Swansea University
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D-band: Offering The Next Frontier And Path Forward For 6G Communications For Civil And Defense

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The Promises of 6G

- Higher Data Rates
- Greater Bandwidth
- Lower Latency

Natural Next Step

- Networks as Sensors
- Highly Compact Antenna
- Satellite Integration

Disruptive 6G

D-Band (110GHz to 170GHz)

High Speed

Low Latency

Bandwidth

D-Band (110GHz to 170GHz)

High Speed

Low Latency

Bandwidth

Network as Sensors

D-Band

High Speed

Low Latency

Bandwidth

Network as Sensors

Compact Arrays

D-Band

High Speed

Low Latency

Compact Arrays

Bandwidth

Network as Sensors

Security

D-Band

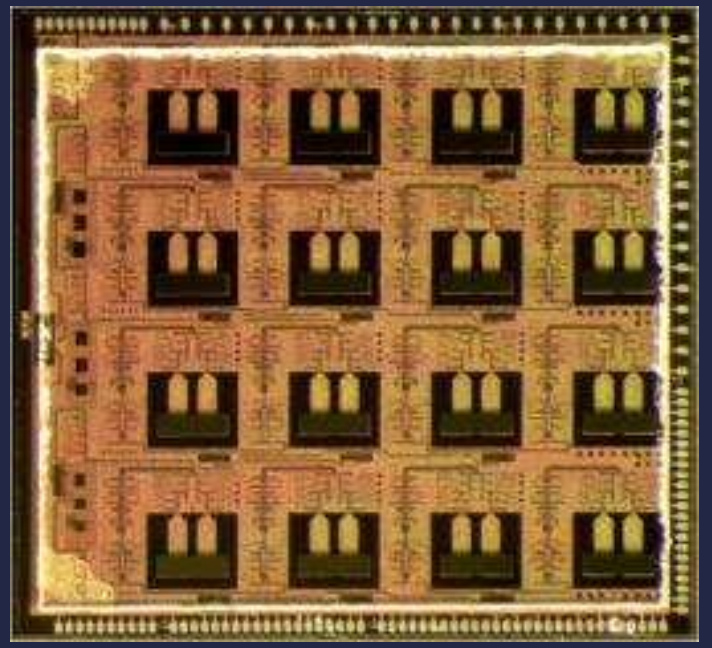
- RF Technology is now mature to delivery beam steering system.
- Requires very high gain and narrow beam width for range + data rate.
- Highly compact phased arrays designs now ready research domain.
- Detailed sensing (RADAR etc).

- Challenges:
  - How do we build these arrays at these sizes?
  - How to we maintain low cost when large arrays are required for gain?

On-Chip Antenna Arrays

- Move from PCB structures with RFIC chips to fully integrated on-chip antenna arrays
- Promising solution for compact manufacturing at D-band

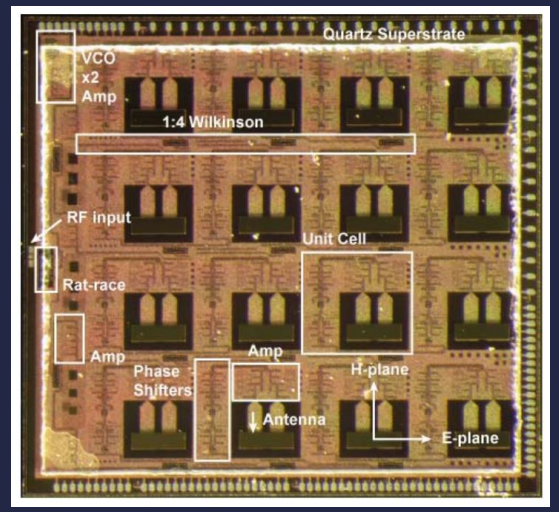
- Challenges:
  - Material properties & Efficiencies
  - Shared space between feeding network and antenna array (single die)



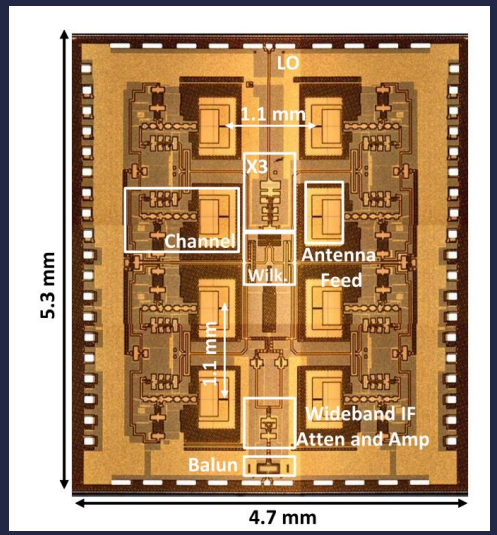
University of California

W. Shin, O. Inac, Y. Ou, B. Ku and G. M. Rebeiz, "A 108–112 GHz 4×4 wafer-scale phased array transmitter with high-efficiency on-chip antennas," 2012 IEEE Radio Frequency Integrated Circuits Symposium, 2012, pp. 199-202, doi: 10.1109/RFIC.2012.6242263.

On-Chip Antenna Arrays



2013 Woorim Shin et al.
108-114GHz
45% efficiency
+/- 30° Beamforming
2-bit phase shifting



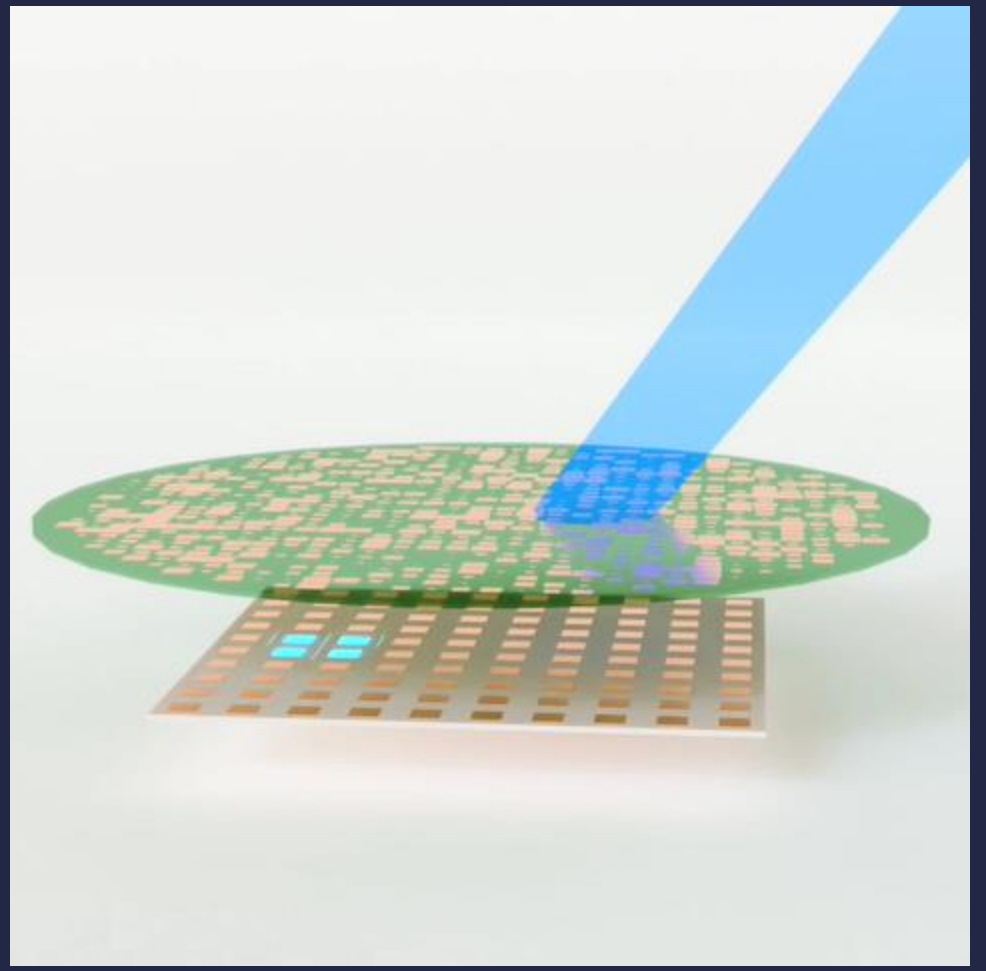
2020 Siwei Li et al.
140GHz
58% efficiency
+/- 35° Beamforming
5-bit phase shifting
4-bit gain control

W. Shin, O. Inac, Y. Ou, B. Ku and G. M. Rebeiz, "A 108–112 GHz 4×4 wafer-scale phased array transmitter with high-efficiency on-chip antennas," 2012 IEEE Radio Frequency Integrated Circuits Symposium, 2012, pp. 199-202, doi: 10.1109/RFIC.2012.6242263.
S. Li, Z. Zhang, B. Rupakula and G. M. Rebeiz, "An Eight-Element 140-GHz Wafer-Scale IF Beamforming Phased-Array Receiver With 64-QAM Operation in CMOS RFSOI," in IEEE Journal of Solid-State Circuits, doi: 10.1109/JSSC.2021.3102876.
W. Lin et al., "320 GHz On-Chip Circularly-Polarized Antenna Array Realized with 0.13 µm BiCMOS Technology," 2020 IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting, 2020, pp. 1467-1468, doi: 10.1109/IEEECONF35879.2020.9329666.

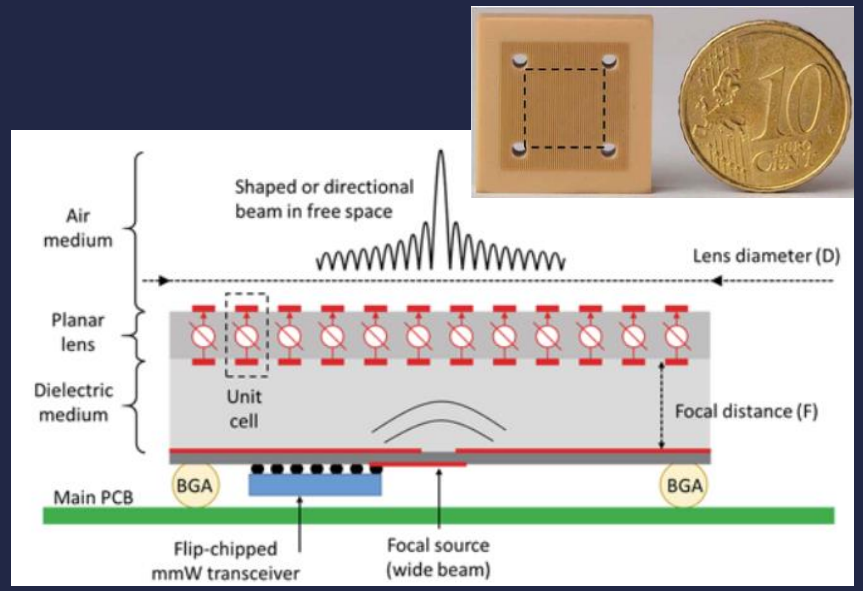
Meta-Material Assisted Antenna

- Meta-Surfaces provide a promising method to enable D-band communication at low cost
- We can use meta-surface lenses and substrates to increase gain and steer a beam from a single antenna
- We may not need full antenna arrays and phase shifters to achieve effective performance

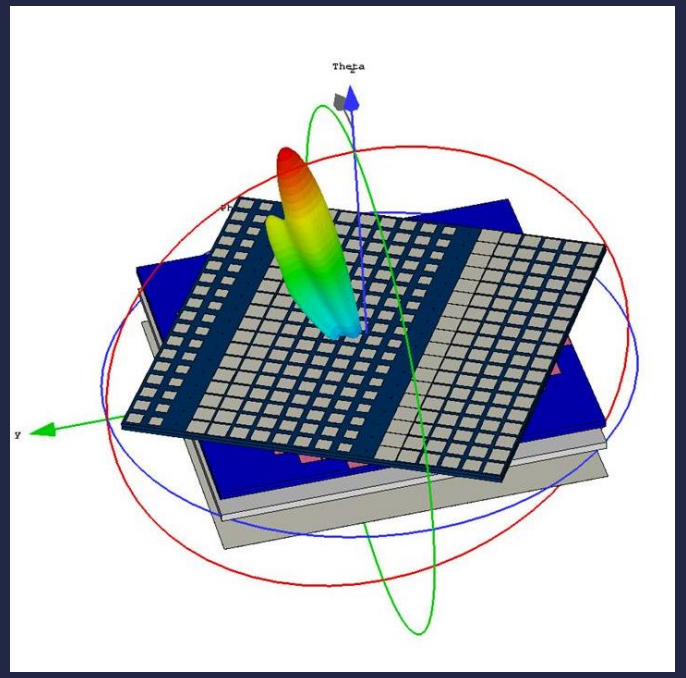
- Challenges:
  - Manufacture of meta-surfaces
  - Optimal beamforming with meta-surface design
  - Layer reduction



Meta-Material Assisted Antenna



21.1 dBi at 153 GHz
Meta-surface lense in PCB

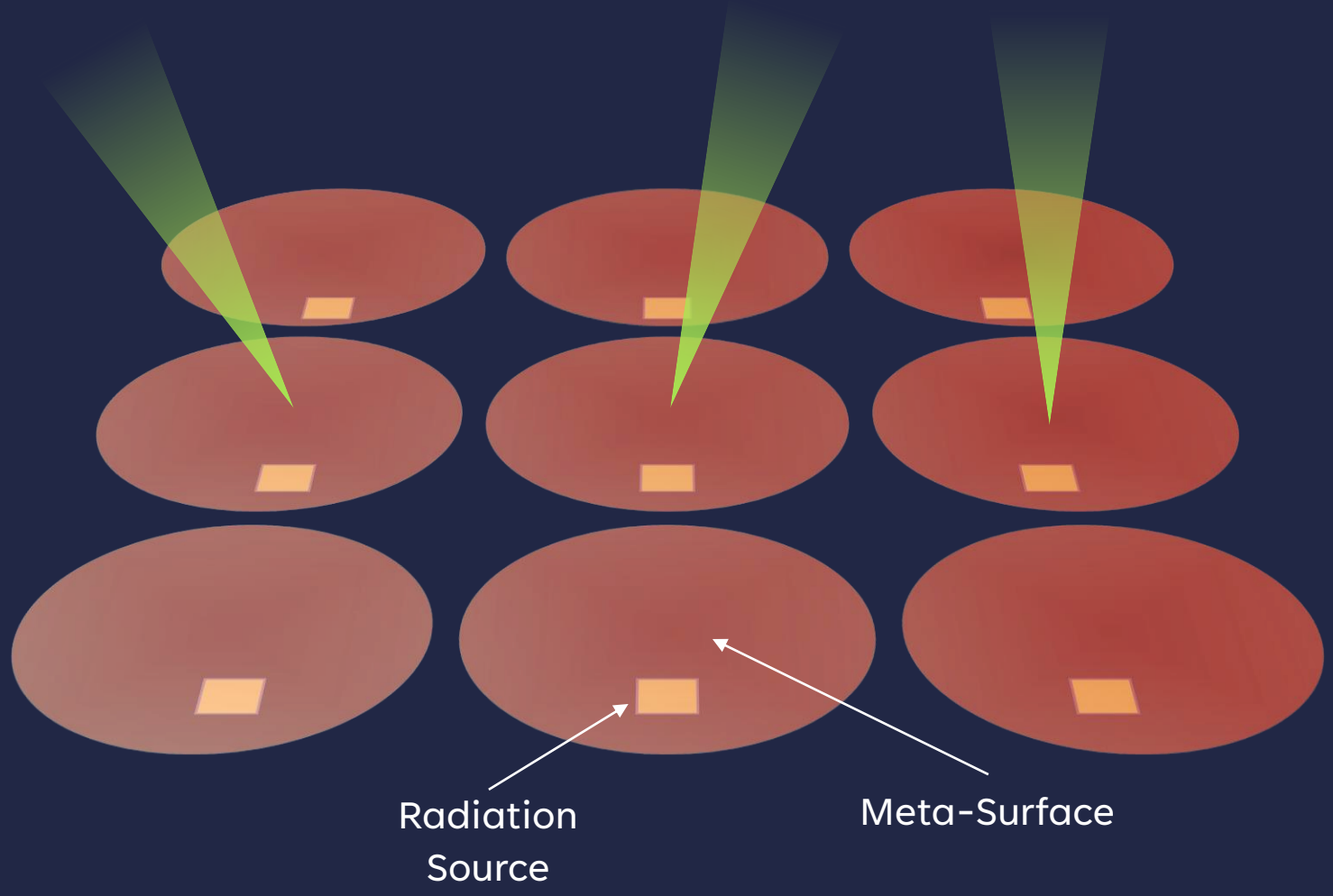


Swansea University Reconfigurable Lens
Physical beamforming using lens + MEMS
Size and gain – 30 mm for <20 dBi steering

L. Marnat, K. Medrar and L. Dussopt, "Highly Integrable High Gain Substrate-integrated Planar Lens for Wide D-band Applications," 2020 14th European Conference on Antennas and Propagation (EuCAP), 2020, pp. 1-4, doi: 10.23919/EuCAP48036.2020.9135477.

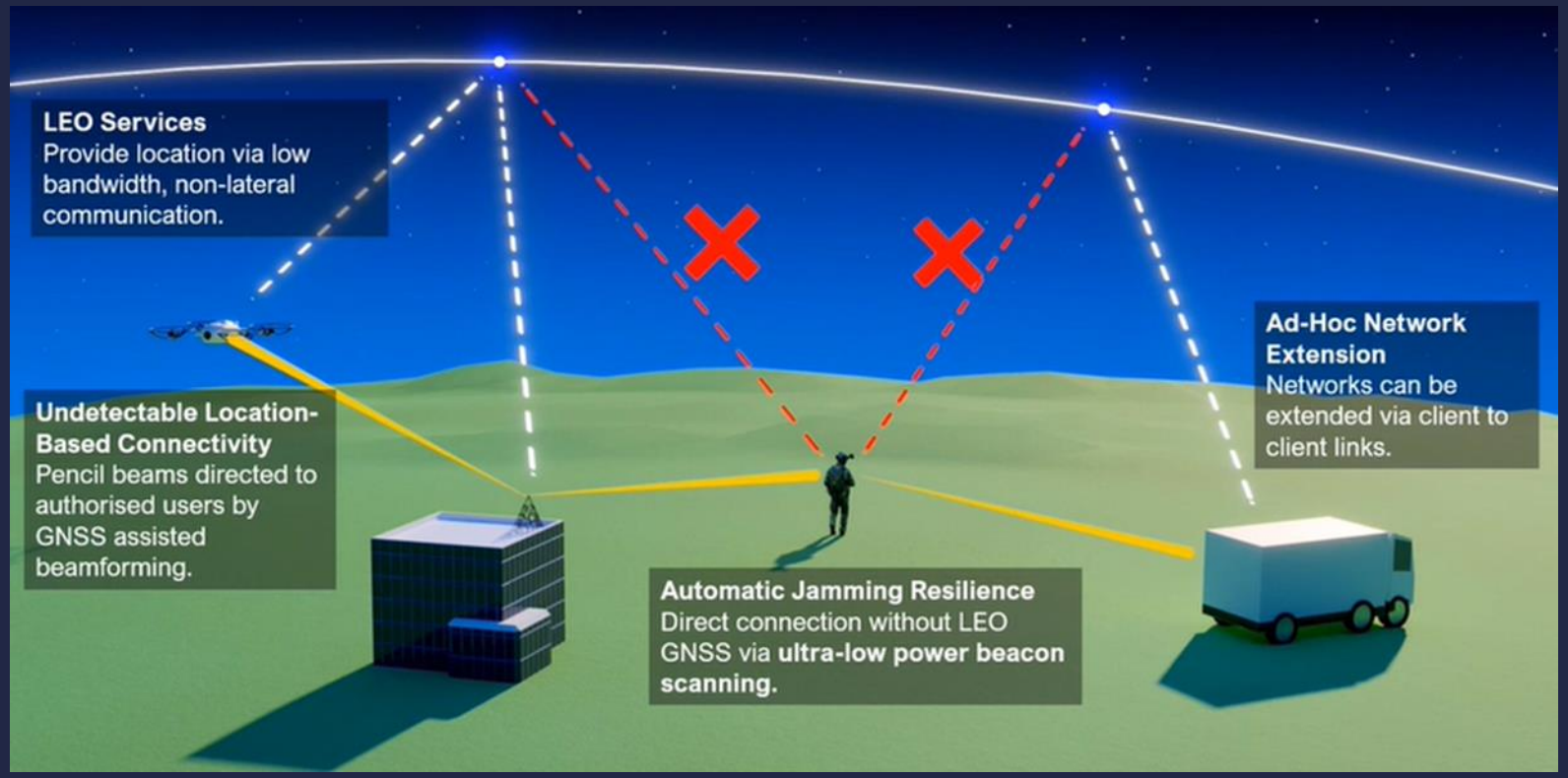
Meta-Material Assisted Antenna

- A meta-surface assisted array could provide one beam per source
- Each source could provide the equivalent of an 8x8 sub array
- This is ideal for multi-beam systems such as base stations



Smart Beamforming for Pencil Beams – for UK MOD work @Swansea

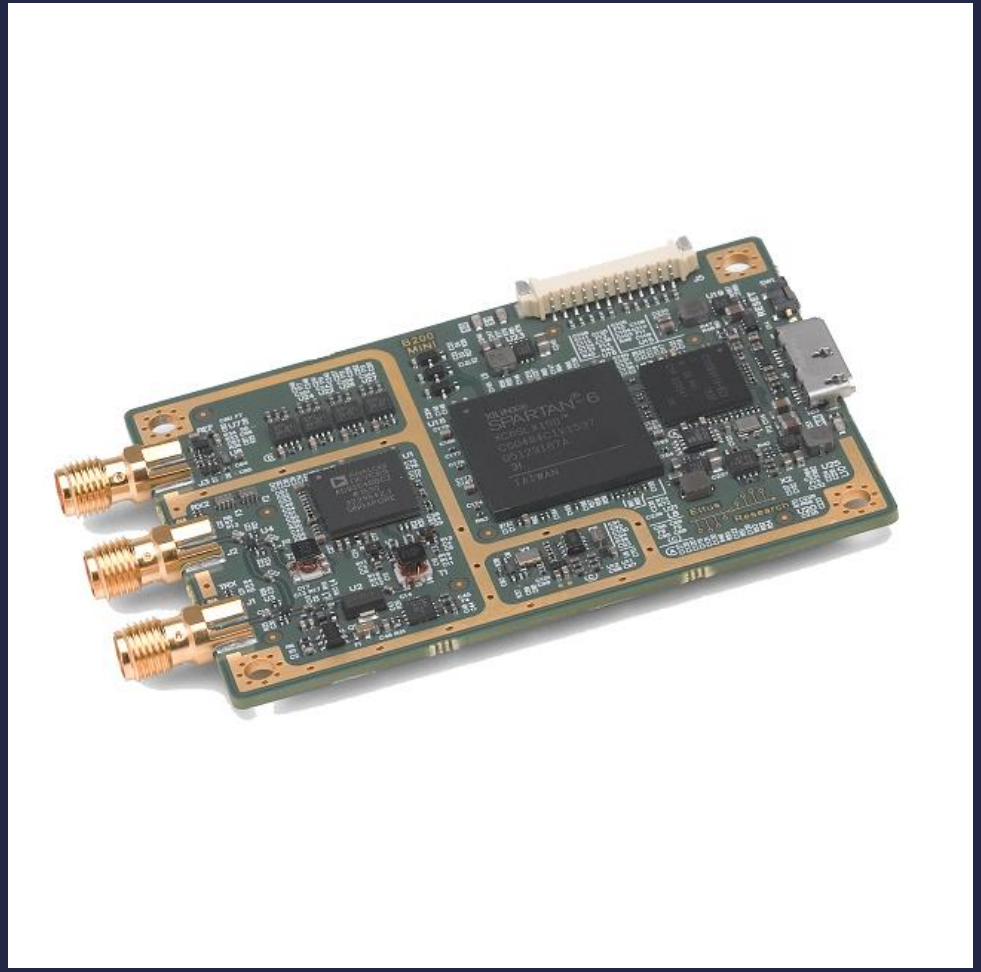
- Due to pencil beams it is vital that beamforming acquisition is fast
- Methods for this include
  - Satellite assisted beamforming
  - Beacon scanning



Beamforming Demo

SDR work for closed loop LPI at Swansea

- For UK MoD in partnership with Airbus
- USRP B205-Mini
- In this case, used for smart wideband power detector for closed loop system
- Final Smart Beamforming systems will use integrated SDR for spectral analysis and hybrid beamforming



Summary

- D-Band provides not only higher throughput but also key disruptive advantages for 6G (sensing, security)
- New technologies such as meta-structures and on-chip antennas are potential enabling technologies
- Next generation beamforming will be smarter and quicker via satellite and AI assisted acquisition

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Thank you!

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