Collaborative Research: SWIFT: LARGE: Broker-Controlled Coexistence of 5G Wireless Artificially Intelligent Power Amplifier Array (AIPAA) with Passive Weather Radiometers (2030243, 2030257, 2030258)

Charles Baylis, Baylor University
Albin Gasiewski, University of Colorado
Dimitrios Peroulis, Purdue University

Baylor University
WIRELESS AND MICROWAVE CIRCUITS AND SYSTEMS
University of Colorado Boulder
PURDUE UNIVERSITY

Acknowledgment

- This work was funded by the National Science Foundation (Grant Nos. 2030243, 2030257, 2030258).

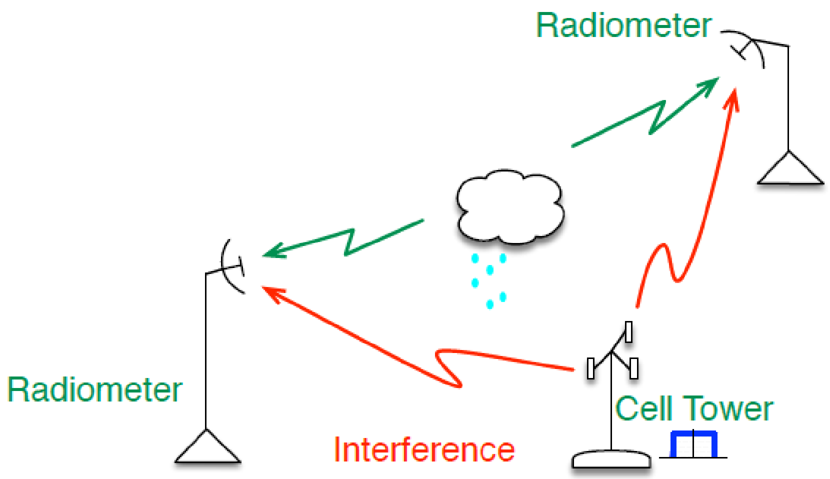
5G Impact on Weather Radiometers

PROBLEM

- Weather radiometers are used to detect water vapor and oxygen signatures:
  - Water vapor: 23.8 GHz
  - Oxygen: 50-58 GHz
- Interference from 5G mm-wave transmitters occupying neighboring or harmonically related bands can cause significant degradation in weather forecasting.

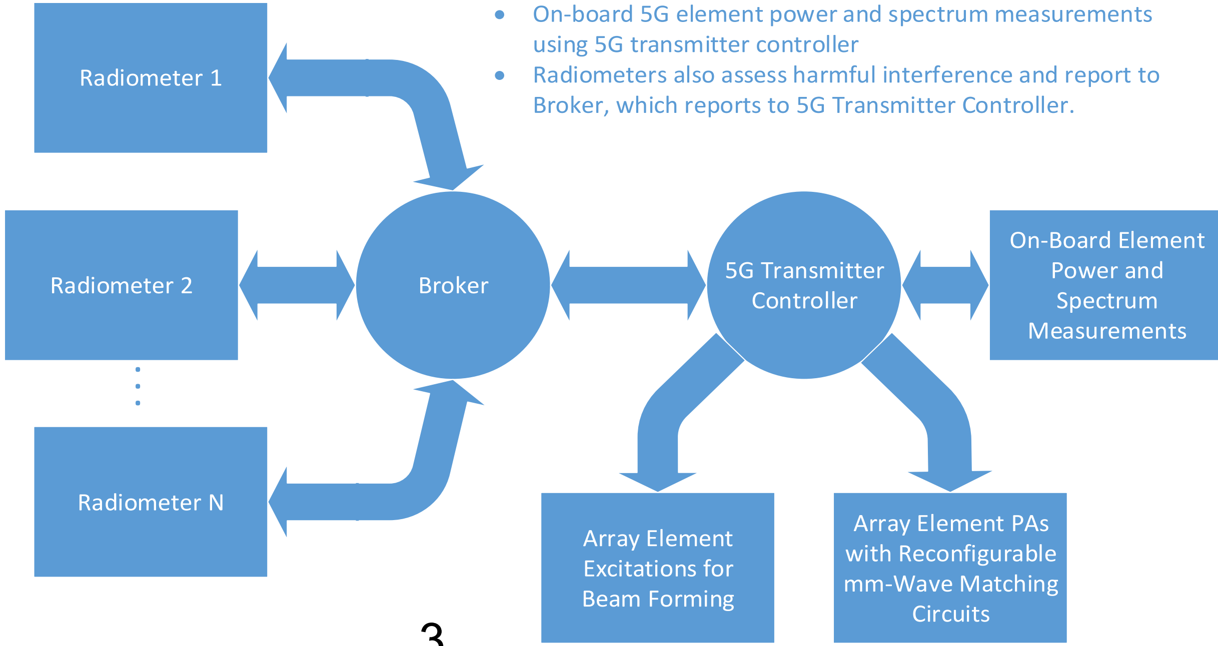
SOLUTION

- Implement a spectral broker that will assign spatial and spectral resources.
- Design an array of reconfigurable circuits for the 5G transmitter to reconfigure transmissions.
- Create an in-situ measurement capability for on-board assessment and feedback.



5G to Radiometer Interference Assessment Mechanisms:

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



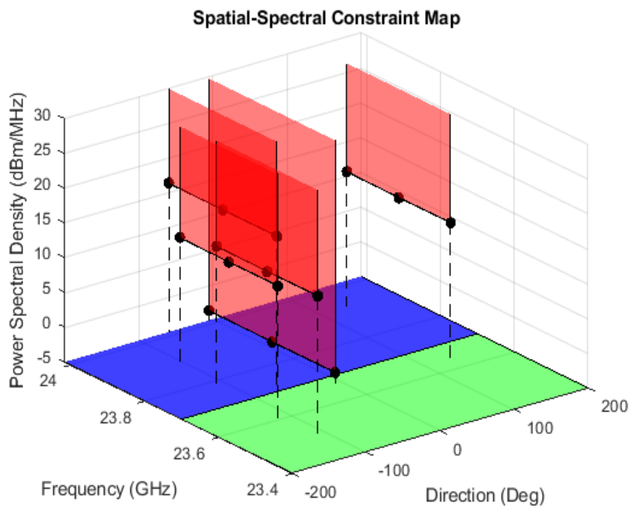
Broker Operation and Spatial-Spectral Mask

- Each wireless system asks the broker for permission to use resources.
- The 14-element request manifold contains the temporal, spectral, and spatial parameters of the request.
- The broker receives all requests and then coordinates them through a culling process:
  - Time overlap
  - Line of sight
  - Cone intersection
  - Friis tolerance
  - Frequency overlap
- A spectral-spatial mask is generated if interference is possible

Manifold Request Parameters (Input):

Data Requested	Units
Date / 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 Frequencies	Hz
Interference Levels	dBm

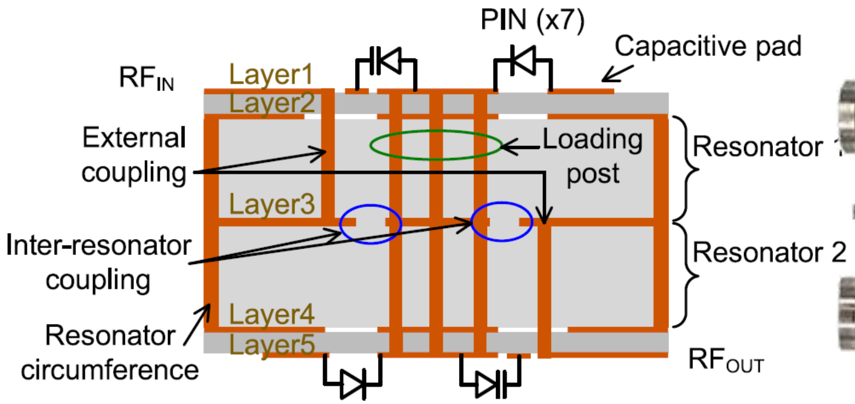
Spatial-Spectral Mask (Output):

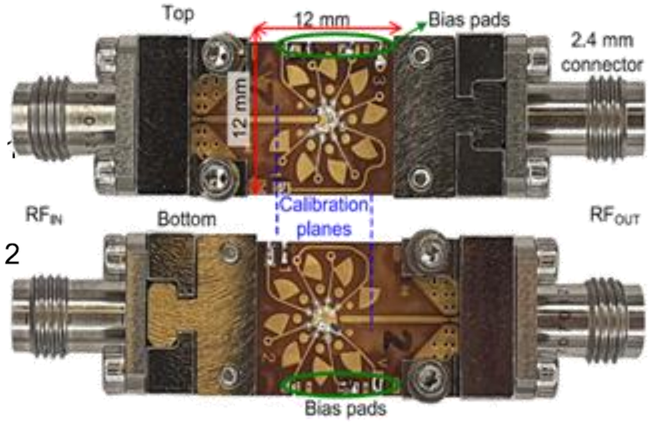


Baylor University
WIRELESS AND MICROWAVE CIRCUITS AND SYSTEMS
University of Colorado **Boulder**

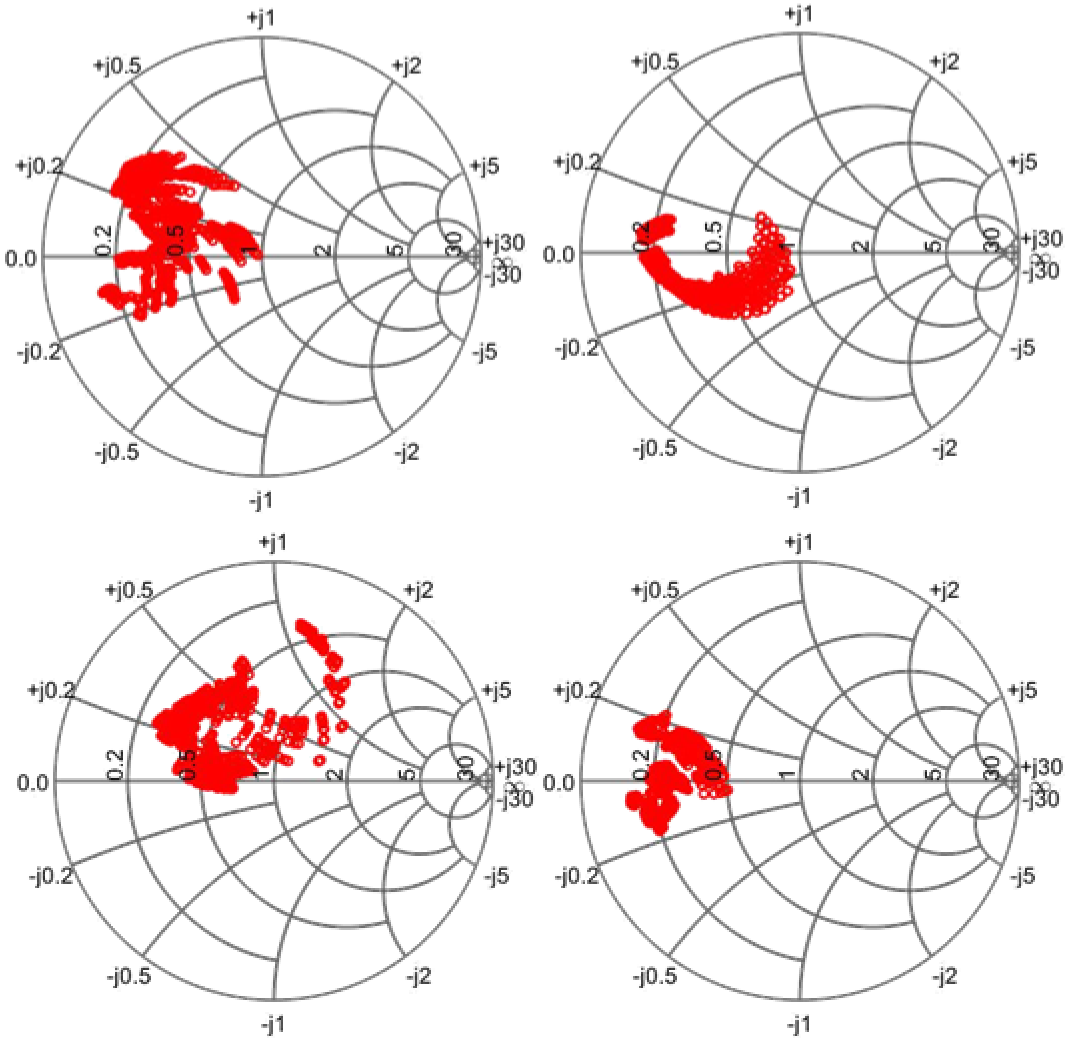
24 GHz Impedance Tuners

Tuner Design:

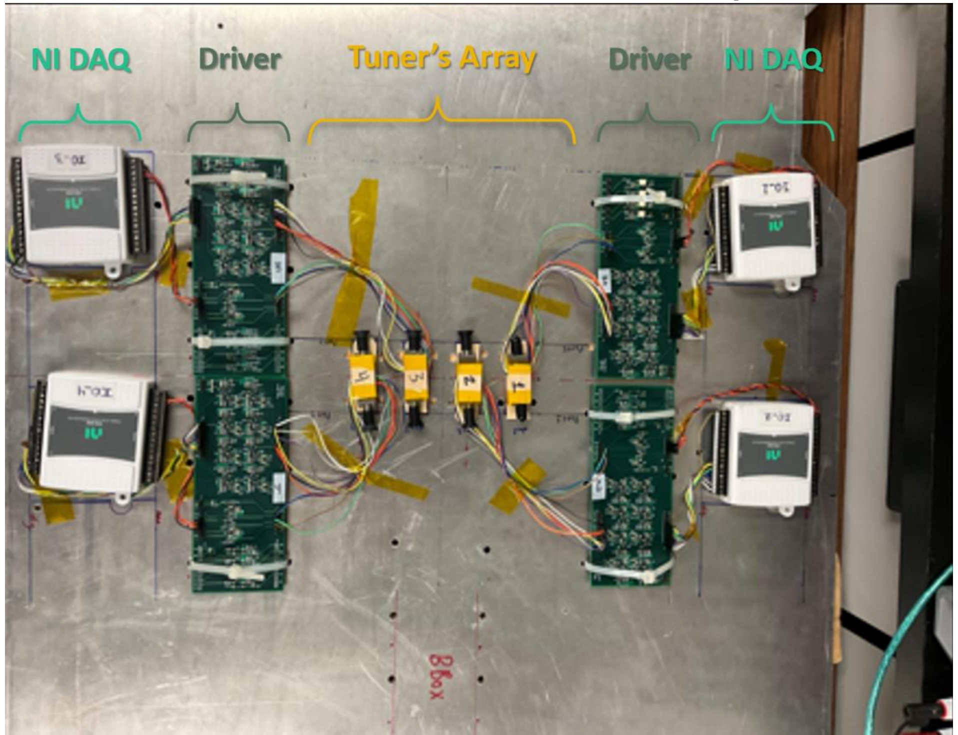




Measured 24 GHz Impedance Coverage:



Tuners in Boulder Test-Bed Setup:



Tuners provide useful Smith Chart coverage even at 24 GHz, allowing improvement of power and linearity (spatial and spectral spreading) in real time.

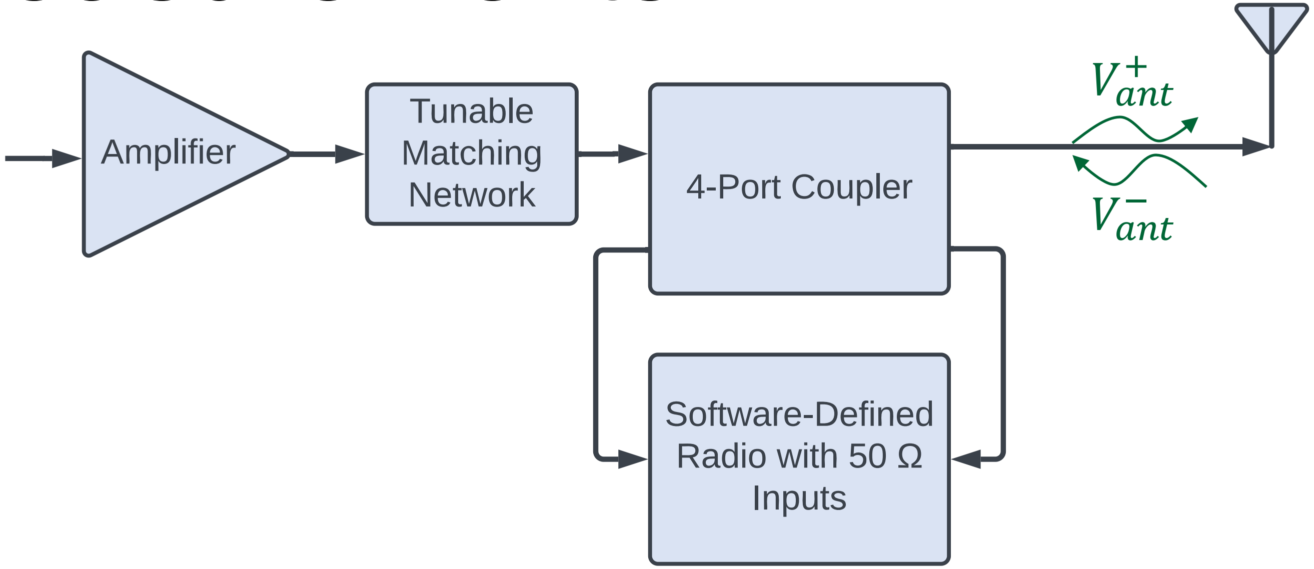
PURDUE UNIVERSITY

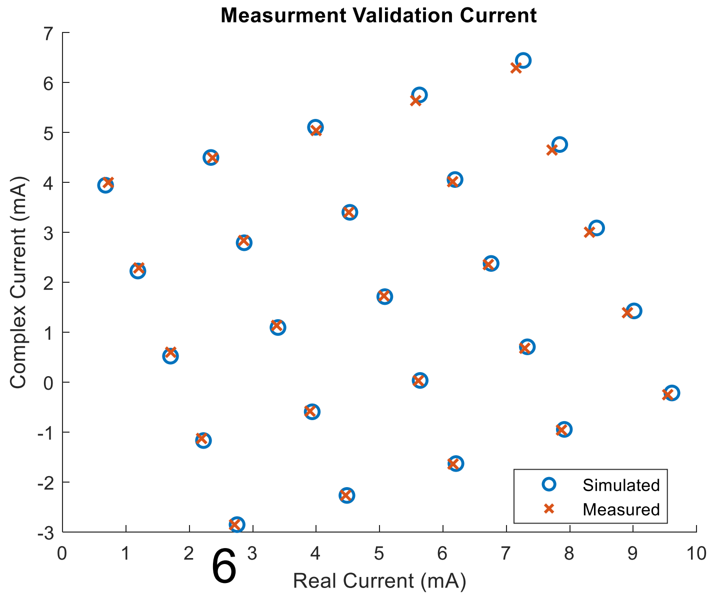
In-Situ Measurements

- Array antenna surface currents determine the array transmit pattern
- Antenna input current can be assessed in terms of traveling-wave voltages using a reflectometer inserted in the transmission path:

$$\boxed{I_{ant} = \frac{V_{ant}^{+} - V_{ant}^{-}}{Z_0}}$$

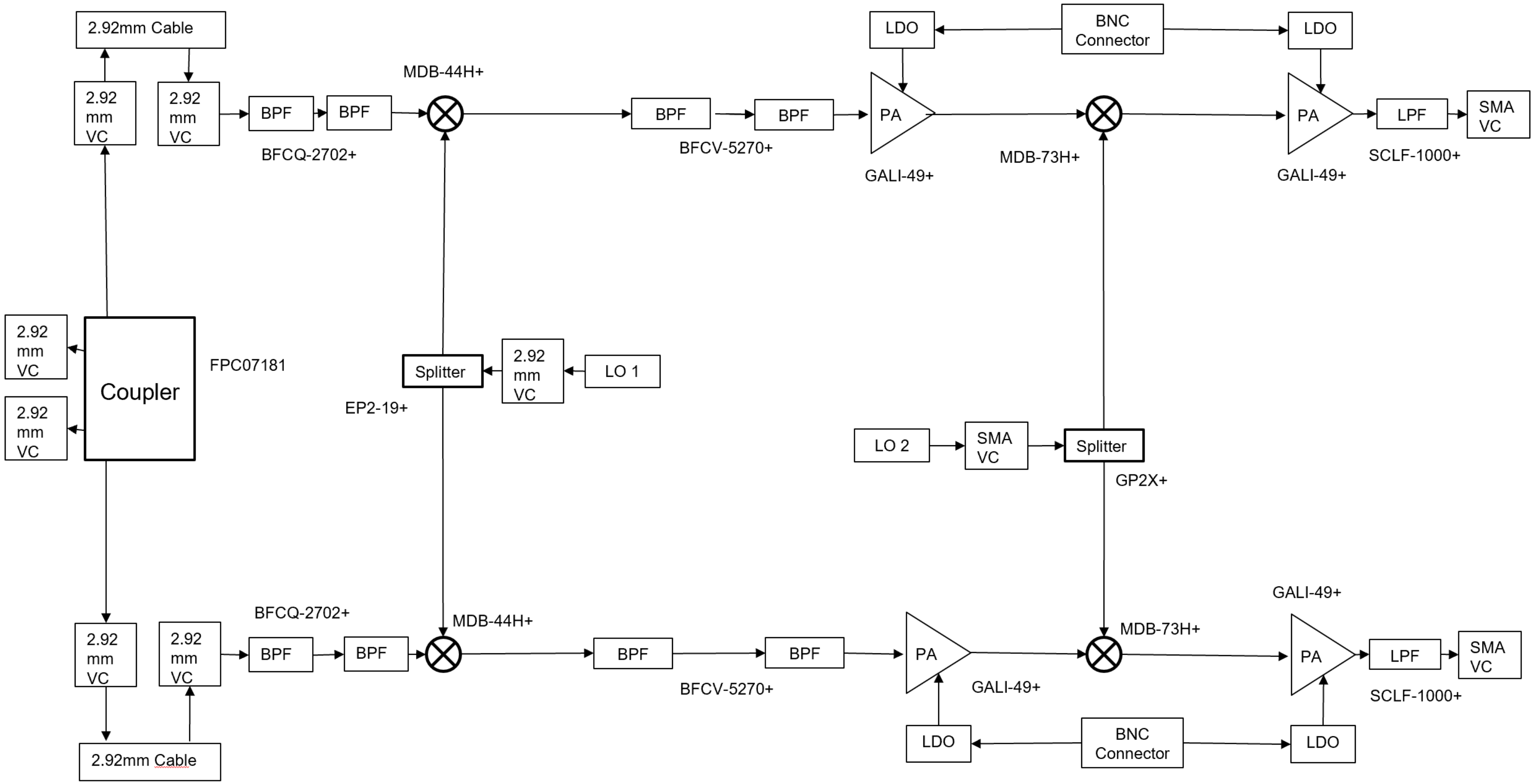
- Measurement validation of this approach shows good agreement in measured and simulated currents.
- A downconverter is needed for this measurement to be performed at 24 GHz.



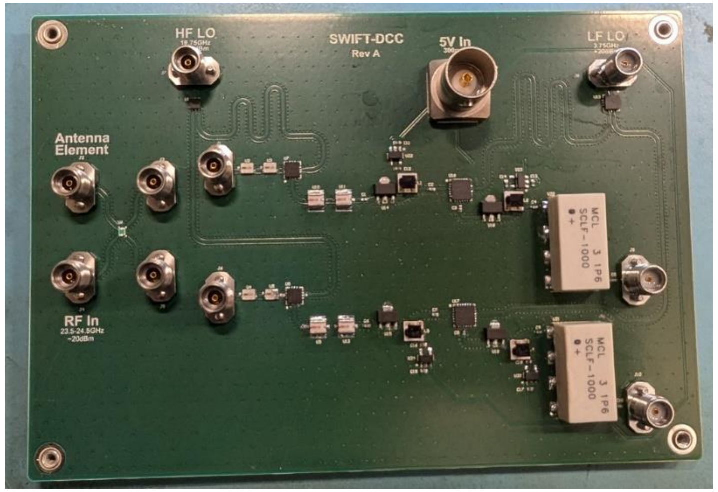


Downconverter for In-Situ Measurement

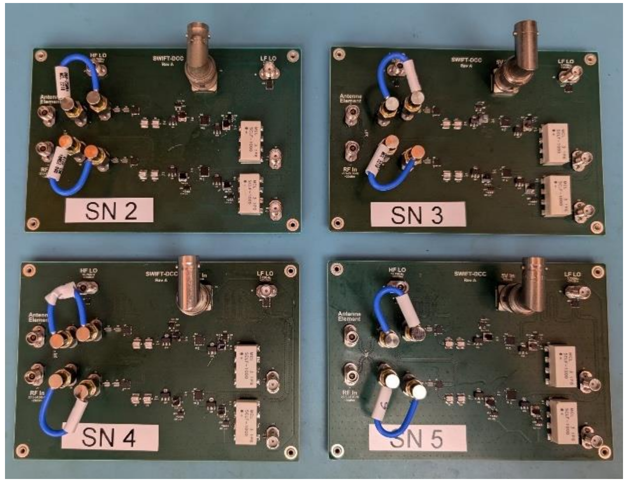
Downconverter Block Diagram:



Downconverter Photo:

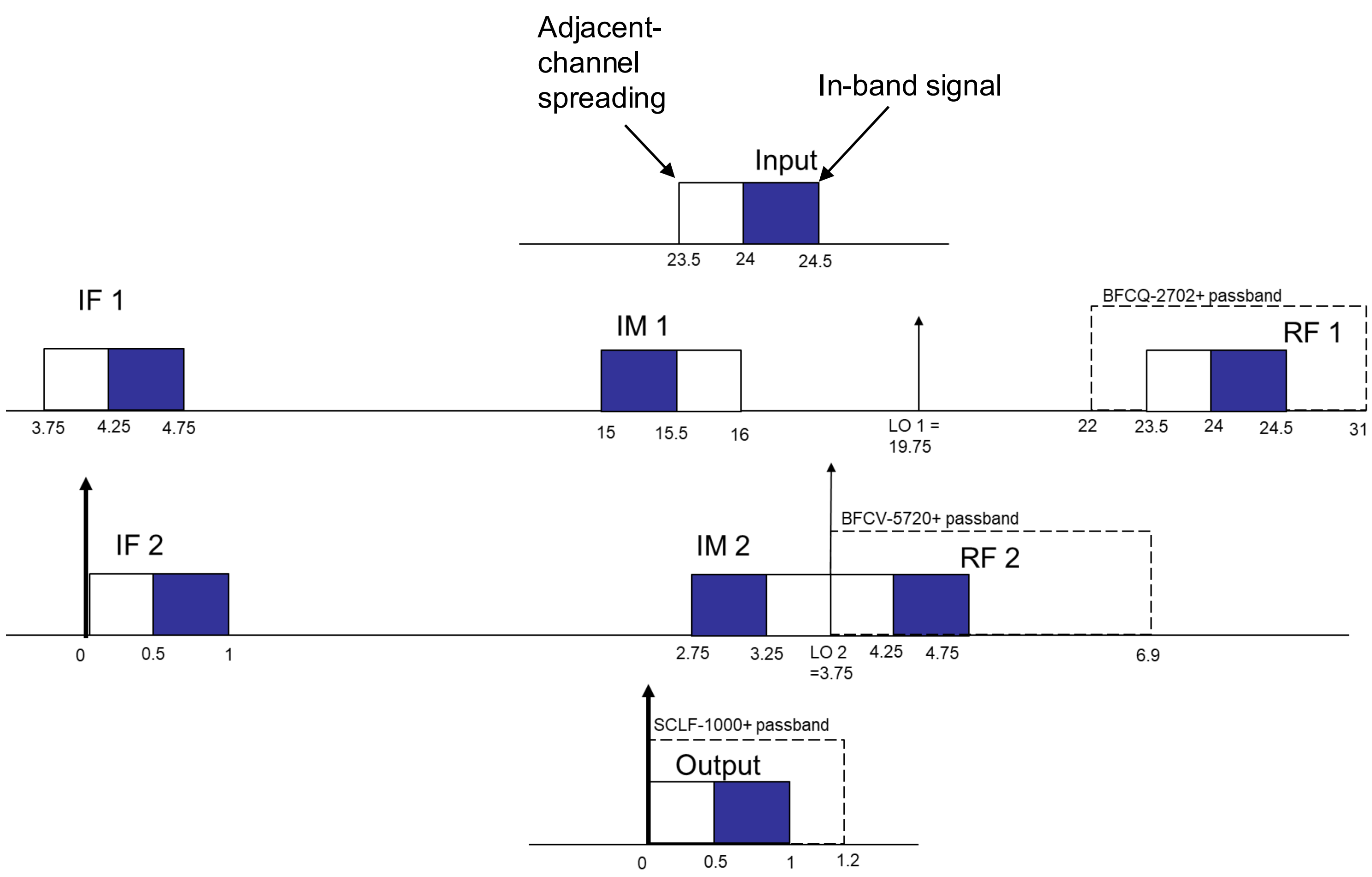


Four Array-Element Downconverter Boards:



The downconverter converts the 24-24.5 GHz “in-band” and 23.5-24 GHz adjacent band to 0-1 GHz, measurable by an oscilloscope.

Down Conversion Stages

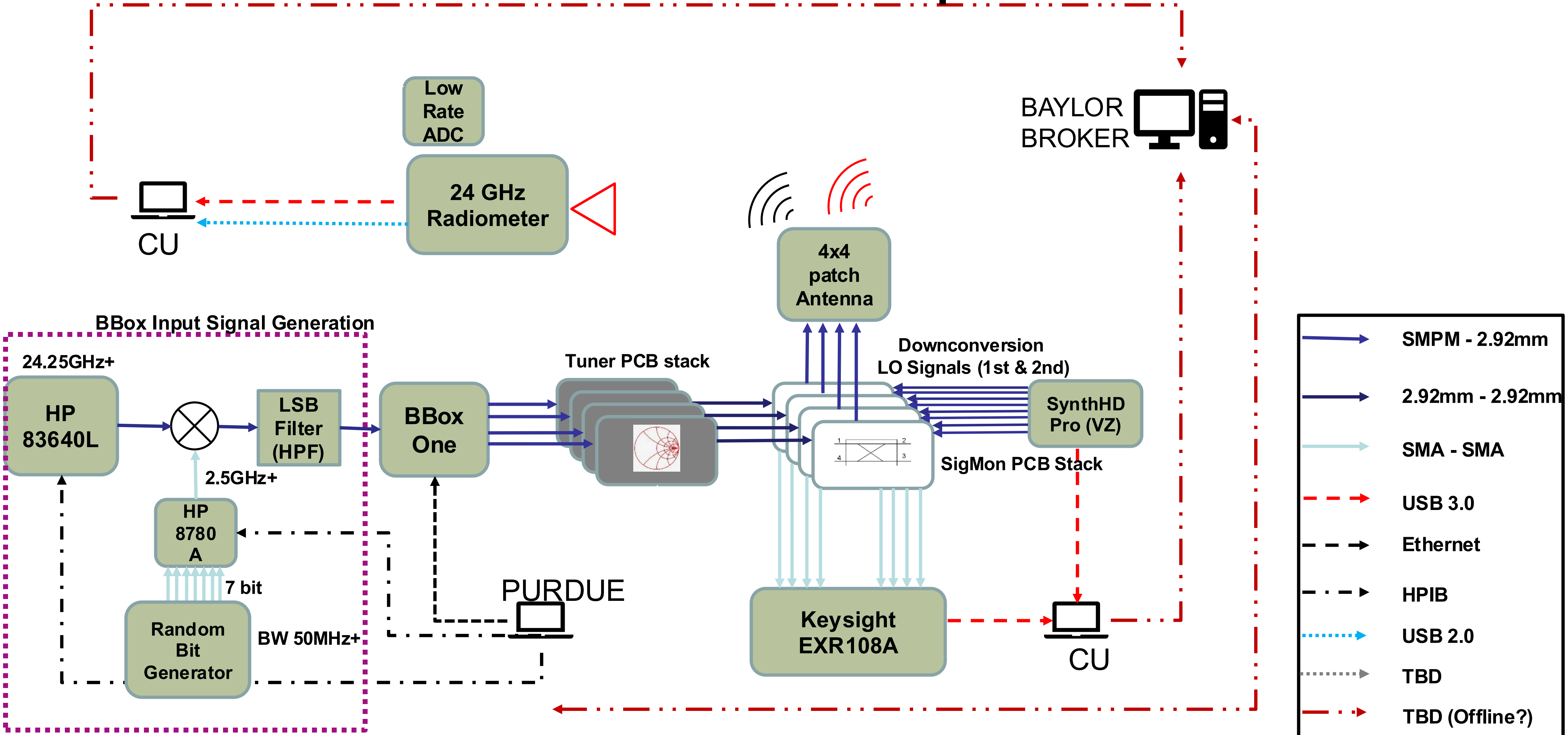


- Multiple stages in the downconverter allow desired image frequency rejection without in-band signal distortion.
- Input passband: 23.5 - 24.5 GHz
- IF 1: 3.75 - 4.75 GHz
- IF 2: 0 – 1 GHz
- Image reject filter at IF 1 should have sharp rolloff (easier at lower frequencies).

Baylor University
WIRELESS AND MICROWAVE CIRCUITS AND SYSTEMS

University of Colorado **Boulder**

Planned Field Test Implementation



Broader Impacts/Policy Supplement

- 2022 International Microwave Symposium Workshop: "Microwave Techniques for Coexistence Between 5G and Passive Scientific Systems"
- May 2023 high school outreach: Belton High School
- Incorporation of the SWIFT mmWave tuner into Purdue's 2024 ECE 307 Fields and Waves Laboratory curriculum.
- M.S. student Samuel Hussey worked with Dr. Andy Clegg to investigate policy enabling spectral brokering:
  - 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.