Broadband Transceivers and Antenna Pre-processing with Reconfigurable, Multi-functional Electromagnetic Interfaces for mm-Wave MIMO Arrays

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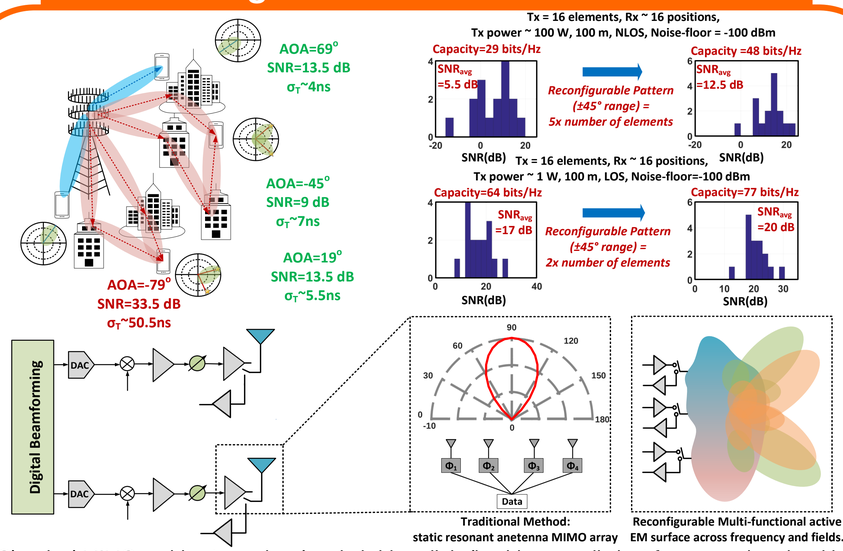
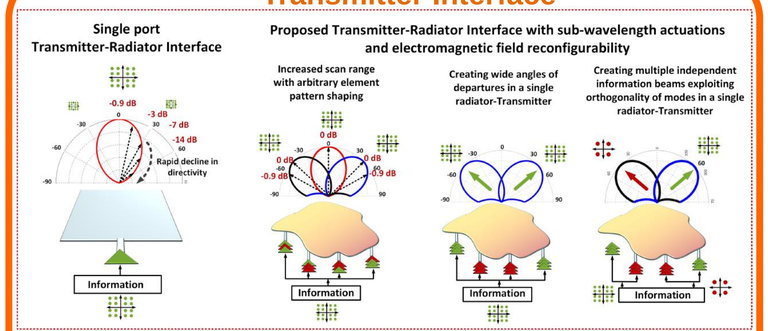
Generalized Broadband MIMO architecture with Programmable Element Patterns



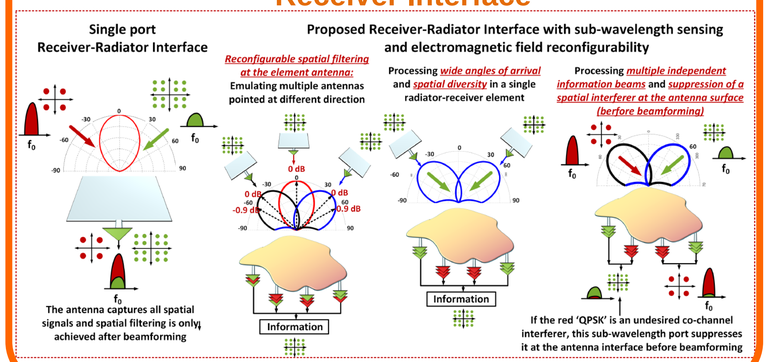
- Classical MIMO architectures (analog, hybrid or digital) addresses distinct frequency bands with an array of identical synchronized elements. The information-to-EM mapping is limited by static element patterns and typically static frequency operation.
- We propose two fundamental innovations through a multi-port circuits-systems-antenna co-design approach to enable
  - A **scalable and broadband transceiver interface** supporting **multiple disjointed frequency** bands potentially extending from 28-100 GHz and beyond.
  - A **multifunctional element EM interface with programmable element pattern and its electromagnetic properties** to enable new array and system functionalities.

Reconfigurale Transceiver-EM Interface and System Properties

Transmitter Interface

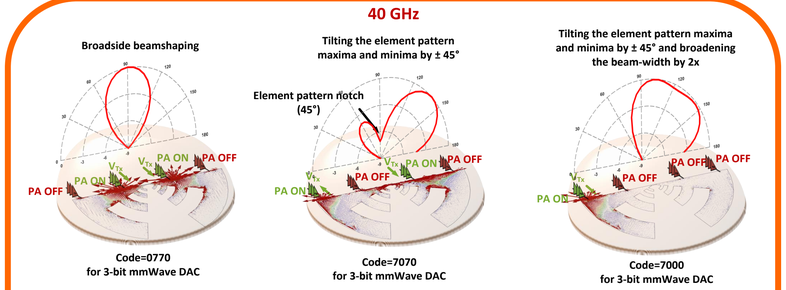


Receiver Interface



The work is supported by grants from AFOSR and ONR.

Multi-port Electromagnetic Interface Programmability

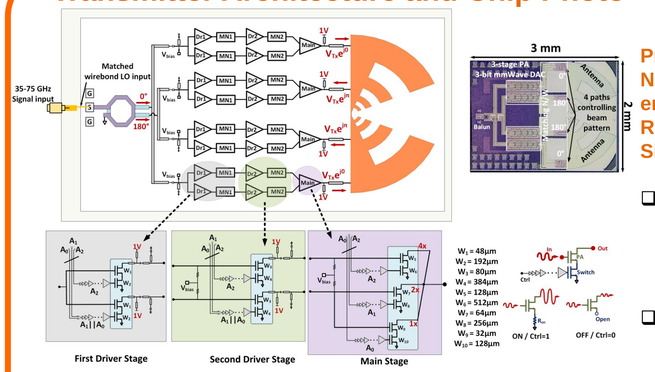


Programmable EM surface with sub-wavelength synthesis/sensing:

- A multi-port antenna surface with close EM-interface and transceiver co-design that can shape the element properties arbitrarily **including aligning element maxima to array maxima, tilting the beam by ±45, rotating the notch to cancel interference at the element antenna level and processing multiple independent beams at the same time across the spectrum.**

Broadband Transceiver Architecture with Integrated Multi-port Radiators

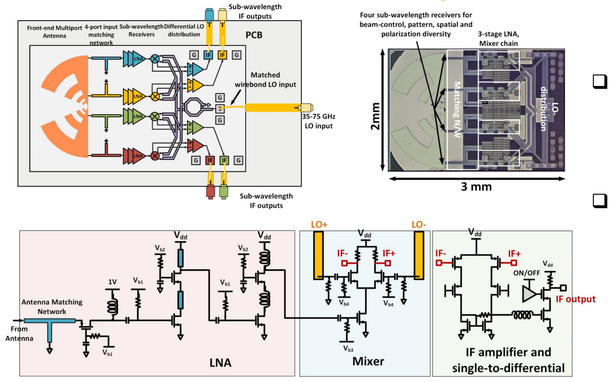
Transmitter Architecture and Chip Photo



Programmable Multi-port Network Synthesis Approach enabling Broadband and EM Reconfigurability Simultaneously

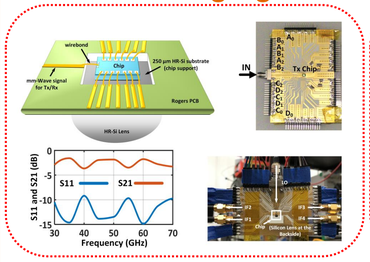
- Integrated radiating surface with a log-periodic tooth antenna split into half and connected to 4 ports.
- A 4-stage mm-Wave DAC PA interfacing with the radiator with bandwidth extending from 37-73 GHz and P_{sat}~18 dBm across the frequency.
- A 4-port sub-wavelength receiver interfacing with the radiator tapping the EM fields locally.
- A multi-port network synthesis approach to enable simultaneously broadband matching and across the various codes for EM reconfigurability.

Receiver Architecture and Chip Photo

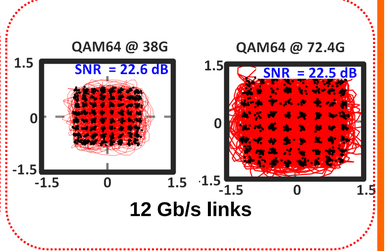


Measurement Setups and Results

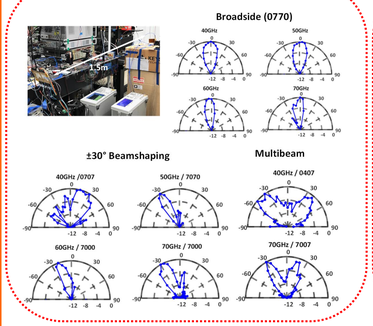
Packaging



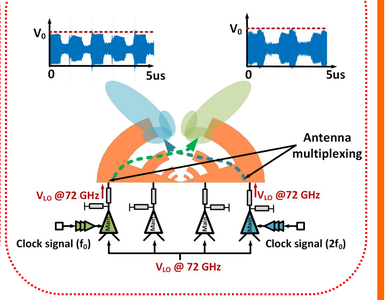
Wireless links 37-73 GHz



Transmitter Beam Pattern



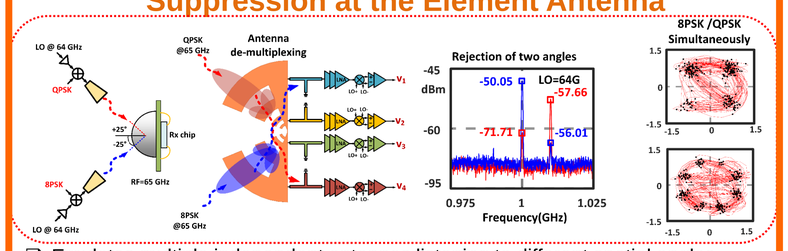
Transmitter Multiplexing



- Packaged with Rogers PCB with silicon lens on the back achieving ~50% radiation efficiency across different conditions for a 50-um lossy substrate, >95% with a high resistivity substrate. (Works without a lens as well)
- 4095 possible set of element patterns showing the ability to shape the beam from broadside, creating tilted beams suppressing the main beam to create multiple beams for wide angles of departure (NLOS) and creating independent beams exploiting EM mode orthogonality in a single radiator interface.

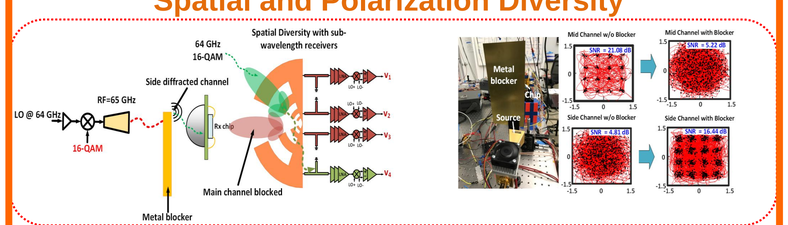
Frequency, Spatial, Pattern an Polarization Diversity

Spatial Multiplexing and Spatial Interference Suppression at the Element Antenna



- Emulates multiple independent antennas listening to different spatial angles.
- Allows selection of the optimal configuration to reject an interference up to 14-20 dB at the antenna surface.
- Processing multiple independent beams simultaneously in a single radiating surface at the same frequency band exploiting EM orthogonality.

Spatial and Polarization Diversity



- Sub-wavelength spacing of the receivers even upto λ/10 can extend diversity gains up to 20 dB for wide angles of arrival.
- Can enable significant enhancement in capacity during blockage of the main channel in heterogeneous EM environment.

Acknowledgements

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