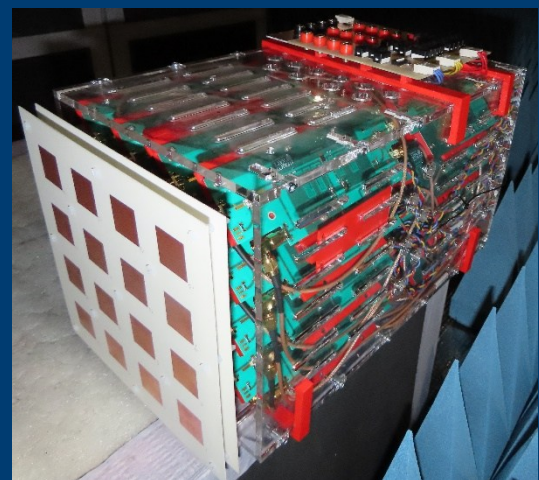
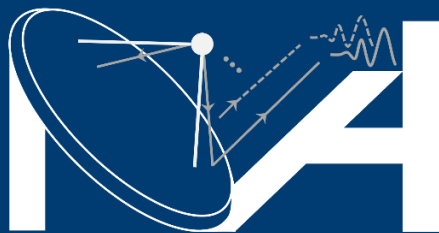




## Active Array Platform (3.5 GHz)

Developed by Jiayu Hou and Yuan Ding

Document last updated on 22<sup>nd</sup> Mar. 2025



**Microwaves and Antenna Engineering Group**

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

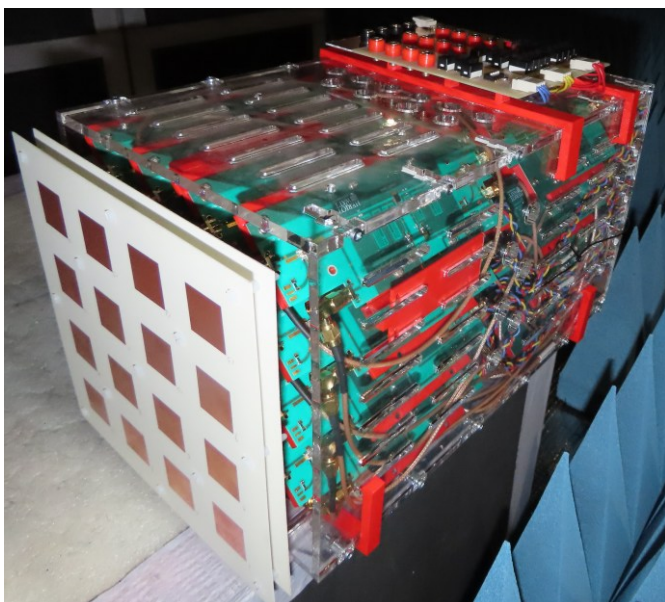
## Motivation

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 that relies on transmitter and receiver reciprocity, and eventually on link and network capacity.

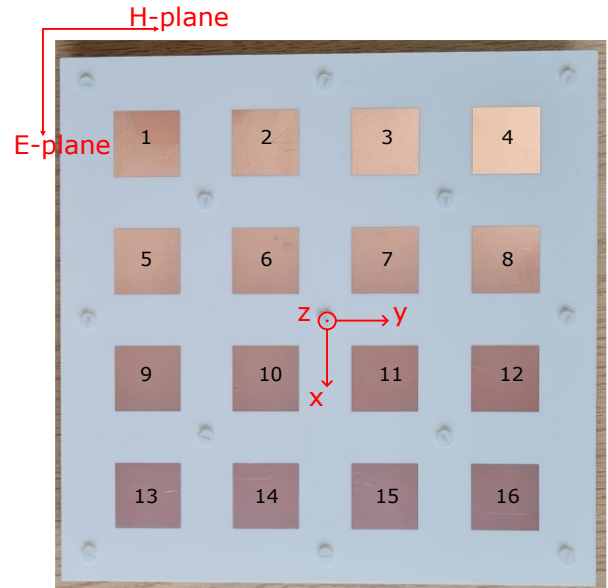
## Active Array Platform Specs



**Operation Frequency:** 3.5 GHz

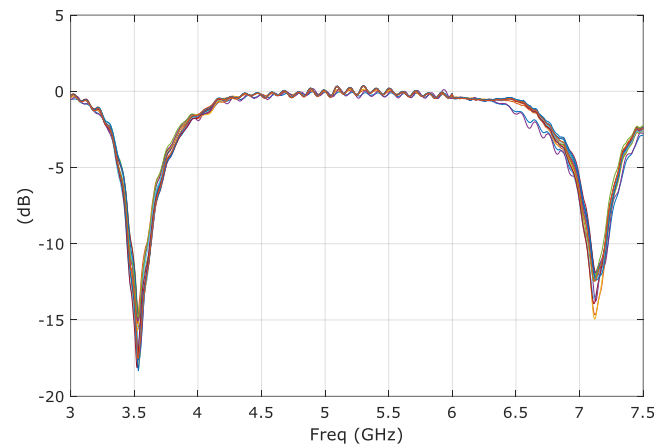
**Array Size:** 4×4, 16-chain array

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

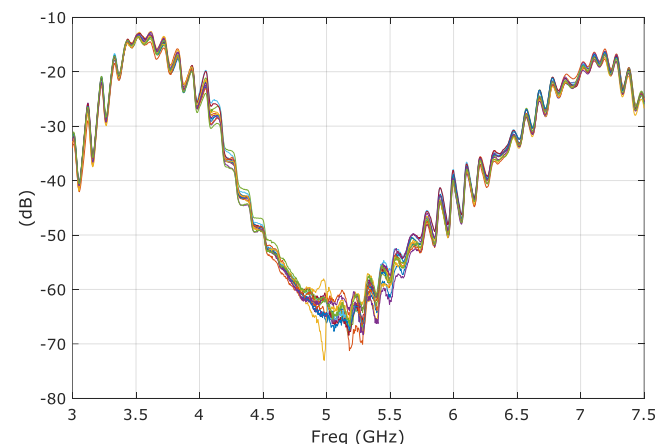


## Measured S-parameters

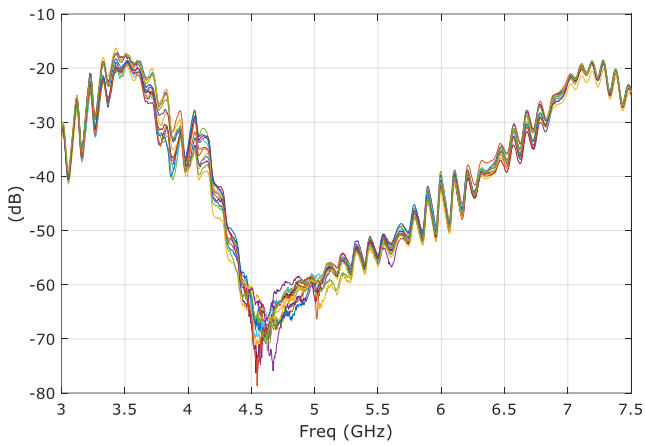
- Reflection Coefficients  $S_{ii}$  ( $i = 1, \dots, 16$ )



- Coupling between two adjacent elements in E-plane.

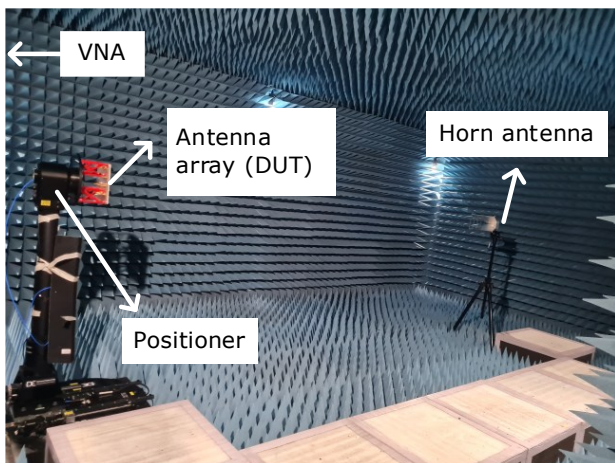


- Coupling between two adjacent elements in H-plane.

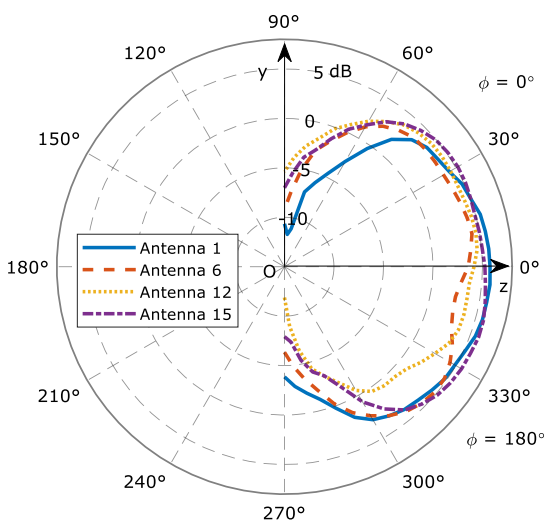


**Measured Radiation Patterns**

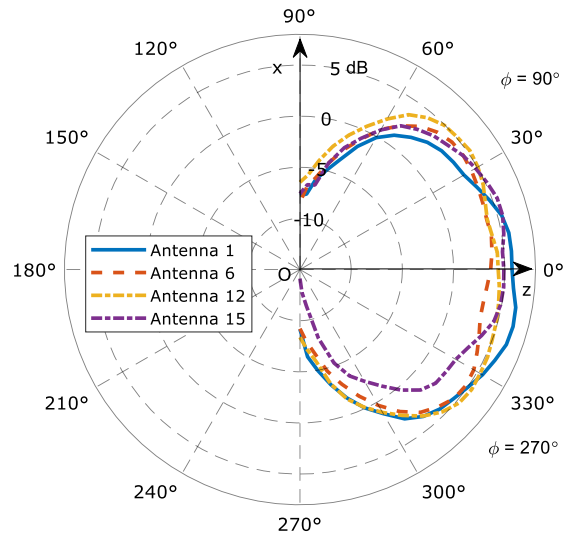
Patterns @3.5 GHz of four selected antenna elements (1, 6, 12, 15) are illustrated as below.



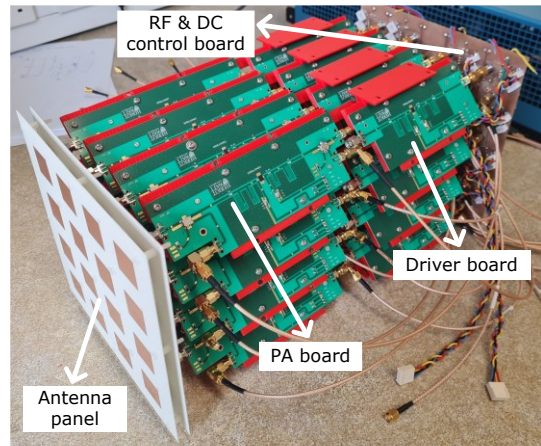
- $G_{\phi}$  in yoz plane



- $G_{\theta}$  in xoz plane



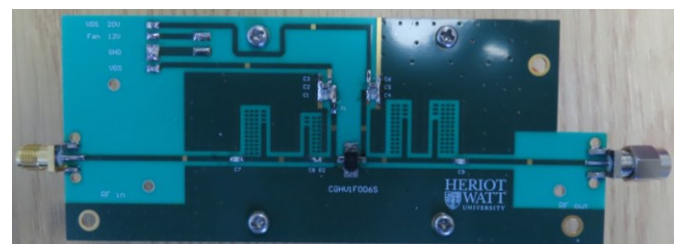
Active array platform assembly without case



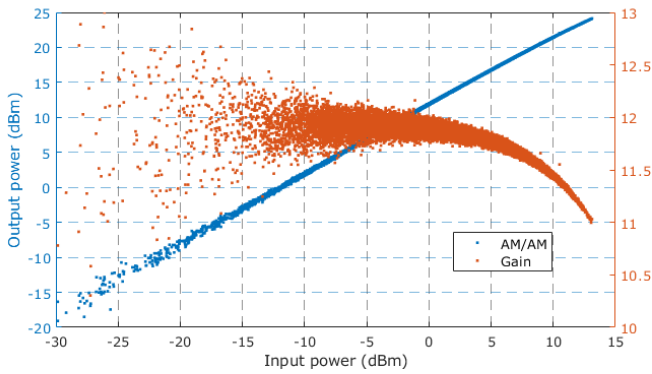
**Driver:**

Transistor: GaN CGHV1F006S

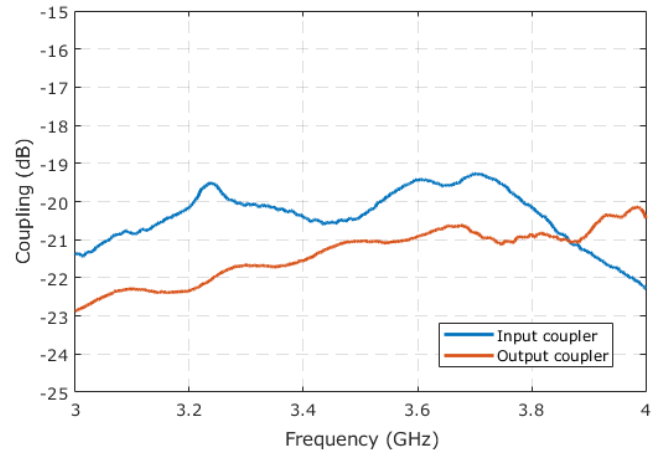
Biasing: 20V Vd; 100mA Iq



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



- Input and output couplers (cabling and connectors included)

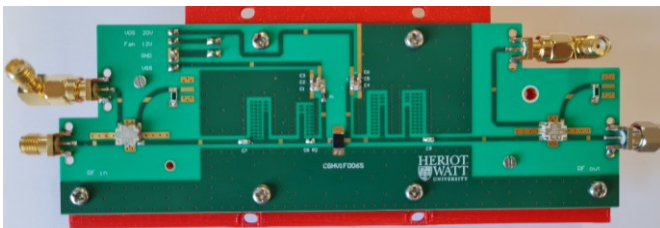


**Final Stage PA:**

Transistor: GaN CGHV1F006S

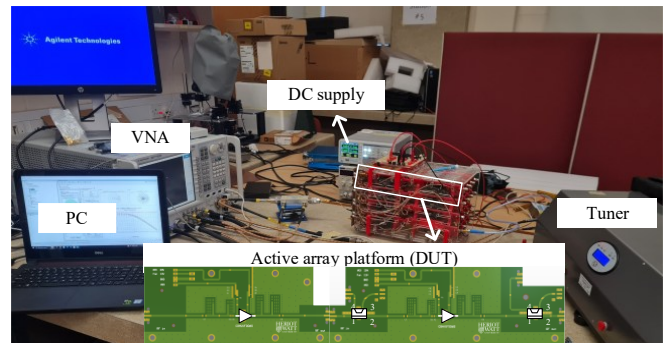
Biasing: 20V Vd; 100mA Iq

Input & Output coupling: ~-20 dB

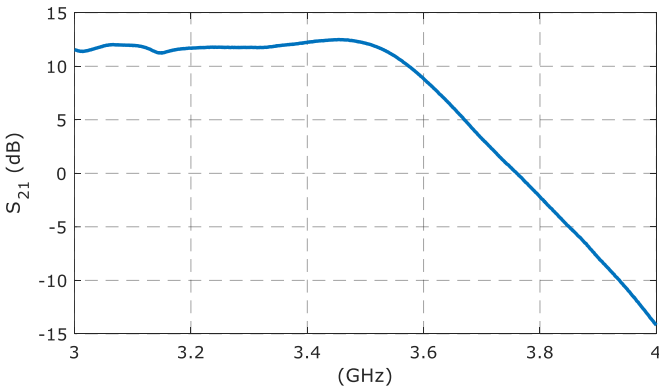


**Loadpull Measurement:**

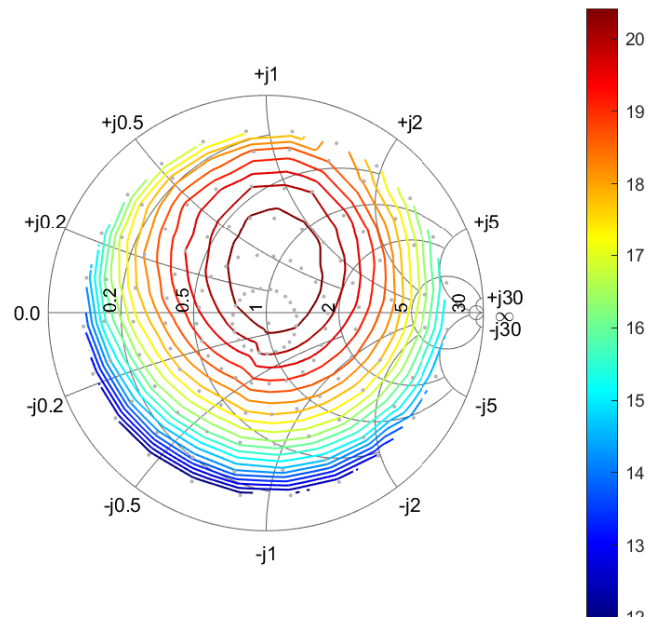
Loadpull measurement was performed with Maury passive tuner XT982ML01, and Keysight PNA N5225A.



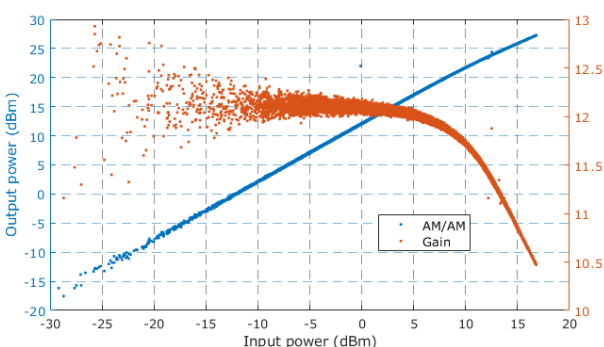
- Typical measured small-signal  $S_{21}$



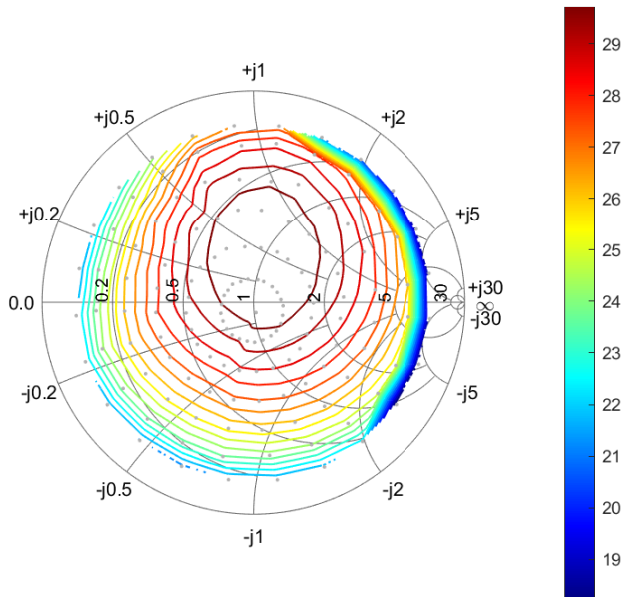
- Gain (dB) @ 2.5dB compression – Chain6



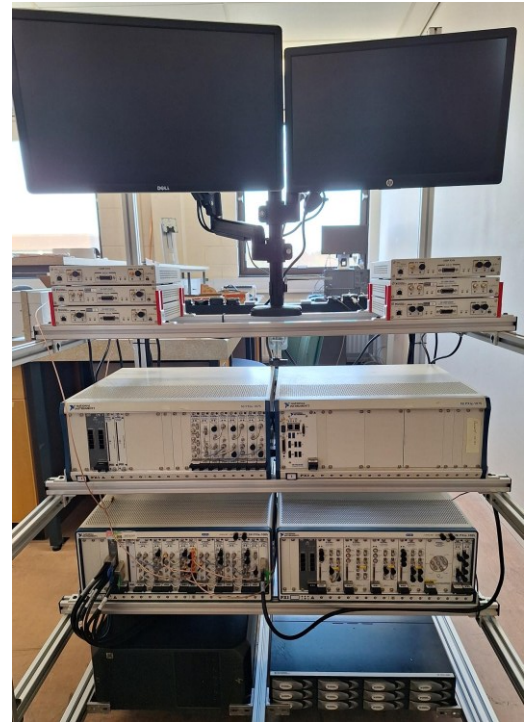
- Typical measured AM/AM and Gain compression curves (using LTE signals of 200kHz bandwidth)



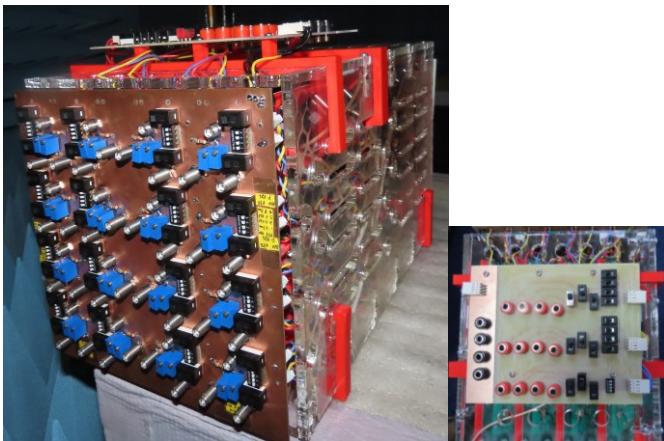
- Pdel (dBm) @ 2.5dB compression – chain6



## Digital Baseband & RF Chains



### RF and DC Control Board:



For each chain,

- the drain voltage can be switched on/off;
- the gate voltage for driver and PA can be individually switched on/off;
- the gate voltage for driver and PA can be individually tuned;
- the fans for driver and PA can be individually switched on/off;
- coupled RF signals from PA input and output can be individually monitored.
- the entire drain and gate currents can be monitored.

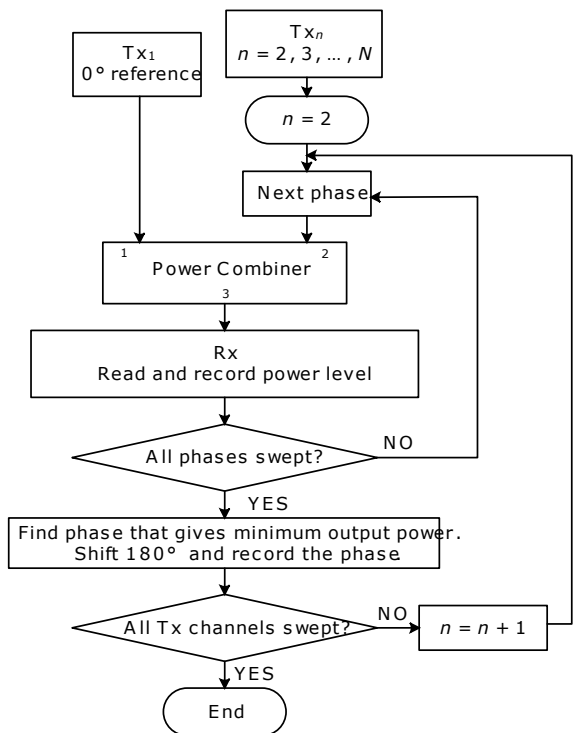
National Instruments (NI) Software Defined Radios (SDRs) are used for digital baseband generation, RF up/down-conversion, IF sampling, etc. Tx and Rx SDR modules include

- 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:

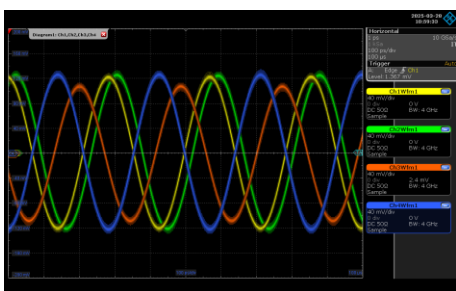
- Frequency is synchronised by distributing a 10 MHz reference signal to every Tx and Rx modules using an OctoClock.

- 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:

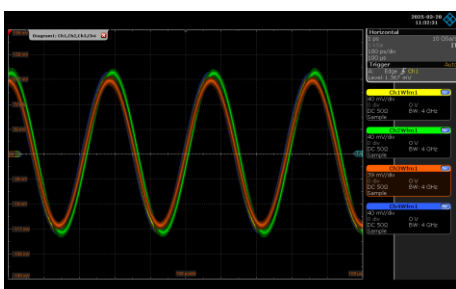


See an example below of 4 Tx phases at 3.5 GHz before and after the phase calibration;

- 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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