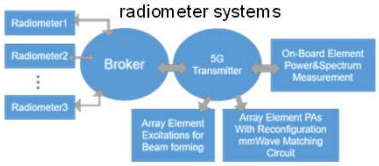
Broker-Controlled Coexistence of 5G Wireless Artificially Intelligent Power Amplifier Array (AIPAA) with Passive Weather Radiometers

Project IDs: 2030243, 2030258, 2030257

PIs C. Baylis [1], A. Gasiewski[2], D. Peroulis[3]
Baylor University [1], University of Colorado at Boulder[2], Purdue University[3]

Project Summary

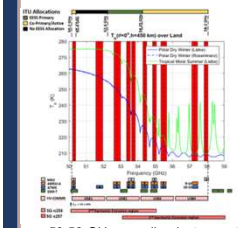
Spatial-Spectral Broker coordination between 5G and passive radiometer systems



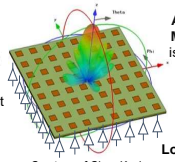
5G to Radiometer Interference Assessment Mechanism:

- On-Board 5G element power & spectrum measurement using 5G transmitter controller.
- Radiometers also assess harmful interference and report to Broker, which reports to 5G Transmitter Controller.

Manifold Request Parameters	
Data Requested	Unites
Data/Time	(24 hour time), start and stop time
Latitude	Decimal degrees
Longitude	Decimal degrees
Altitude	meters
Center Frequency	Hz
Bandwidth	Hz
Azimuth	Degrees
Elevation	Degrees
Transmitter Power	dBm
Receiver Power Tolerance	dBm
Antenna Gain	dBi
Time Interval Request	seconds
Interference Frequency	Hz
Interference Levels	dBm



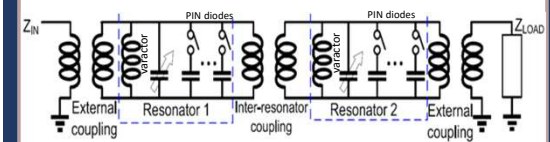
50-58 GHz sounding instrument bandwidths and the effect of potential 5G second harmonic emission regions.



Courtesy of Chen Kenle

Antenna Impedance Mismatch: A classical issue in antenna array during beamforming

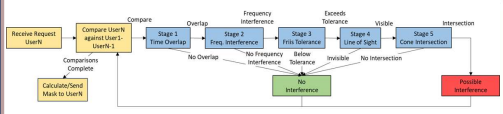
Load mismatch on PAs



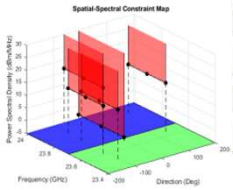
To the author's best knowledge, the presented tuner is the first high-Q stand alone solid-state mmWave impedance tuner.

Project Progress

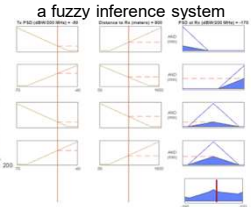
We have implemented a spatial-spectral broker, and impedance tuner with fast real-time array tuning algorithms for 5G transmitters to coexist with passive weather radiometers. We integrated the impedance tuner system to NOAA Lab's.



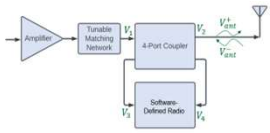
Spatial-spectral transmission mask

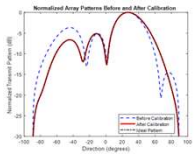


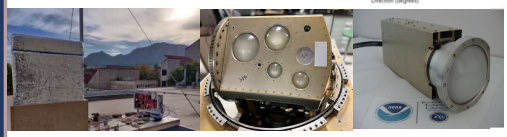
Rapid path loss modeling using a fuzzy inference system



In-situ antenna current measurement to determine array pattern:



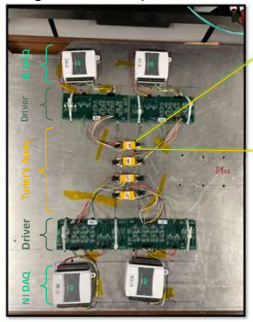


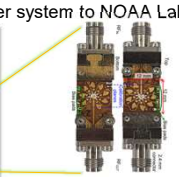


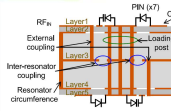
50-58 GHz correlation , radiometer at CU Boulder, ECEE building rooftop [2]

Polarimetric Scanning Radiometer (PSR) scan head [8]

24GHz Radiometer box housed inside PSR scan head [8]

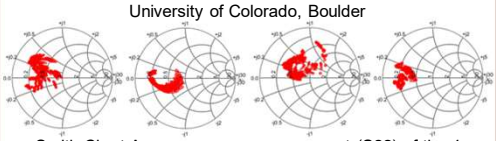




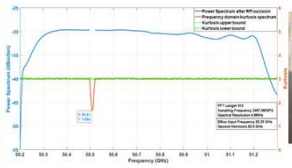


The implemented resonator-based impedance tuner [1]

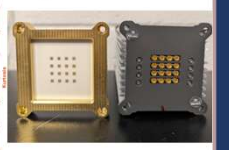
The **high-Q mmWave impedance tuners** after integration to the test bed at Center for Environmental Technology Lab, University of Colorado, Boulder



Smith Chart Area coverage measurement (**S22**) of the 4 Tuners at 24 GHz after integration

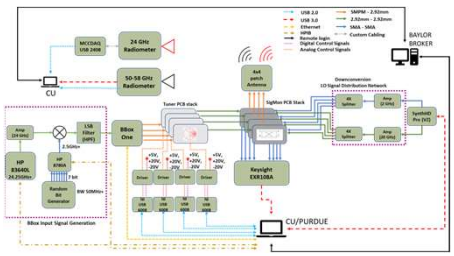


RFI due to second harmonic emission from prototype 5G beamformer detected and mitigated using frequency domain kurtosis statistic [2]

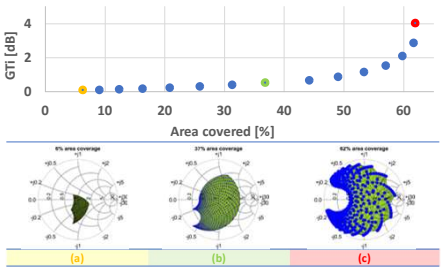


COTS prototype 5G beamformer solution (16 elements with 4x4 patch array

Future Directions and Broader Impacts

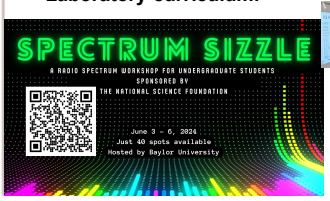


- **Development of an integrated test bed at CU Boulder.**
- **Policy innovations to accompany new technology:**
  - Passive radiometers are protected by emission limits on active services, but these limits may not be stringent enough.
  - Policy innovation is needed to support the spectral broker in practice by providing authority to arbitrate spectrum assignments and guidelines for devices' behaviors to ensure proper operation.
  - Case study performed on extending broker to new scenarios with supporting policy.
  - IEEE 1900.5.2 Spectrum Consumption Models.
- **Development of a systematic Optimization algorithm for an area-specific tuner design. Optimized for Smith Chart coverage area, transducer losses, and bandwidth.**



Inverse relation between the impedance area coverage on the SmithChart and the transducer loss of the impedance tuner.

- **May 2023 high school outreach**
- **2022 IEEE IMS Workshop: "Microwave Techniques for Coexistence Between 5G and Passive Scientific Systems"**
- **2023 & 2024 Undergraduate Spectrum Workshop (NSF Grant No. 2240960)**
- **Incorporation of the SWIFT mmWave Tuner into Purdue's 2024 ECE 307 Fields and Waves Laboratory curriculum.**



References

1. M. Abu Khater, M. Awajan and D. Peroulis, "A K-band Resonant Impedance Tuner with a Solid-State Hybrid Tuning," *2022 IEEE 22nd Annual Wireless and Microwave Technology Conference (WAMICON)*
2. A. Venkitasubramony, A. Gasiewski, and C. Baylis, "High spectral resolution V-band digital correlating spectrometer for climate monitoring," *2023 National Radio Science Meeting (NRSM), Boulder, CO.*
3. S. Hussey, A. Clegg, C. Baylis, A. Egbert, A. Goad, T. Van Hoosier, and R.J. Marks II, "Spectrum Sharing Policy for a Cooperative Broker System," 2023 IEEE Texas Symposium on Wireless and Microwave Circuits and Systems, Waco, Texas, April 2023.
4. C. Baylis, A. Goad, T. Van Hoosier, A. Egbert, and R.J. Marks II, "In-Situ Assessment of Array Antenna Currents for Real-Time Impedance Tuning," 2022 IEEE Symposium on Phased Array Systems and Technology, Waltham, Massachusetts, October 2022.
5. A. C. Goad, C. Baylis, T. Van Hoosier, A. Egbert and R. J. Marks, "In Situ RF Current Assessment for Array Transmission and Optimization," in IEEE Transactions on Microwave Theory and Techniques, vol. 71, no. 12, Dec. 2023.
6. S.A. Seguin, T. Van Hoosier, A. Goad, C. Baylis, A. Gasiewski, and A. Venkitasubramony, "Spectrum Sharing Brokers for Active and Passive Devices," 2022 IEEE Electromagnetic Compatibility Symposium, Spokane, Washington, August 2022.
7. C. Baylis and R.J. Marks II, "Solving the 5G Crisis: Enabling Coexistence with Crucial Safety Systems through Adaptivity and Reconfigurability," 2022 IEEE Texas Symposium on Wireless and Microwave Circuits and Systems, Waco, Texas, April 2022.
8. O. Egbert, J. Batra, D. Orthel, J. Tang, D. Baatarkhuyag, A. Zainaddin, A. Gasiewski, "K-Band Spectrum Survey Demonstration Mission," 2024 NSF Spectrum Week, Arlington, VA