# ITA2025 Day 1
# Stuff that ORI Might be Interested in Knowing About

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Michelle Thompson 10 February 2025

# Active Beam Learning for Full-Duplex Wireless Systems

Ian Roberts

A novel active beam learning method for in-band full-duplex wireless systems, that aims to design transmit and receive beams which suppress self-interference and maximize the sum spectral efficiency. Rather than rely on explicit estimation of the downlink, uplink, and/or self-interference channels like in most existing work, our method instead actively probes all three channels through measurements of SNR and INR over a fixed number of time slots. Then, once this probing concludes, all collected probing measurements are used to design transmit and receive beams which serve downlink and uplink in a full-duplex fashion. We realize this active beam learning scheme through a network of LSTMs and DNNs, which learns to design each probing beam pair and subsequently extract and record valuable information from each probing measurement such that near-optimal serving beams can be designed following the probing stage. Simulation indicates that our method reliably suppresses self-interference while delivering near-maximal SNR on the downlink and uplink with merely 3-10 probing time slots, while exhibiting robustness to measurement noise and the structure of the self-interference channel.

# Interpretation

## I only have an MSEE!

- MIMO antenna arrays
- In-band full-duplex can help deliver on the 6G promise
- DL and UL same time same spectrum so is of Neptune project interest
- But! Full duplex in the real world doesn’t look like math land
- Assume analog beam forming
- SNR, MIMO self-interference channel, couple TX/RX, there’s crosslink interference

# Interpretation

## This is the A in ITA

- Rician channels assumed
- Key metric: UL/DL spectral interference
- How to close the link as fast as possible
- Acquire the channel information fast
- This is a classic massive MIMO problem
- Prior work includes LONESTAR, STEER, STEER+
- How do we set things up without explicitly estimating the DL, UL, and self-interference channels?

# Interpretation

## There are tradeoffs here

- We implicitly estimate what we need to know from probes
- There’s tau time slots in the front end of the “supersymbols” (Think OFDM)
- Beam learning happens here
- Measure SNR, UL, DL, beam pair data, INR, self interference
- We don’t need all of the channel information - just the parts that matter for our particular beams - be data driven, not do a bunch of work then extract data
- Design a new probing beam pair from the first probe and repeat

# Interpretation

## This could actually work

- Judiciously expend resources to reduce overhead of beam learning
- Target the actual user pairs
- LSTMs are used to learn *what to do with the information*
- However: Those DNNs have to be trained on the full data
- Big unknown at this point is latency - beam inference may still take too long.
- Contact Ian Roberts at the Wireless Lab at UCLA https://wireless.ee.ucla.edu/

## Quantization for optimal UAV Network Deployment — Hamid Jafarkhani


## Hamid Jafarkhani



Abstract

UAVs will have different roles, as users, base stations, relays, and sensors, in highly heterogeneous next generation of wireless networks. We study the deployment of UAV networks and the role of quantization theory in finding optimal solutions.

# Repercussions

## Looking at drones with 3d footprints in a new way (for us)

- Drones are a disruption, but the presentation proposes somewhat of a reset
- Is there a mathematical model from information theory that can deal with it?
- Maybe, but 20 minutes was pretty short to absorb

On pulse shaping filters and I/O relation estimation & equalization in Zak-OTFS

**Ananthanarayanan Chockalingam**

The basic information-bearing carrier in Zak-OTFS is a pulse in the DD domain which is a quasi-periodic localized function. The Zak-OTFS performance is influenced by how well these pulses are localized in the DD domain. A DD filter matched to the transmit filter is used at the receiver. The `effective' channel in Zak-OTFS includes the cascade of the transmit DD filter, the physical channel, and the receive DD filter. Consequently, the choice of the pulse shaping filter influences the DD spread of the effective channel. Estimating the DD domain input-output (I/O) relation in Zak-OTFS amounts to estimating the coefficients of the effective channel. The estimated I/O relation is used for subsequent equalization/detection in the DD domain. Therefore, the pulse shape influences the performance of the two important receiver functions, namely, I/O relation estimation and equalization/detection. This talk will focus on the choice of the pulse shaping filter and its effect on the I/O relation estimation and equalization performance in Zak-OTFS.

# OTFS

## Orthogonal Time Frequency Space

Orthogonal Time Frequency Space (OTFS) and Orthogonal Frequency Division Multiplexing (OFDM) are both methods of spreading signals across time and frequency. Our Neptune project is an OFDM implementation.

OTFS has some advantages over OFDM, including better spectral efficiency, energy efficiency, and robustness against synchronization errors.

OTFS requires a smaller cyclic prefix*.
OTFS has better energy efficiency.
Data is transmitted in the delay-Doppler channel*. Therefore the constant channel measurements are not required.

# Cyclic Prefix?

## Wikipedia explains it very well!

- A cyclic prefix provides a guard interval to eliminate intersymbol interference from the previous symbol. “Guard Time” But wait! There’s more!
- If you repeat, say, the end of the symbol as the CP, the **linear** convolution of a frequency-selective multipath channel can be modeled as **circular** convolution, which in turn may transform to the frequency domain via a discrete Fourier transform. This approach leads to simple frequency domain processing, such as channel estimation and equalization. It makes the math so much better!
- Shorter cyclic prefixes? Yes please.

# Delay Doppler Channel

## WTF is that

- a channel where signals have time delays (from things like multipath propagation) and Doppler shifts (due to relative motion between a satellite transmitter and ground receiver)

- You can set this up as a two dimensional visualization (delay and doppler)

- Radar people deal with this a lot

- Analyzing both factors at the same time gives better performance in many ways - it is a new coordinate system for your data that looks very much like a resource grid for OFDM.

- OTFS is being considered for 6G, primarily because it avoids the constant channel estimation requirements of OFDM.

# Can you combine shaping filters?

## The heart of the talk

- The talk introduced a Gaussian-Sinc (GS) filter.
- For OTFS we see it splitting the difference between Gaussian and Sinc pulse shaping filters
- Why not just make a compromise filter?

# Error Correction in Interference-Limited Wireless Systems

## Charles Waive

- We introduce a novel approach to error correction decoding in the presence of additive alpha-stable noise, which serves as a model of interference-limited wireless systems. In the absence of modifications to decoding algorithms, treating alpha-stable distributions as Gaussian results in significant performance loss. Building on Guessing Random Additive Noise Decoding (GRAND), we consider two approaches. The first accounts for alpha-stable noise in the evaluation of log-likelihood ratios (LLRs) that serve as input to Ordered Reliability Bits GRAND (ORBGRAND). The second builds on an ORBGRAND variant that was originally designed to account for jamming that treats outlying LLRs as erasures. This results in a hybrid error and erasure correcting decoder that corrects errors via ORBGRAND and corrects erasures via Gaussian elimination. The block error rate (BLER) performance of both approaches are similar. Both outperform decoding assuming that the LLRs originated from Gaussian noise by ~2 to ~3 dB for [128,112] 5G NR CA-Polar and CRC codes.

# It’s like IRC Channel Own

## Oh, you have noise? I will remove it

- The basic idea is that you have the ability to sample the channel often and with enough resolution that you can simply subtract the noise or interference from the received signal, and you just might get that signal back.
- Where does this work?
- High SNR low INR just use Gaussian noise assumptions and detection (legacy)
- Decent SNR and high INR, best case, sample and subtract interference from signal and get a cleaner signal
- Equal SNR to INR, worst case you might be hosed
- High INR compared to SNR, then you need to subtract just that interference and not just the noise.