CUbiC

Center for Ubiquitous Connectivity

Student Catalog

Annual Review
June 27- 28, 2023

Semiconductor Research Corporation

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CUbiC Annual Review June 27-28, 2023

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TUESDAY, JUNE 26 @ 11:55 AM- 1:00 PM

Connectivity Networks and Systems

Theme Leader (s): Manya Ghobadi & Upamanyu Madhow

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1.2	Canan Cebeci	A Fourier Analysis of Digital Beamforming with Severely Quantized mmWave Arrays
1.3	Lalitha Giridhar	Creating Spatial Degrees of Freedom for Long-Range LoS MIMO using Reflect-arrays
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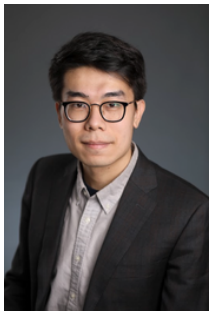
1.9	Atsutse Kludze	Wavefront Manipulation Attack via Programmable mmWave Metasurfaces

THEME 1 PRESENTATION DETAILS

RESEARCH SCHOLAR	POSTER DETAILS



Zhenguo Wu
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Advisor: Keren Bergman
Available for hire date:
May 31, 2025

1.1 Title: FlexPAC: Flexible Photonic Accelerated Computing

Abstract: Distributed Deep Learning (DDL) has emerged as the leading solution for training large- scale deep learning models. To speed up DDL, accelerator systems consisting of clusters of computing units (CU) have been proposed. In state-of-the-art accelerator systems, the bandwidth discrepancy between intra-cluster interconnect and inter-cluster network has created communication bottlenecks for DDL, severely limiting training efficiency. This bandwidth discrepancy issue is further compounded when multi-tenant jobs are mapped non-uniformly onto clusters, leading to bandwidth waste in certain links and congestion in others. In this work, we present Flex-SiPAC, a Flexible Silicon Photonic Accelerated Compute architecture. Flex-SiPAC addresses the bandwidth discrepancy issue by adopting a multi- dimensional all-to-all topology where each CU is equipped with an embedded comb-driven photonic I/O which provides massively parallel DWDM bandwidth. The wavelengths are flexibly routed through micro-ring resonator based multi-wavelength selective switches. And the free-spectral-range of the resonators are tuned to realize optical multi-casting as well as job-placement-aware topology optimization. Building on top of the multi-casting and topology reconfiguration primitives, we further propose a topology-aware collective algorithm that can efficiently utilize dynamically allocated wavelengths.

Additional Authors: Liang Yuan Dai & Yuyang Wang

Canan Cebeci
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Available for hire date: June 1, 2026

1.2 Title: A Fourier Analysis of Digital Beamforming with Severely Quantized mmWave Arrays

Abstract: Recent progress in silicon radio frequency integrated circuits (RFICs) has opened the possibility of fully digital massive MIMO with hundreds of antennas in millimeter wave (mmWave) bands. A critical bottleneck in “mostly digital” processing is the cost and power consumption of analog-to-digital converters (ADCs). We consider here a mmWave massive MIMO receiver employing 1-bit ADCs, a particularly energy-efficient choice. Unlike prior work utilizing Bussgang linearization, our work concentrates on the effect of 1-bit quantization on a small number of users propagating over spatially sparse mmWave channels. We focus on beamspace techniques based on a spatial FFT across antenna elements, which concentrate the energy of each user to a small number of FFT bins. We provide a Fourier analysis of the spatial harmonics for one user through one path, characterizing the impact of the ADC nonlinearity, alongside the aliasing and spectral spread due to sampling and windowing corresponding to an array with a finite, discrete number of antennas. The analysis provides guidance on training sequence design for isolating the “fundamental” spatial frequency corresponding to the true angle of arrival. Simulations show that the design succeeds in suppressing higher-order harmonics for two users with disparate power levels.

Additional Authors: Upamanyu Madhow

1.3 Title: Creating Spatial Degrees of Freedom for Long-Range LoS MIMO using Reflect-arrays

Abstract: Line-of-Sight (LoS) MIMO has gained popularity as a means of taking advantage of the increased spatial degrees of freedom available with increasing carrier frequency. However, for fixed transceiver form factors, the available degrees of freedom decay quickly with link range. We explore an innovative approach for creating spatial degrees of freedom for long-range links by utilizing large virtual apertures created by placing multiple Reflect-Arrays (RAs) near the transceivers. The introduction of an RA between a transmitter and receiver results in an end-to-end gain scaling as 1/d1^(2)d2^(2), where d1 is the distance between the transmitter and RA and d2 is the distance between the RA and the receiver. While this leads to poor scaling when d1 and d2 are both comparable to the link range. The problem is avoided in the settings where RAs are deployed near the transmitter and receiver to create large virtual apertures. We illustrate our ideas for 4-fold spatially multiplexed LoS MIMO operating at 28 GHz at a link distance of 1,500 m. The use of reflect-arrays in this setting provides beamforming gain in addition to creating spatial degrees of freedom. We provide design guidelines for efficient deployment based on link budget calculation.

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MIT

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1.4 Title: ALfrEd: Application-aware Links for Edge and Cloud

Abstract: This project explores developments of algorithmic and systems foundations to facilitate the construction of practical application-aware clusters. More specifically, we focus on design of application-aware scheduling and resource allocation algorithms, development of reconfigurable network topologies, implementation of reconfigurable link-layer protocols, and investigation of dynamic error correction techniques.

Additional Authors: Sudarsanan Rajasekaran, Weiyang Wang, & Mingran Yang

1.5 Title: Efficient and Flexible Beamforming and Scheduling with Multi-User Support in Millimeter-wave Networks

Abstract: 5G New Radio (NR) leverages the millimeter wave (mmWave) frequency bands to significantly improve wireless data rates, where beamforming using phased array antennas to compensate for the high signal attenuations is highly exploited. However, the spatial resolution of the generated beams can be limited by the number of antenna elements. Such limitation raises significant challenges in supporting massive multi-user communications between a base station and user equipment (UEs), mainly due to the strong cross-interference between closely spaced UEs.
In this work, we develop a multi-user beamforming system in 5G mmWave context that maximizes the overall throughput by balancing the signal and interference power among UEs and conducts the scheduling over time with the fairness consideration. We implement our framework on three levels: simulation, beamforming pattern measurement in an anechoic chamber, and real-world experiments using programmable mmWave software-defined radios. Exhaustive evaluations reveal the feasibility of achieving higher throughput for the next-generation mobile network, compared to time division multiple access systems, and other state-of-the-art multi-user communication systems.

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Available for hire date:
June 30, 2025

Additional Authors: N/A

Atsutse Kludze
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Available for Hire Date:
May 29, 2026

1.6 Title: Wavefront Manipulation Attack via Programmable mmWave Metasurfaces

Abstract: Reconfigurable surfaces enable on-demand manipulation of electromagnetic wave properties in a controllable manner. These surfaces have been shown to enhance mmWave wireless networks in many ways, including blockage recovery. In this paper, we investigate the security vulnerabilities associated with the deployment of reconfigurable surfaces, i.e., an adversary may deploy new rogue surfaces or tamper with already-deployed surfaces to maliciously engineer the reflection pattern. In particular, we introduce Metasurface-enabled Sideband Steering (MeSS), a new metasurface-in-the-middle attack in which the spectral-spatial properties of the reflected wavefront are manipulated such that a concealed sideband channel is created in the spectral domain and steered toward the eavesdropper location, while maintaining the legitimate link toward the victim intact.
We fabricate a custom reconfigurable surface prototype and evaluate MeSS through theoretical analysis as well as over-the-air experiments at the 60 GHz band. Our results indicate that MeSS significantly reduces empirical secrecy capacity (up to 81.7%) while leaving a small power penalty at the victim that can be masked under normal channel fluctuations.

Additional Authors: Haoze Chen, Hooman Saeidi, Suresh Venkatesh, Kaushik Sengupta, & Yasaman Ghasempour

1.7 Title: Algebraic Codes for Lightweight Forward Error Correction

Abstract: The overall goal of this task is to develop an adaptive and lightweight error correction code that minimizes performance deterioration while satisfying the strict computational complexity and latency of the envisioned high-speed links. To this end, we study algebraic codes which are known to provide the best performance, under complex maximum likelihood decoders, for short-to-medium code block lengths and are often rate-adaptive making them appealing for high-rate regimes. In particular, we consider state-of-the-art binary algebraic codes including Reed-Muller (RM) and Bose–Chaudhuri–Hocquenghem (BCH) codes at very high rates together with a light belief propagation (BP) decoder, i.e., employing min-sum approximation and limiting to a very small, e.g., less than five, iterations.
Simulation results demonstrate that RM code outperforms BCH code and provide a much sharper curve, when plotting the performance in terms of error rate versus the signal-to-noise ratio (SNR), compared to an uncoded transmission even with a very small amount of redundancy, e.g., rate > 0.93, over additive white Gaussian noise (AWGN) channel. Furthermore, we consider a certain concatenation of RM codes with themselves, called RM-staircase codes, in order to improve the performance of plain RM code at high rates and when the code block length is large, i.e., in the order of several thousands. Simulation results demonstrate that RM-staircase code with soft BP decoder outperforms the conventional RM code under BP decoder over AWGN channels.

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December 30, 2023

Additional Authors: Hessam Mahdavifar

1.8 Title: Secret Sharing with Local Statistical Leakage Resilience

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Available for Hire Date:
April 29, 2026

Abstract: Secret sharing can be an instrumental tool for sharing secret keys in distributed wireless networks. In a classical setting, secret sharing involves a dealer who has a secret/key, a set of parties/users to which shares of the secret are sent, and a threshold on the number of users whose presence are needed in order to recover the secret. In secret sharing, secure links with no leakage are often assumed between the involved parties. However, when the users are nodes in a wireless network and all the links are wireless, such assumptions are not valid anymore.
In order to address this critical problem we study secret sharing under certain leakage models, where some noisy version of all the secret shares might be leaked to an adversary. In this work, we study how to bound certain measures of security (i.e., semantic security, mutual information security) given other parameters of the system including the amount of leakage from each secret share. To the best of our knowledge, this is the first attempt towards understanding secret sharing under statistical noisy leakage which is very crucial towards the goal of the project under this task.

Additional Authors: Hessam Mahdavfiar

1.9 Title: Wavefront Manipulation Attack via Programmable mmWave Metasurfaces

Abstract: Reconfigurable surfaces enable on-demand manipulation of electro-magnetic wave properties in a controllable manner. These surfaces have been shown to enhance mmWave wireless networks in many ways, including blockage recovery. In this paper, we investigate the security vulnerabilities associated with the deployment of reconfigurable surfaces, i.e., an adversary may deploy new rogue surfaces or tamper with already-deployed surfaces to maliciously engineer the reflection pattern. In particular, we introduce Metasurface-enabled Sideband Steering (MeSS), a new metasurface-in-the-middle attack in which the spectral-spatial properties of the reflected wavefront are manipulated such that a concealed sideband channel is created in the spectral domain and steered toward the eavesdropper location, while maintaining the legitimate link toward the victim intact.
We fabricate a custom reconfigurable surface prototype and evaluate MeSS through theoretical analysis as well as over-the-air experiments at the 60 GHz band. Our results indicate that MeSS significantly reduces empirical secrecy capacity (up to 81.7%) while leaving a small power penalty at the victim that can be masked under normal channel fluctuations.

Atsutse Kludze
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Available for Hire Date:
May 29, 2026

Additional Authors: Haoze Chen, Hooman Saeidi, Suresh Venkatesh, Kaushik Sengupta, & Yasaman Ghasempour

POSTER SESSION THEME 2 OVERVIEW

TUESDAY, JUNE 26 @ 3:10 PM- 4:10 PM

Wireline and Lightwave Interconnects

Theme Leader: Naresh Shanbhag

POSTER NO.	PRESENTER	TITLE
2.1	Sujay Patel & Hyungyo Kim	High-density die-to-die interconnects
2.2	Han-Mo Ou	Energy-efficient, High-throughput, Low-Latency Forward Error Correction Decoders
2.3	Juzheng Liu	Adaptive Low-Cost High-Speed ADC: Sampler and Quantizer Structure
2.5	Ahmed Abdelrahman	Low-Complexity Coherent Optical Receivers
2.7	Ramin Javadisafdar	Use of Data Encoding and Machine Learning in a Wireline Communication System

POSTER NO.	PRESENTER	TITLE
2.10	Jianheng Luo	Integrated Microlens Couplers for Photonic Circuits
2.12	Oliver Liu Wang	Broadband Compact Multimode Waveguide Bends with Low Mode Crosstalk
2.13	Graydon Flatt	Efficient Cavity Loading via Induced Virtual Critical Coupling in an Overcoupled Microresonator

THEME 2 PRESENTATION DETAILS

RESEARCH SCHOLAR	POSTER DETAILS

Sujay Patel
University of Illinois

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Available for hire date: May 10, 2027

Hyungyo Kim
University of Illinois

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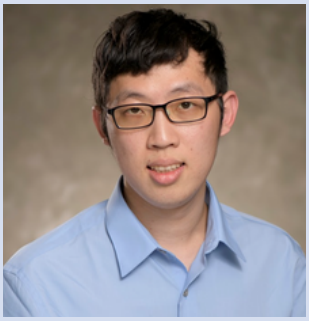
Advisor: Naresh Shanbhag
Available for hire date: May 1, 2027

2.1 Title: High-density die-to-die interconnects

Abstract: We explore the development of massively parallel dense electrical links for heterogeneously integrated chiplet-based and high-density optical systems. We explore two key areas: (1) employing partially terminated single-ended simultaneous bidirectional signaling and four-level pulse amplitude modulation schemes to achieve a 2X density improvement, and (2) developing low-cost, low-latency solutions for crosstalk and echo cancellation/avoidance. The research aims to enhance data transfer rates and reliability in ultra-bandwidth dense optical interconnects and die-to-die connections.

Additional Authors: Mohamed Younis & Mingyuan Han



Han-Mo Ou
University of Illinois

Email:
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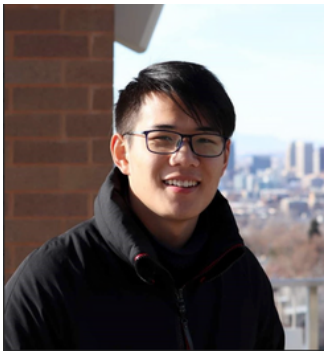
Advisor: Naresh Shanbhag
Available for hire date: May 10, 2025

2.2 Title: Energy-efficient, High-throughput, Low-Latency Forward Error Correction Decoders

Abstract: This task explores energy-efficient high-throughput VLSI architectures to realize connectivity algorithms being explored in ALEC. Forward error-correction (FEC) decoders are an important subsystem whose coding gain can help in the design of energy-efficient high-throughput short reach links. We begin by setting a baseline for our research by benchmarking FEC decoder ICs published in the recent past, and compare those with our own synthesized BCH systolic decoder in a 28nm technology. We find that algebraic decoders are a promising candidate for short-reach connectivity since they achieve high-throughput and low-latency at decent coding gains.

Additional Authors: N/A



Juzheng Liu
University of Southern California

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Advisor: Mike (Shuo-Wei) Chen
Available for hire date: March 31, 2024

2.3 Title: Adaptive Low-Cost High-Speed ADC: Sampler and Quantizer Structure

Abstract: The objective of this task is to explore an optimal ADC architecture that achieves unprecedented low area/power with adaptive resolution and high sampling speed.

Additional Authors: Mostafa Toubar &
Mike (Shuo-Wei) Chen

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Pavan Kumar Hanumolu
Available for hire date:
May 31, 2024

2.5 Title: Low-Complexity Coherent Optical Receivers

Abstract: A wide bandwidth analog carrier phase recovery (CPR) loop for short-reach coherent optical links is presented. Using 16-phase switched-inverter-based harmonic-rejection complex mixers (HRMs) and low latency phase detection circuits, the prototype QPSK receiver fabricated in 28 nm CMOS achieves 100 MHz bandwidth, 600 MHz tracking range, and recovers 24 Gb/s QPSK data without errors. The power efficiency of the QPSK coherent receiver is 3.2 pJ/bit.

Additional Authors: N/A

Ramin Javadisafdar
Oregon State University

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Advisor: Tejasvi Anand
Available for hire date:
October 1, 2026

2.7 Title: Use of Data Encoding and Machine Learning in a Wireline Communication System

Abstract: This study presents a new strategy for communicating on bandwidth-limited wireline channels without using conventional equalizers or filters. The key observation is that by employing data encoding on the transmitter and classification on the receiver, we can reduce the impact of inter-symbol interference (ISI) caused by the channel's low-pass behavior. Instead of using conventional equalizers, the proposed machine learning approach leverages classifier-based receiver, which helps to increase the energy efficiency of the overall wireline transceiver without incurring latency penalty. The simulation results demonstrate that by utilizing the decision tree classifier in the receiver and a PAM-4 encoding in the transmitter, the transceiver can achieve low BER with high energy efficiency while communicating on a channel with an insertion loss of 20dB at Nyquist.

Additional Author: Tejasvi Anand

Jianheng Luo
UC Berkeley

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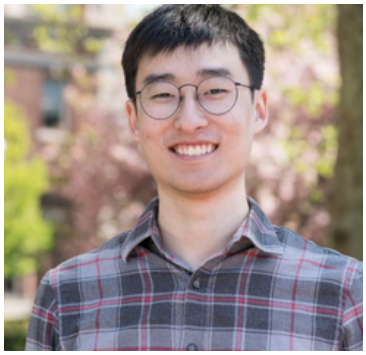
Advisor: Ming Wu
Available for hire date:
December 30, 2023

2.10 Title: Integrated Microlens Couplers for Photonic Circuits

Abstract: We design and experimentally demonstrate a new silicon photonic optical packaging method using integrated microlens couplers. Efficient, broadband, and polarization insensitive coupling to a single mode fiber with best coupling loss of 0.6 dB is achieved.

Additional Author: Johannes Henriksson



Oliver Liu Wang
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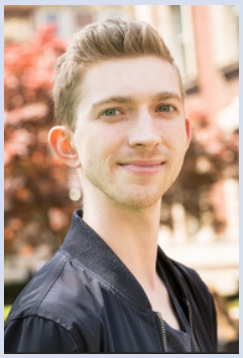
Email: olw2106@columbia.edu
Advisor: Michal Lipson
Available for hire date: May 15, 2025

2.12 Title: Broadband Compact Multimode Waveguide Bends with Low Mode Crosstalk

Abstract: Mode division multiplexing is a promising path towards greatly scaling bandwidth in optical devices. We report an optimized 90-degree compact waveguide bend which supports 5 TE modes with less than -12 dB modal crosstalk and lower than 0.4 dB insertion loss over a 250 nm bandwidth.

Additional Authors: Ziwei Zhu, Janderson R. Rodrigues, Michal Lipson, & Changxi Zheng



Graydon Flatt
Columbia University

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Advisor: Michal Lipson
Available for hire date: May 19, 2027

2.13 Title: Efficient Cavity Loading via Induced Virtual Critical Coupling in an Overcoupled Microresonator

Abstract: We induce a virtual critical coupling regime in a silicon nitride microresonator by loading with complex-frequency pulses. Temporally shaping the pulses facilitates efficient loading of the cavity by virtually changing the waveguide-ring coupling of an initially-overcoupled ring. By imparting various pulse time constants, we observe a wide range of virtual coupling conditions. These include a virtual critical state where the resonant transmission is suppressed from 0.58 to 0.11, representing a cavity energy increase of around 8 times during the pulse. This dynamic tuning of the effective coupling may open new avenues for overcoming the delay-bandwidth tradeoff.

Additional Authors: Jakob Hinney, Seunghwi Kim, Ipshita Datta, Andrea Alu, & Michal Lipson

POSTER SESSION THEME 3 OVERVIEW
WEDNESDAY, JUNE 28 @ 10:15 AM- 11:15 AM

Wireless Circuits and Technology

Theme Leader: Harish Krishnaswamy

POSTER NO.	PRESENTER	TITLE
3.1	Hesham Beshary	Cobra IC: A Wideband 140 GHz 2D Massive Array
3.2	Seungchan Lee	Low-power Compact Sub-circuits for LAIR Receiver in 45-nm SOI Technology
3.3	Utku Soylu	A 202 GHz Link Using Planar Transceiver Modules
3.4	Alfred Davidson	Reflectarrays for Next-Generation Communication Systems
3.6	Shimin Huang	High-dynamic-range Interference-tolerant Wideband Signal Processing at Analog/RF(HI-SPAR): Techniques for High Performance N-path Circuits
3.7	Rohit Braganza	Broadband Interference and VSWR Tolerant RF Front End Designs

POSTER NO.	PRESENTER	TITLE
3.8	Ce Yang	Time-based Signal Processing at Radio Frequencies
3.9	Jamie Ye	Optimized RF-to-Photonic Interfaces for mmWave Massive MIMO Arrays (OPeRA): Power-Adaptive MU-MIMO Receivers and Efficient Photonic Links for Distributed Circuitry
3.10	Ji Yoon Han	Beam Space Processing for mmWave Massive MU-MIMO Communication Systems
3.11	Wei Tang	Unified soft/hard-decision decoder for product-like codes

THEME 3 PRESENTATION DETAILS

RESEARCH SCHOLAR	POSTER DETAILS

Hesham Beshary
UC Berkeley

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Available for hire date: May 15, 2025

3.1 Title: Cobra IC: A Wideband 140 GHz 2D Massive Array

Abstract: This project aims to build a low-cost 2-D scalable 140 GHz high-performance phased arrays.

Additional Authors: N/A

Seungchan Lee
UC Santa Barbara

Email: sclee@ucsb.edu
Advisor: Mark Rodwell
Available for hire date: February 1, 2024

3.2 Title: Low-power Compact Sub-circuits for LAIR Receiver in 45-nm SOI Technology

Abstract: To make low-power and compact size large array inexpensive radio (LAIR), low-power and small-size sub-circuits are essential. In this effort, we focused on the design of low-power and compact circuits with a minimum performance sacrifice. This approach is a notable concept for large-array transceivers because overall performance can be improved signal-to-noise ratio by combined signal.
We will present two sub-circuits using a 45-nm SOI process: 1) an on-off receiver front-end with a low-noise amplifier, a 1-bit phase-shifter, and an on-off function, and 2) an x8 frequency multiplier by cascading three push-push doublers.

Additional Authors: N/A

Utku Soylu
UC Santa Barbara

Email:
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Advisor: Mark Rodwell
Available for hire date:
June 20, 2023

3.3 Title: A 202 GHz Link Using Planar Transceiver Modules

Abstract: We report a 202 GHz wireless data transmission link, communicating 32 Gb/s over 7.1 meters, using planar InP HBT transmitter and receiver modules. The modules are highly integrated and require simple physical assembly without waveguide interfaces. A single 2.8 mm × 0.75 mm InP HBT transmitter IC and a single 2.3 mm × 0.85 mm InP HBT receiver IC, operating from a 24.5 GHz local oscillator (LO) reference, provide frequency conversion between 6 GHz (I, Q) intermediate-frequency (IF) and the 202 GHz modulated carrier. Signals are radiated and received by directly wire-bonding the InP ICs to 2 × 2 patch antenna arrays on 50 μm SiO2 substrates, with these antennas coupled to external 50 mm diameter PTFE lenses. 8 Gbaud 16QAM data transmission (32 Gb/s) over 7.1 m, on a link with 10.4 dB added attenuation, showed 13.4% RMS error vector magnitude.

Additional Authors: Amirreaza Alizadeh & Esra Ceylin Bormali

Alfred Davidson
Columbia University

Email:
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Advisor: Harish Krishnaswamy
Available for hire date:
June 1, 2026

3.4 Title: Reflectarrays for Next-Generation Communication Systems

Abstract: Next-generation communication technologies utilizing >100GHz millimeter-wave frequencies to enable high data-rate links require large arrays and beamforming to close the link budget. Conventional phased-array based beamforming architectures are limited by the challenges in the heterogeneous integration of GaN, InP, and CMOS ICs within a compact package, and signal distribution within a large array.
This poster elaborates on the use of reconfigurable intelligent metasurfaces in such systems, which can now utilize few high-performance GaN/InP transmit and receive antennas coupled to extremely-large, low-power, low-cost CMOS active reflective arrays that can reflect the illuminating signal to form multiple beams and enable >100GHz millimeter-wave links. This paradigm allows the usage of the best junction for the function, with GaN being used for high-power generation, InP for low-noise amplification, and CMOS being used for the implementation of a large highly programmable antenna array, while avoiding the challenges of the conventional architecture.

Additional Authors: Harish Krishnaswamy

Shimin Huang
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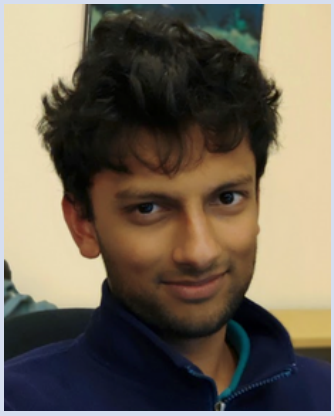
Available for hire date:
January 1, 2024

3.6 Title: High-dynamic-range Interference-tolerant Wideband Signal Processing at Analog/RF(HI-SPAR): Techniques for High Performance N-path Circuits

Abstract: The wireless frequency spectrum is a critical resource for next-generation wireless systems. While widely tunable receivers are highly desired in 5G/6G wireless systems to enable frequency usage, they pose new design challenges on interference tolerance. Here we present two approaches to implement widely-tunable interference-tolerant receivers with N-path circuits due to their linear periodically time-varying (LPTV) property.
The first approach explores different techniques to relax the local oscillator (LO) generation requirements. This includes using multi-resonance LO waveforms with LO overlap suppression for N-path switching, subharmonic N-path receiver via multi-resonance waveform shaping, and sinusoidal LO drives for series GaN/CMOS N-path circuits. The second approach aims to suppress interferer artifacts by various passive networks. We investigated different architectures to create channel diversity similar to MIMO systems in a single-antenna receiver to mitigate interference artifacts generated by reciprocal mixing of the LO phase noise or spurious tones as well as aggregate bandwidth from multiple bands to utilize the frequency spectrum optimally. These techniques allow us to have high-dynamic-range interference-tolerant wideband receivers at RF/mm-Wave frequencies.

Additional Authors: Jamie Ye, Damla Dimlioglu, Sanaz Sadeghi, & Alyosha Molnar



Rohit Braganza
UC Berkeley

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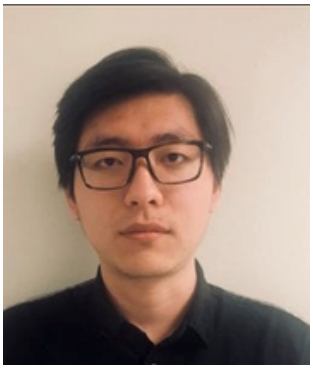
Advisor: Ali Niknejad
Available for hire date: May 30, 2023

3.7 Title: Broadband Interference and VSWR Tolerant RF Front End Designs

Abstract: In this talk we will cover using mixed-signal leakage cancellation to remove self-interference from short range reflection or antenna coupling in a 10GHz instantaneous bandwidth FMCW radar. We will also discuss various PA designs with improved intolerance to antenna VSWR variations.

Additional Authors: Yikuan Chen &Yahia Ibrahim



Ce Yang
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Advisor: Mike (Shuo-Wei) Chen
Available for hire date: January 1, 2024

3.8 Title: Time-based Signal Processing at Radio Frequencies

Abstract: This project presents a time-based analog signal pre-conditioning technique for a wireless receiver (RX) to reject unwanted blockers. The proposed time-based signal processing technique leverages the alias-spreading property of NU sampling (NUS) and the programmable signal transfer function of the gated ring oscillator array. The implemented gated ring oscillator approximates a finite impulse response (FIR) filter response in the time domain, achieving an overall flexible filter response with a higher attenuation factor. Besides, the embedded N-path filter front-end enables the complex filter capability with extra blocker rejection. The filter response can be readily reconfigured by changing the controlling waveform without adjusting the passive component value. The on-chip digital post-processing blocks are also integrated with the related clock generation implementation.

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3.9 Title: Optimized RF-to-Photonic Interfaces for mmWave Massive MIMO Arrays (OPeRA): Power-Adaptive MU-MIMO Receivers and Efficient Photonic Links for Distributed Circuitry

Abstract: The increasing demand for extremely high data rates has led to the development of all-digital millimeter-wave massive multi-user multiple-input multiple-output (MU-MIMO) receivers. However, these receivers consume a significant amount of power. To address this challenge, we recently proposed the first resolution-adaptive all-digital MU-MIMO receiver ASIC.
This ASIC is capable of dynamically adjusting the resolution of data-converters and baseband-processing to accommodate varying communication scenarios. It incorporates analog-to-digital converters, beamspace channel estimation, and spatial equalization. In addition, we designed an arbitrary waveform generator to demonstrate the capabilities of our ASIC. This generator supports up to 16 users with quadrature and amplitude modulation, programmable beamforming weights, and individual power adaptability for each user. Furthermore, in modern mmWave MU-MIMO systems, the increased loss and cost associated with long wires at high frequencies suggests the need to position circuitry close to the respective antennas. This raises the challenge of optimally distributing many high bandwidth signals between transceivers and centralized circuitry for digital processing. To tackle this issue, we propose the use of photonic links enabled by recent advancements in comb photonic sources allowing for independent modulation of optical signals on a single waveguide.

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3.10 Title: Beam Space Processing for mmWave Massive MU-MIMO Communication Systems

Abstract: We address one of the critical challenges, complexity in mmWave massive multiuser multi-input multi-output (MU-MIMO) techniques. While mmWave communication enables high-band transmission to multiple users using the same time-frequency resource, the large number of M antennas at the Base Station (BS) and K User Equipment (UEs) leads to a larger Channel State Information (CSI) matrix compared to traditional MIMO systems. Consequently, processing tasks such as uplink channel estimation and detection become computationally demanding for massive MU-MIMO configurations.
To mitigate this complexity, we propose a novel beam space processing-based MIMO system that leverages the sparsity of the massive MU-MIMO channel in the angular domain. Specifically, we observe that in the case of a BS equipped with a Uniform Linear Array (ULA), the received power is concentrated along a limited number of angles. This characteristic allows us to effectively process with the compressed CSI, thus reducing the computational burden. Additionally, we introduce a low-complexity beam space hardware design that facilitates the transformation between the antenna and beam space domains. An M-point Fast Fourier Transform (FFT) across the BS antennas is employed for this domain transformation, underscoring the significance of an efficient FFT design. The preliminary results highlight the advantages of utilizing the beam space domain and efficient FFT design. These findings demonstrate the feasibility of our proposed approach in mitigating complexity challenges associated with massive MU-MIMO systems. Further investigations and evaluations are ongoing to validate and refine our methodology, offering potential enhancements for mmWave communication in massive MU-MIMO scenarios.

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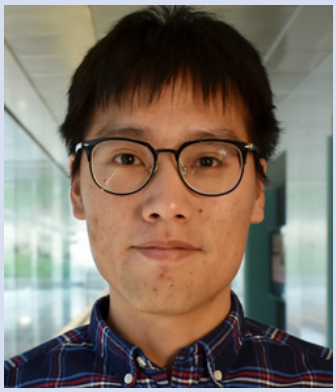

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3.11 Title: Unified soft/hard-decision decoder for product-like codes

Abstract: Recent advancements in FEC schemes aim to merge convolutional and product coding principles to achieve low bit error rates and high throughput, while suppressing the error floor. This work presents a programmable decoder architecture with an embedded unified decoding tile that offers flexibility for both soft-decision and hard-decision methods within a single iteration. In addition, the architecture supports FEC codes, such as OpenFEC (OFEC), turbo product code (TPC) and staircase code (SC), used in the optical communication, and allows for adjustment of the decoding iterations. This inherent flexibility enables the decoder to adapt to diverse channel conditions. Moreover, the decoder achieves a throughput exceeding 100Gbps, providing a substantial data transfer capacity that is highly desirable for next-generation communication systems.

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ACKNOWLEDGEMENTS

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