiver Processing and Performance Metrics • Frame Synchronization, Frequency Offset Correction, FFT, MAC Decode • PER
Advantages • Performance of $M \times N$ from $M + N$ elements	Advantages • Diversity • Multiplexing

Co-existence

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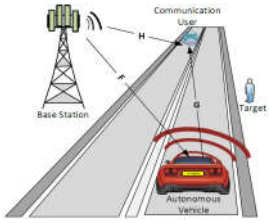
Coexisting MIMO-radar-MIMO-comm (MRMC) desirable due to spectrum congestion

- Radar and comm share the same antennas
- MIMO comm crucial in millimeter-wave 5G communications
- mm-wave MIMO radar beneficial for automotive applications

MRMC Challenges:

- High-dimensional system design
- waveform multiplexing
- interference management
- accurately decoding of data and estimation target parameters including DoA



Contributions:

- Prototype of co-existence
  - Vehicle-to-vehicle (V2V) or point-to-point MIMO communications
  - Code Division Multiplexing MIMO Radar
  - Frame multiplexing for Radar and Communications

- Demonstrate co-existence and MIMO aspects
- Currently sub 6-GHz, plans to extend to mm-wave

Demonstration Overview

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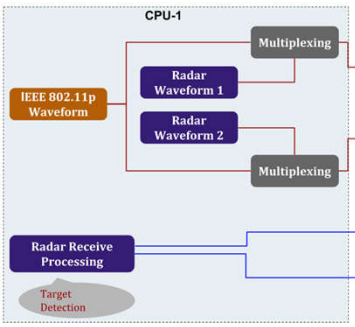
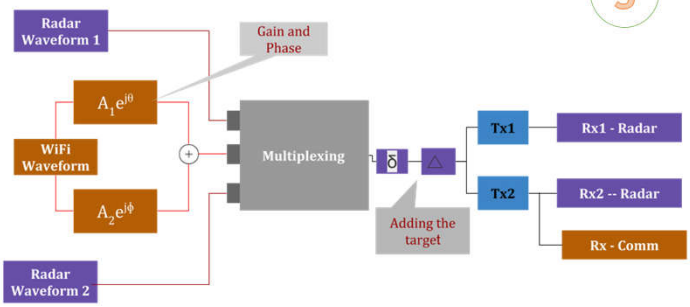


Simplified block diagram of MRMC



Block diagram of Emulation using Wired Connection

Prototype

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Radar Waveform:

- Polyphase
  - Frank, Golomb, Legendre
  - P1/P2/P3/P4/Px
  - Random
- Binary:
  - Barker, m-Sequence
  - Gold, Kasami
  - Random
- Frequency Modulated:
  - Up-LFM, Down-LFM

Communication Waveform:

- OFDM:
  - IEEE 802.11p
    - BPSK, QPSK
    - 16-QAM, 64-QAM

Echo Generation:

- Real-time range adjustment
- Real-time Doppler adjustment
- Real-time angle adjustment
- Real-time amplitude adjustment
- Stochastic amplitude based on Swerling 1/2/3/4

ADC/DAC:

- Simulation of quantization error
- Signed/Un-signed

Analyzer:

- Real and Imaginary parts
- Amplitude and Phase
- Spectrum
- Spectrogram
- Ambiguity Function

Software:

- LabVIEW and GNU Radio
- Real-time updating of the transmit waveform
- Real-time processing

Hardware:

- NI USRP 2944
- Full duplex operation with independent TX and RX frequencies
- Two wide-bandwidth RF daughterboard slots
- Two Tx/Rx real-time channels
- PCIe Express (Desktop) – 200 MS/s Full Duplex
- Bandwidth : Up to 160MHz bandwidth each
- Frequency: 10-6000 MHz Rx/Tx
- Configurable sample rate
- Coherent/ Phase-aligned operation

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