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Active Array Platform (3.5 GHz)

Developed by Jiayu Hou and Yuan Ding

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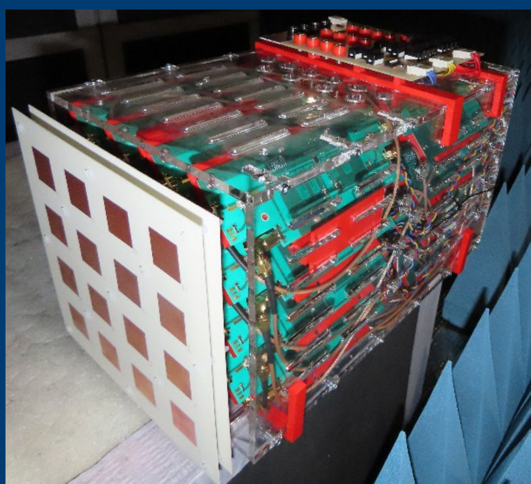


Microwaves and Antenna Engineering Group

https://microwaves.site.hw.ac.uk

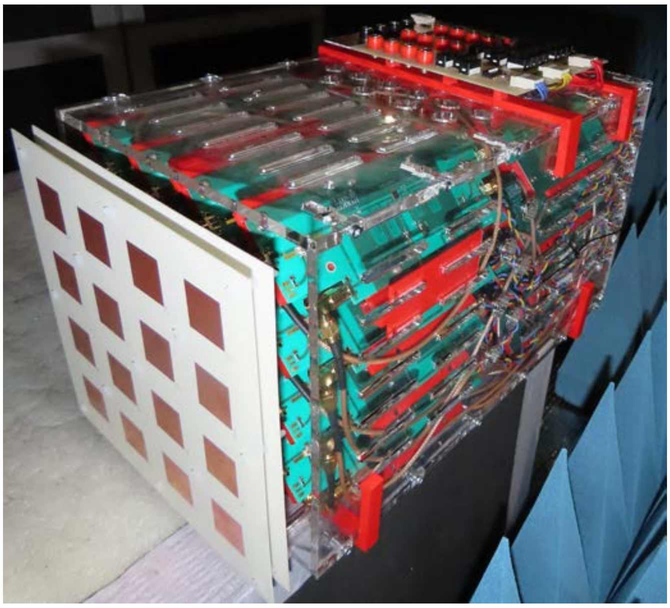
Motivation

Increasing demand for higher wireless link/network capacity inevitably requires transmitters (Tx) and receivers (Rx) equipping more antennas, normally forming different types of arrays. Integration, thus, becomes a trend, and, on the other hand, a challenge, to reduce the system complexity, power consumption and cost, especially at Tx end.

To enable our physical-layer wireless research in the group, we have developed, and will continue making further improvements, an active array platform that can be used in many fronts of our research, including, but not limited to:

- Power amplifier (PA) non-linearity characterisation/modelling, and its predistortion algorithms;
- PA active loadpulling phenomenon, i.e., non-linear interaction between PAs and coupled antenna arrays;
- Inter-modulation and harmonic distortions in multi-beam or MIMO Tx active arrays;
- Physical-layer wireless security systems, e.g., directional modulation (DM) and radio frequency fingerprinting (RFF).
- The impact of RF imperfection on the quality of wireless channel estimation and precoding that relies on Tx and Rx reciprocity, and eventually on link and network capacity.

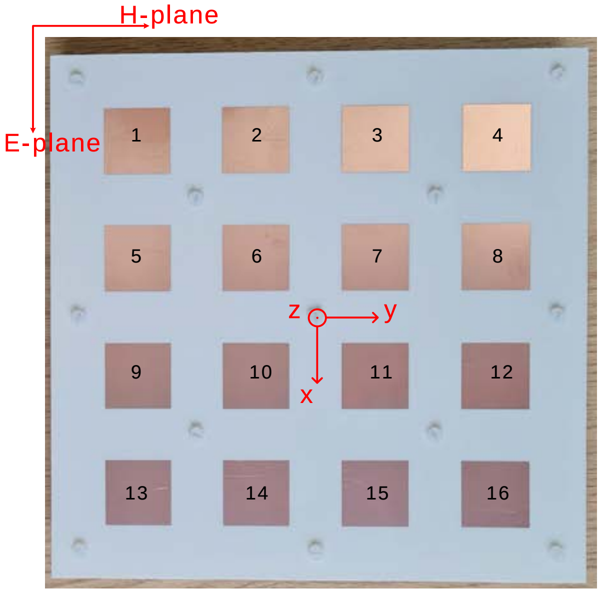
Active Array Platform Specs



Operation Frequency: 3.5 GHz

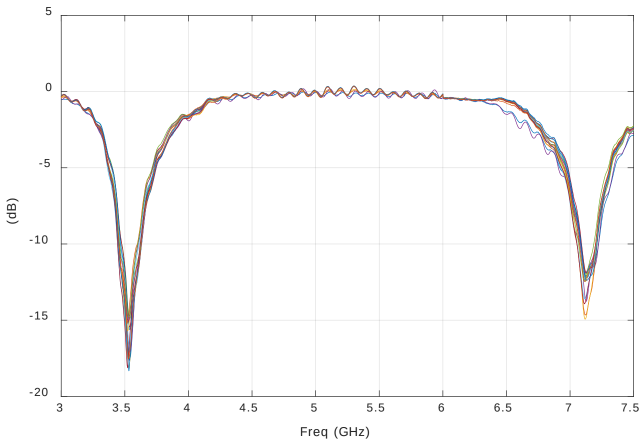
Array Size: 4×4, 16-chain array

Antenna Array: 4×4, 16-element capacitively-fed microstrip patch array with half-wavelength spacing.

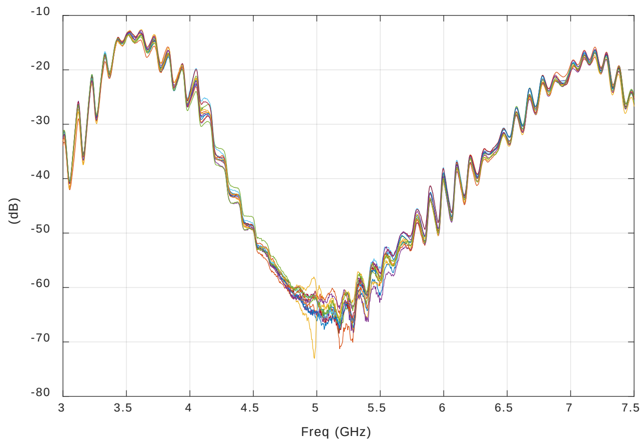


Measured S-parameters

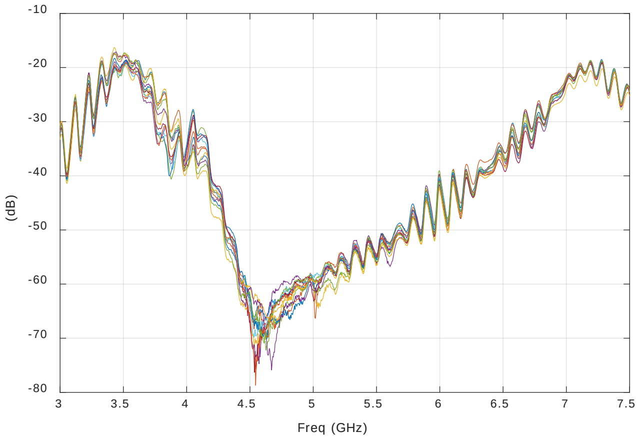
- Reflection Coefficients S_{ii} (i = 1, ..., 16)



- Coupling between two adjacent elements in E-plane.

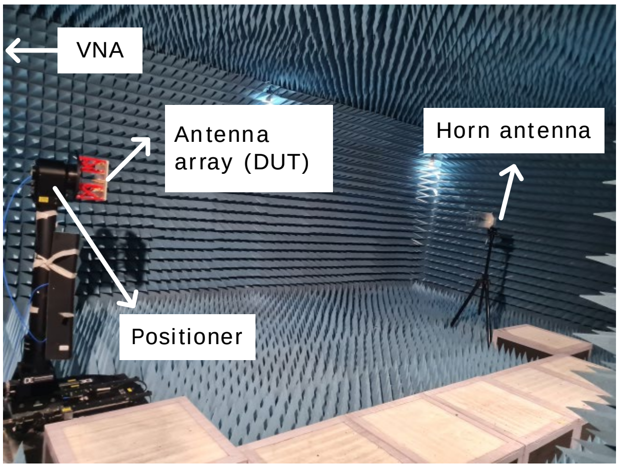


- Coupling between two adjacent elements in H-plane.

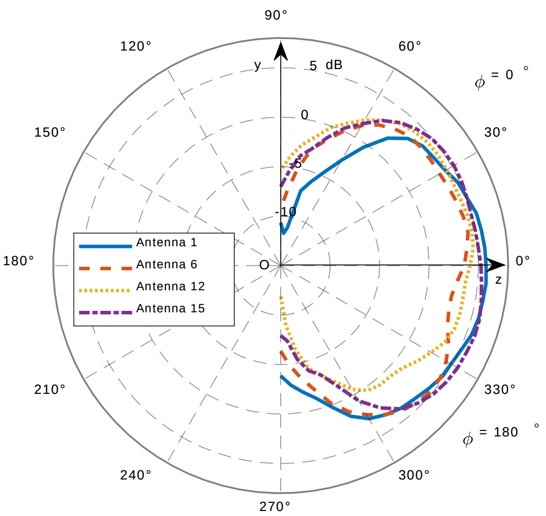


Measured Radiation Patterns

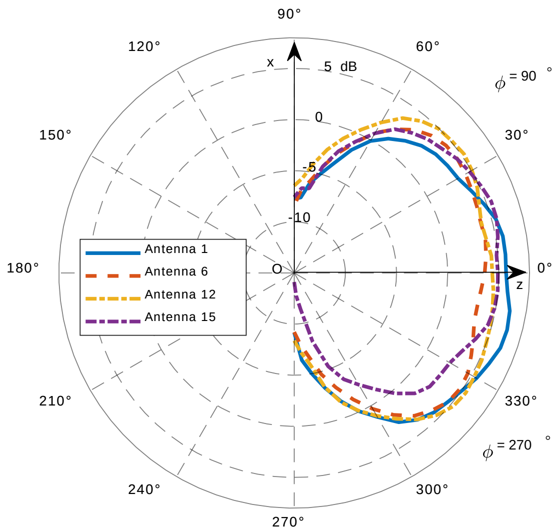
Patterns @3.5 GHz of four selected antenna elements (1, 6, 12, 15) are illustrated as below.



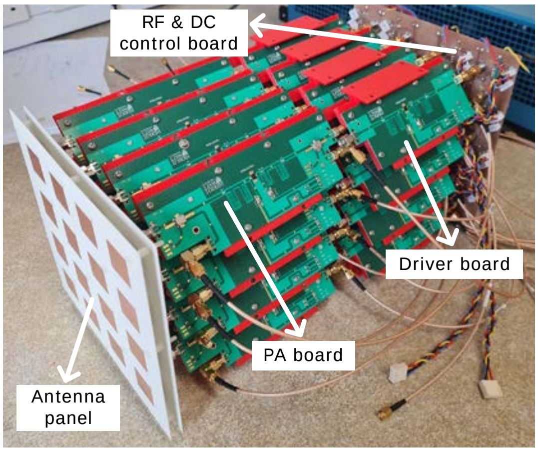
- G_φ in yoz plane



- G_θ in xoz plane



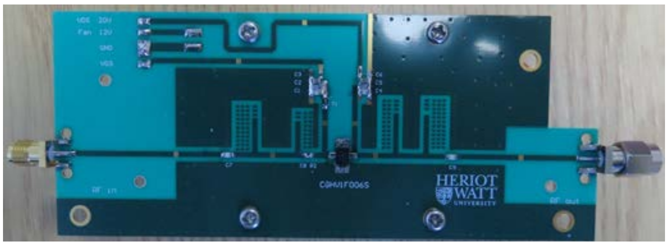
Active array platform assembly without case



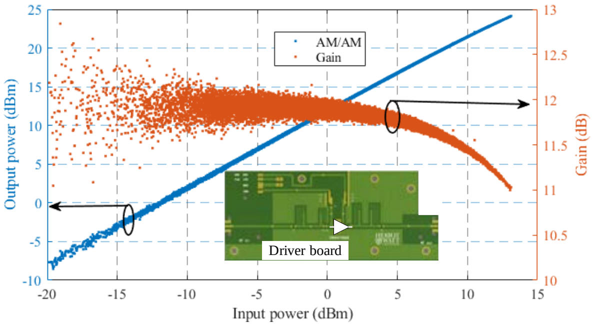
Driver:

Transistor: GaN CGHV1F006S

Biasing: 20V Vd; 100mA Iq



- Typical measured AM/AM and Gain compression curves (using OFDM signals of 200kHz bandwidth)

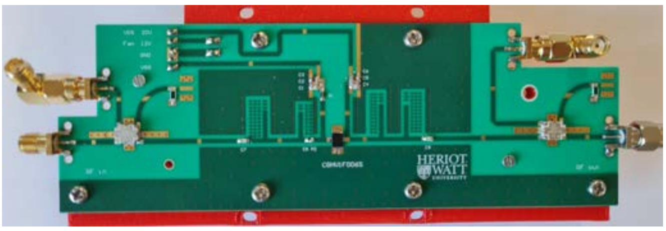


Final Stage PA:

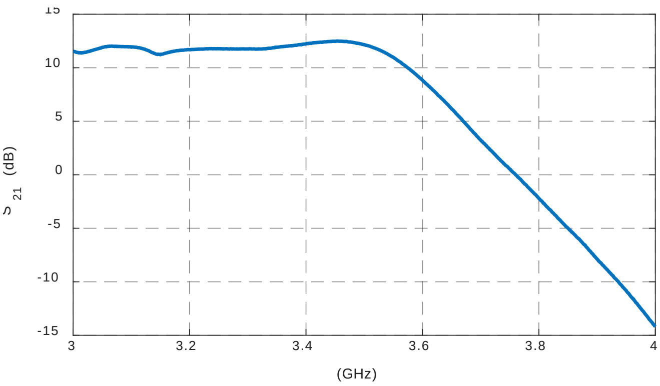
Transistor: GaN CGHV1F006S

Biasing: 20V Vd; 100mA Iq

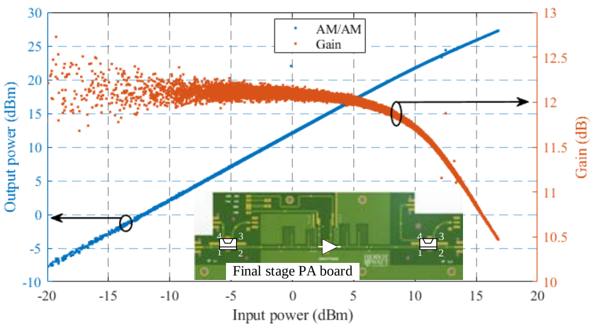
Input & Output coupling: ~–20 dB



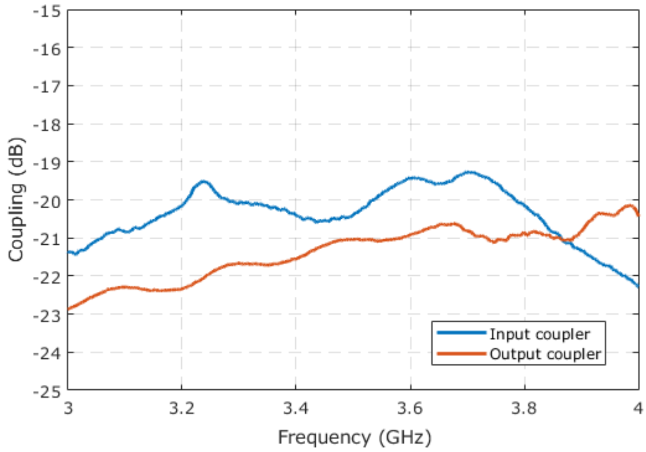
- Typical measured small-signal S_{21}



- Typical measured AM/AM and Gain compression curves (using OFDM signals of 200kHz bandwidth)

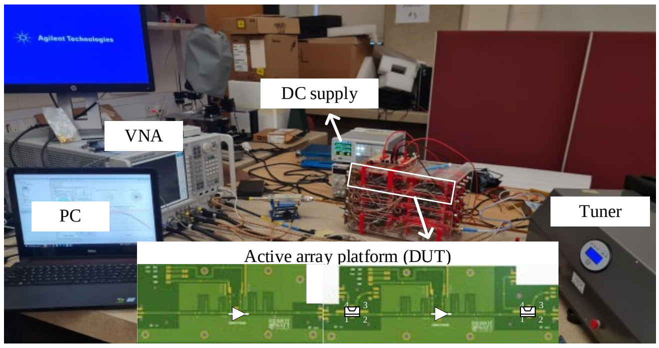


- Input and output couplers (cabling and connectors included)

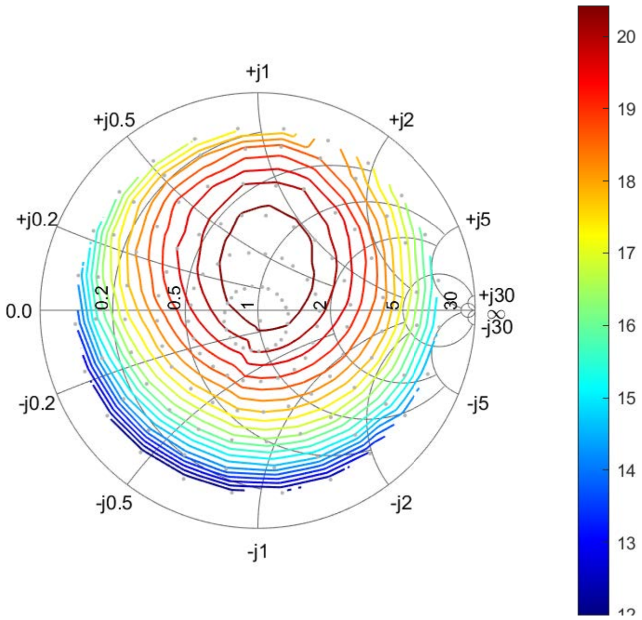


Loadpull Measurement:

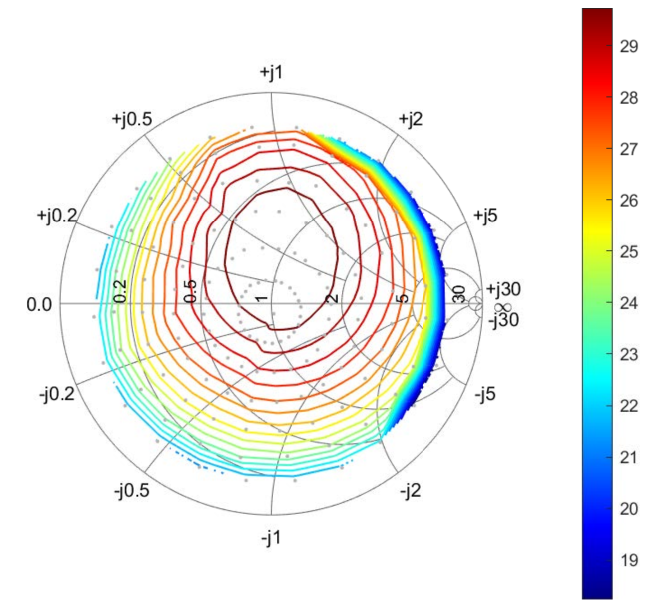
Loadpull measurement was performed with Maury passive tuner XT982ML01, and Keysight PNA N5225A.



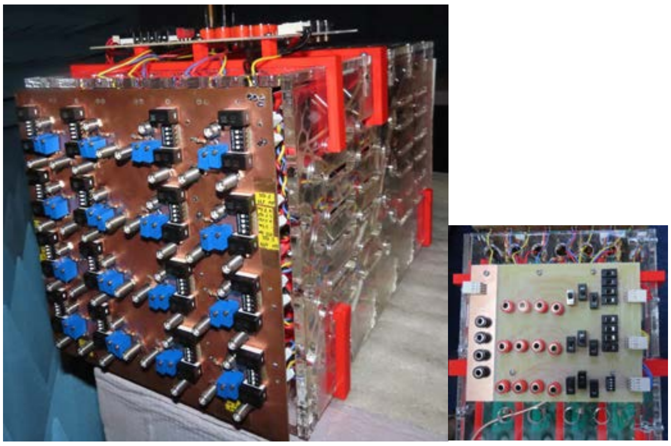
- Gain (dB) @ 2.5dB compression – Chain6

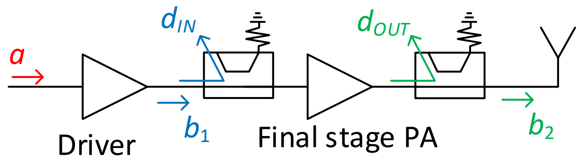


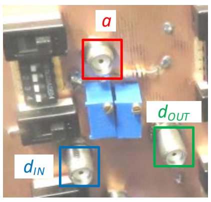
- Pdel (dBm) @ 2.5dB compression – chain6

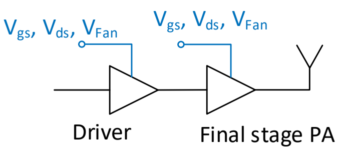


RF and DC Control Board:









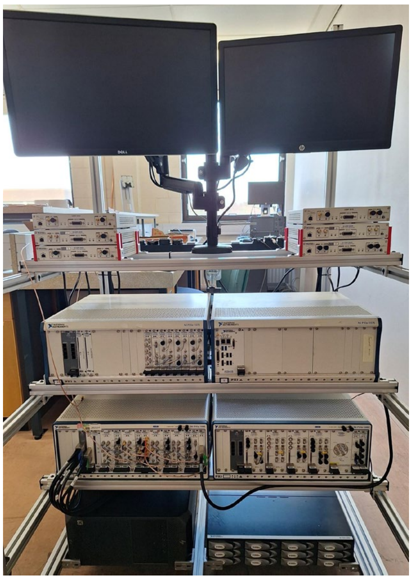
Couplers calibrated:

- Input coupler: coupling read from b_1 and d_{IN} (backplane);
- Output coupler: coupling read from b_2 and d_{OUT} (backplane);
- 50 Ω load: avoid mixing the forward and backward coupling waves.

Independent control and monitoring for each chain:

- Independent RF input a;
- Final stage PA input and output monitoring d_{IN} and d_{OUT};
- Active reflection coefficients estimated from d_{OUT} and antenna S-Matrix;
- Gate voltage ON/OFF and tuning;
- Drain voltage ON/OFF;
- Fan ON/OFF.

Digital Baseband & RF Chains

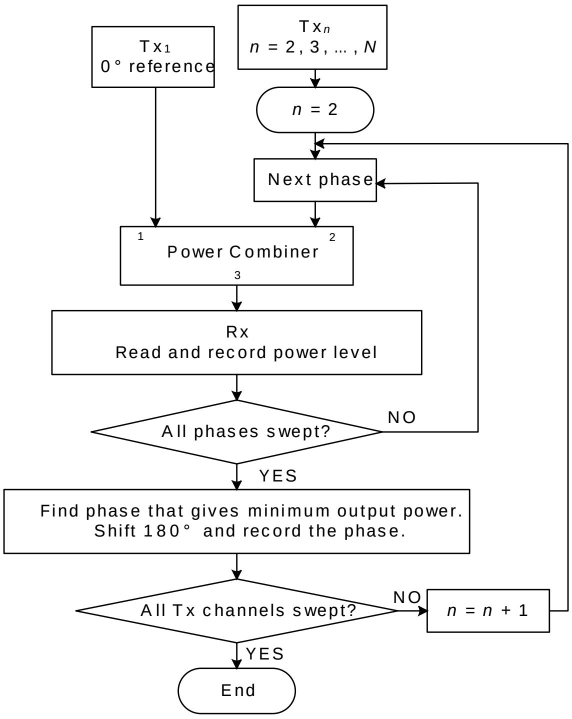


National Instruments (NI) Software Defined Radios (SDRs) are used for digital baseband generation, RF up/down-conversion, IF sampling, etc. Tx and Rx SDR modules include

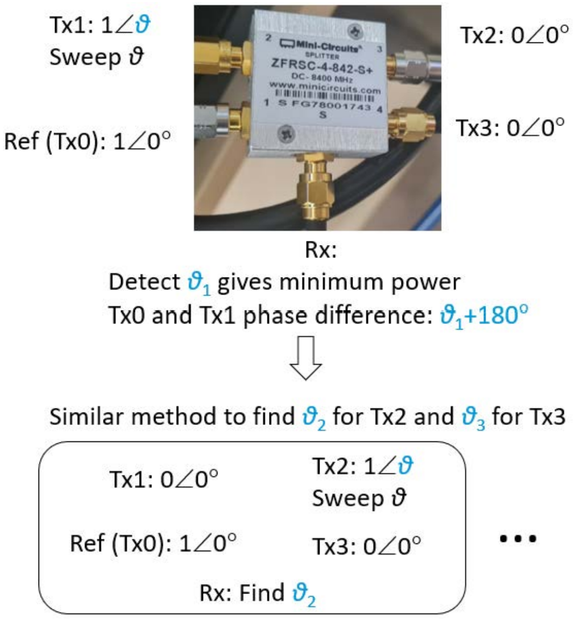
- USRP-2944R (6 pieces) – 12 Tx and 12 Rx
  200MS/s I&Q for each Tx and Rx
  160MHz instantaneous signal bandwidth
- PXIe-5644R (4 pieces) – 4 Tx and 4 Rx
  120MS/s I&Q for each Tx and Rx
  96MHz instantaneous signal bandwidth
- PXIe-5673 (4 pieces) – 4 Tx
  200MS/s I&Q for each Tx
  160MHz instantaneous signal bandwidth
- PXIe-5663 (3 pieces) – 3 Rx
  75MS/s I&Q for each Rx
  60MHz instantaneous signal bandwidth

Synchronisation:

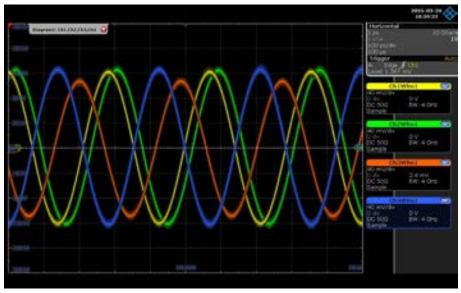
- Frequency is synchronised by distributing a 10 MHz reference signal to every Tx and Rx modules using an OctoClock.
- Phase needs to be synchronised every time the whole platform is powered on. The phases among different Tx chains are random when they are enabled, but they are relatively stable until they are disabled. A phase synchronisation LabVIEW programme has been developed, see the flowchart as below:



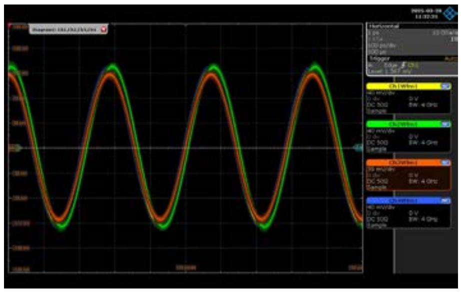
See an example below of 4 Tx phases at 3.5 GHz before and after the phase calibration;



Before phase calibration



After phase calibration



Data

Please send your requests to Jiayu Hou and Yuan Ding.

Funding Support

EPSRC (EP/V002635/1): 'Boosting Power Efficiency of Physical-layer Secured MIMO Communications'

EPSRC (EP/Y037197/1): 'Securing Spectrum Connectivity Over-the-Air Authentication using Radio Frequency Fingerprinting' in HASC: Future Communications Hub in All-Spectrum Connectivity

Selected Publications

Jiayu Hou, Yuan Ding, George Goussetis, 'Active Antenna Array Experimental Platform', EuMC 2025, under review.

Researchers

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