University of Glasgow

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Low-Profile Antenna Package for Efficient Inter-CubeSat Communication in S- and V-band

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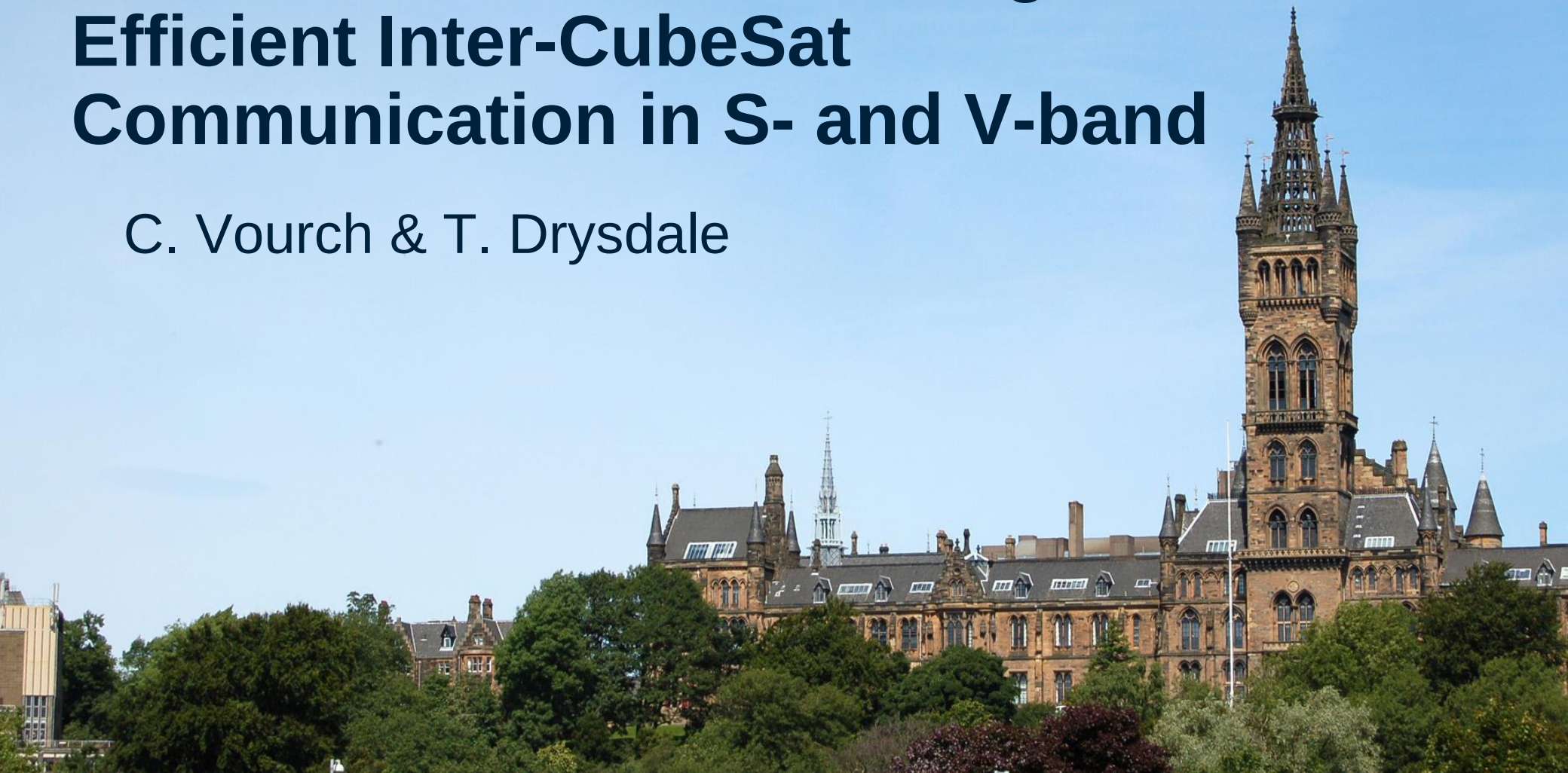


- **Challenge** – A CubeSat flying formation is the only practical and affordable method for observation missions (e.g. OLFAR) that require very large apertures. But for inter-CubeSat link:
  - Conventional frequency bands (VHF/UHF/S-band) can only provide limited data rates
  - Small and directive antennas cannot be designed at those frequencies because of physical limitations

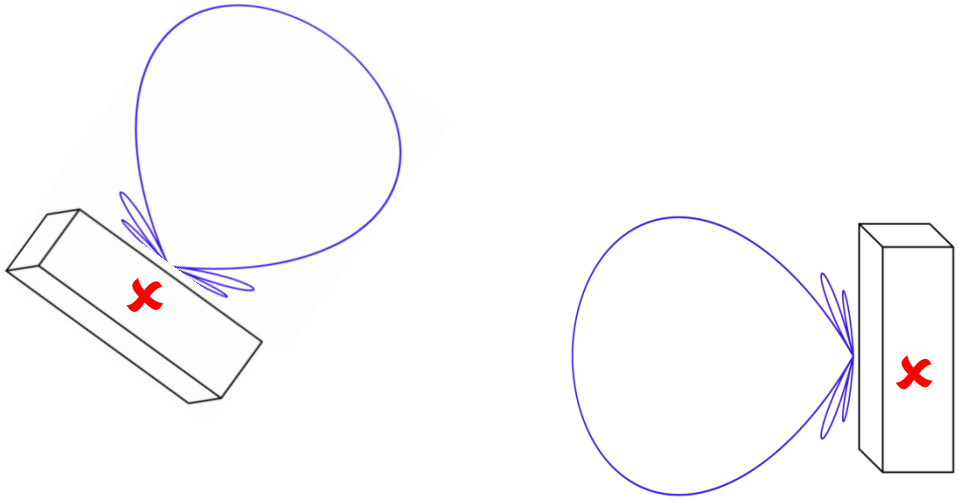
- **Objective** – A high data-rate Inter-CubeSat communication system using the Inter-Satellite service in the V-band (around 60GHz)
  - Possible data-rate higher than 500Mbps (x2000 increase compared to S-band)
  - Directive, CubeSat-friendly antenna

- **Solution** – A 0.5U module integrating:
  - An unconventional type of directive antenna operating in the V-band : the “Bull’s eye antenna”
  - An additional omnidirectional S-band PIFA antenna for manoeuvre phases

Cluster formation considerations

- Requirements for the Inter-CubeSat communication
  - High-data rate – Avoid redundancy in storage and processing units
  - Directive antenna – Avoid interferences and increase communication distance
  - Additional omnidirectional low data-rate communication link – Used during manoeuvre phases

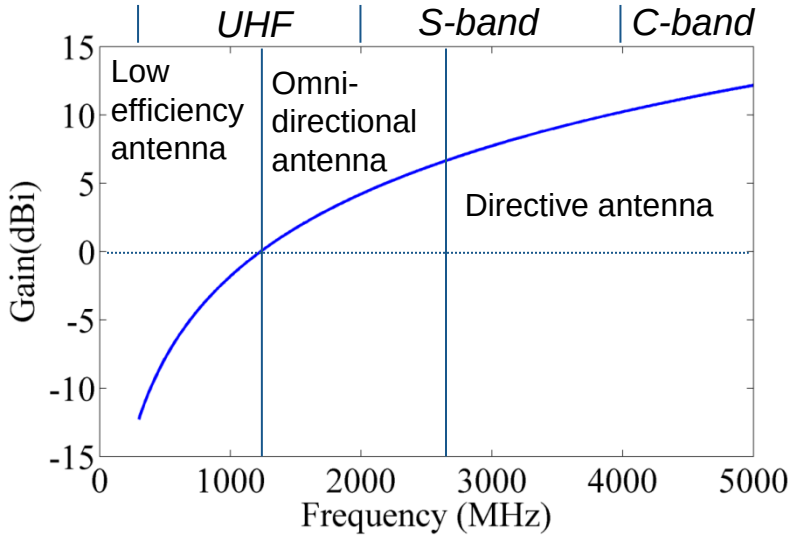
Directive antennas for normal operation



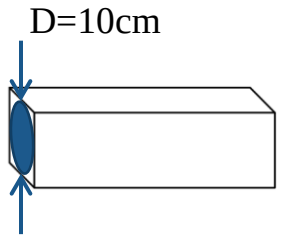
Omnidirectional antennas for manoeuvre phases

Current limitations for CubeSats antennas

- Existing designs are limited by the frequency of operation
  - Deployment systems are required (monopole/dipole)
  - Fixed, directive antennas are not possible for VHF, UHF and low S-band
  - At higher frequencies, common directive antennas are not adapted:
    - Horn antennas: efficient but bulky
    - Array of patch antennas: flat but inefficient

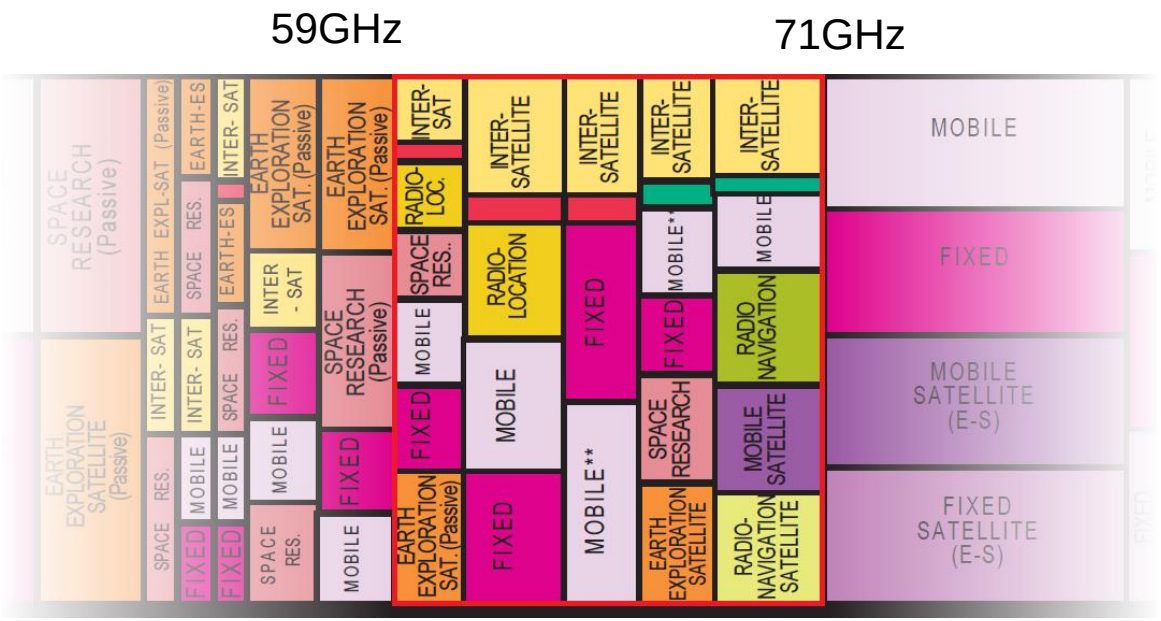


- Data-rate remains limited using conventional bands
  - 9600bps in VHF / 256kbps in S-band



V-band seems to be the best compromise (1)

- Large bandwidth available as primary user using the inter-satellite service (59-71GHz)
- Terrestrial applications target data-rates >1Gbps (x4000 faster than S-band)



V-band seems to be the best compromise (2)

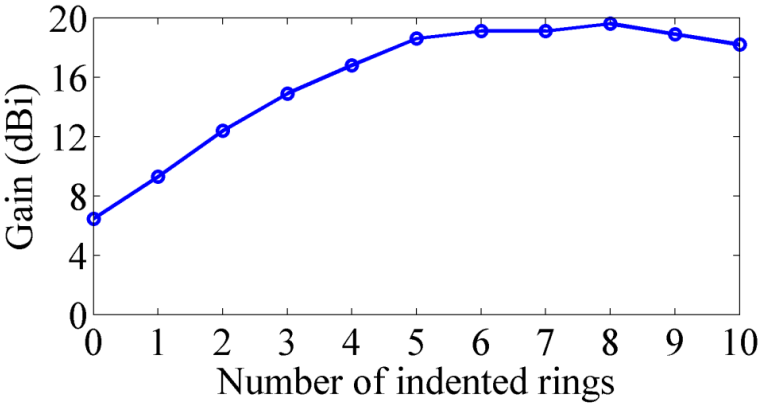
- Small wavelength (5mm): possible to manufacture antennas using simple processes

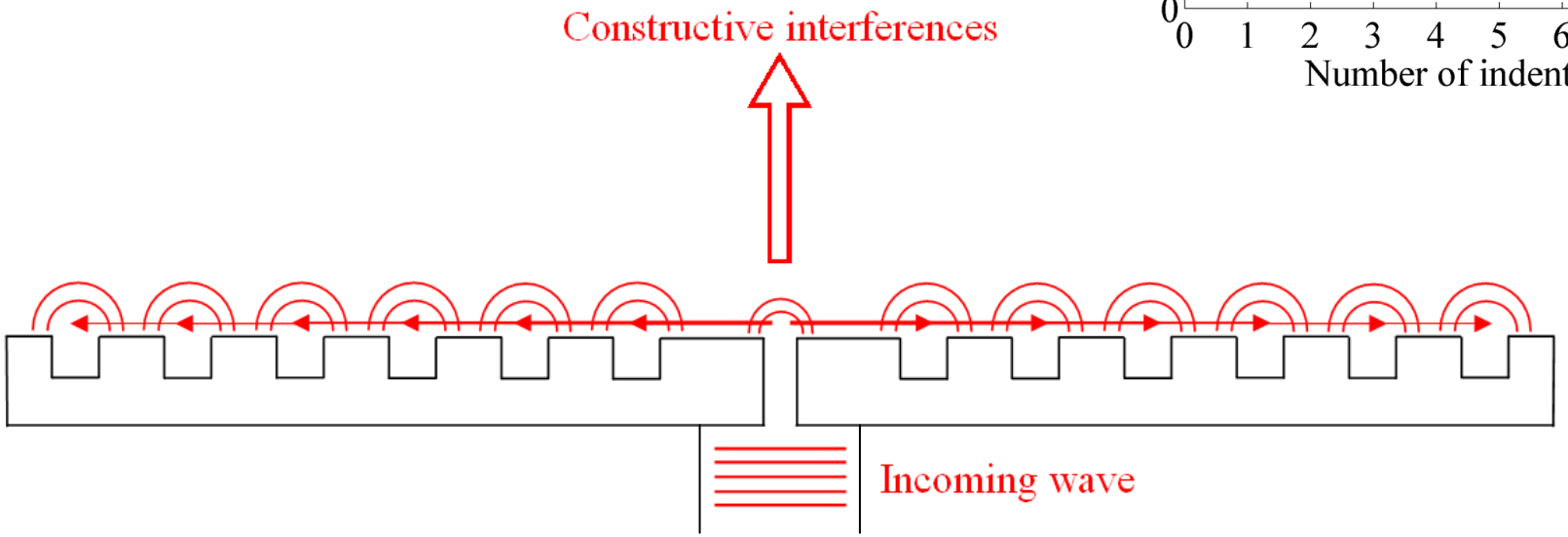
- Available off-the shelf components TX or RX modules used for WirelessHD and other terrestrial applications currently emerging (e.g. VuBiQ)

Credit: Pasternack / VuBiQ Inc.

Concept of the "Bull's eye" antenna

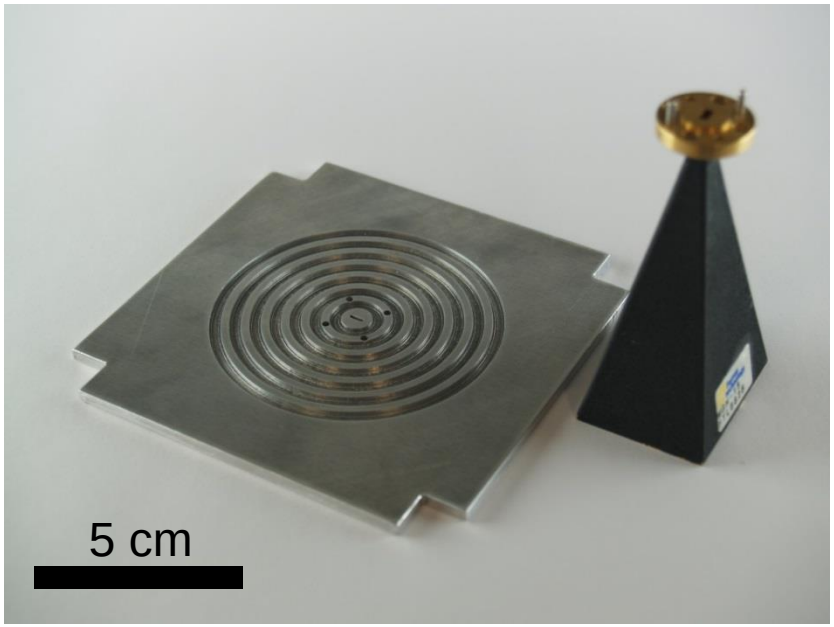
- Subwavelength aperture surrounded by a corrugated structure
- Period of the grooves ~ λ
- Spoof Surface Plasmon Polariton behaviour





"Bull's eye" antenna: first design at 60GHz

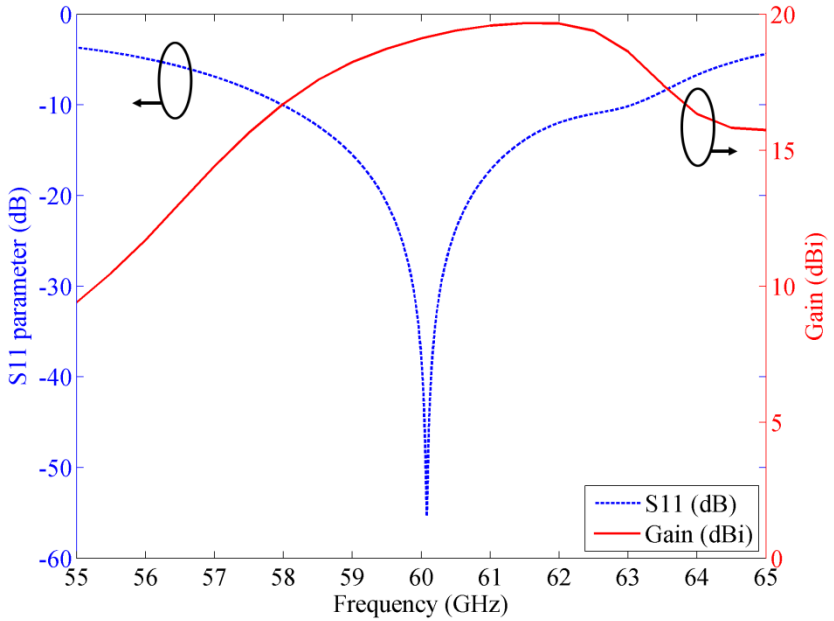
- Designed to fit on a 1U CubeSat face
- 3.2mm thick aluminium plate fabricated using a simple CNC milling machine

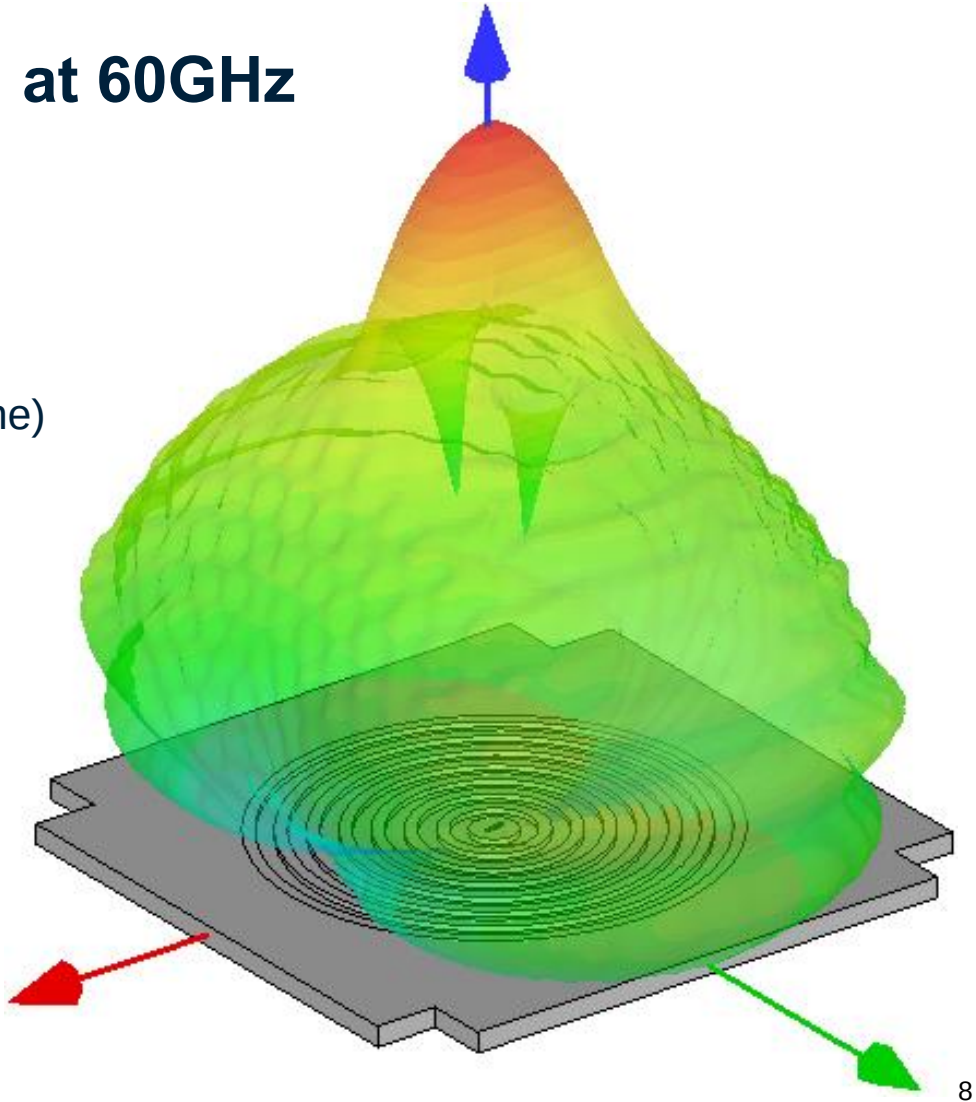


Ref: Vourch, C.J.; Drysdale, T.D., "V-Band "Bull's Eye" Antenna for CubeSat Applications," *Antennas and Wireless Propagation Letters, IEEE* , vol.13, no., pp.1092-1095, 2014

"Bull's eye" antenna: first design at 60GHz

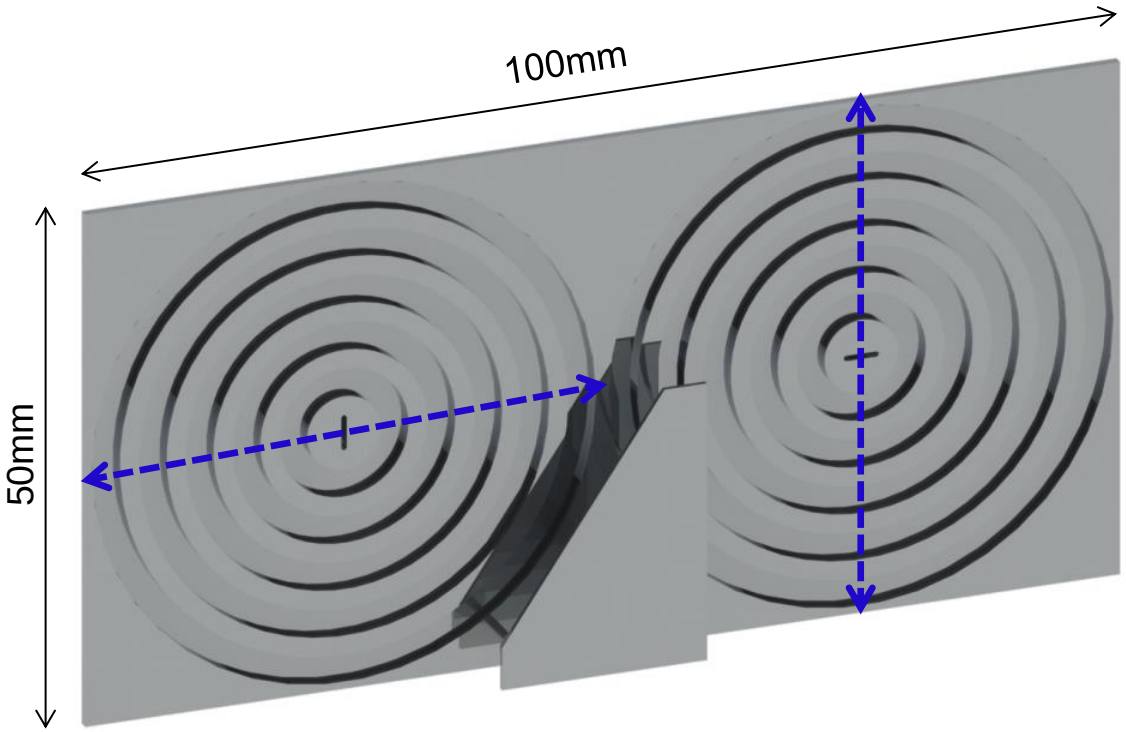
- Performance
  - Realized gain: 19.1dBi
  - BW (-10dB): 5.06GHz (8.4%)
  - Total efficiency: 97%
  - Beamwidth (-3dB): 5.9° (E-plane) / 11.9° (H-plane)





V-band "Bull's eye" and 2.4GHz PIFA module

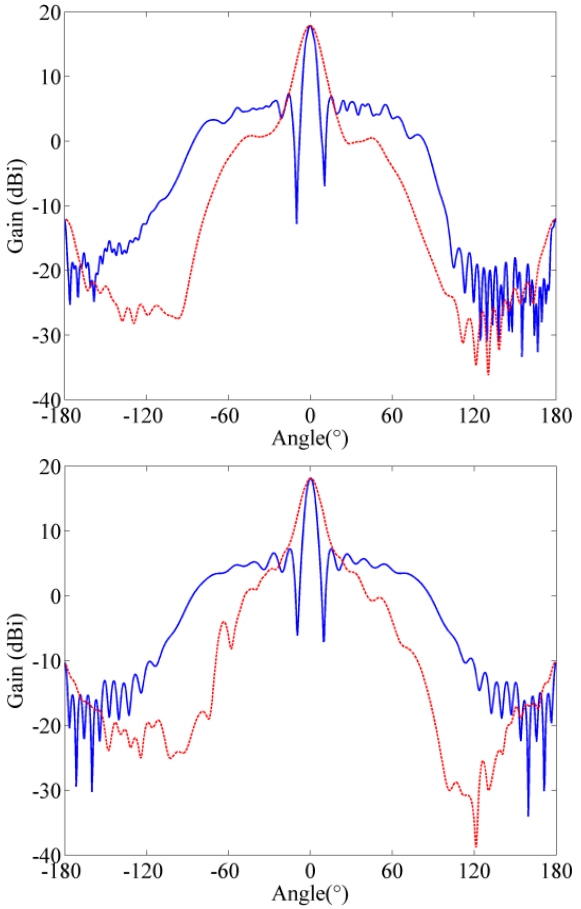
- 0.5U Double Bull's eye 60GHz with cross-polarization RX/TX channels



Polarization plane

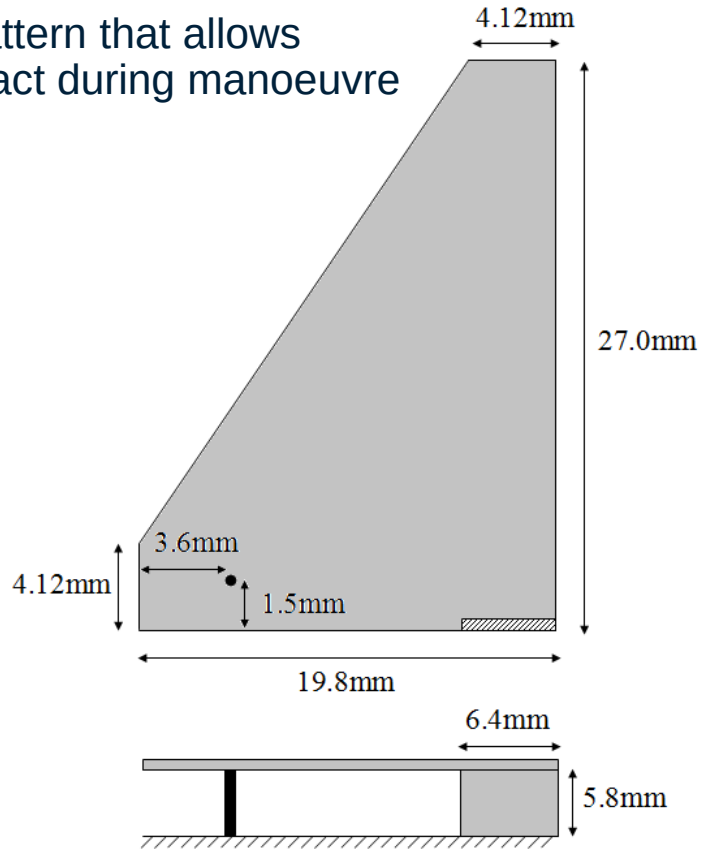
Gain = 18.0dBi

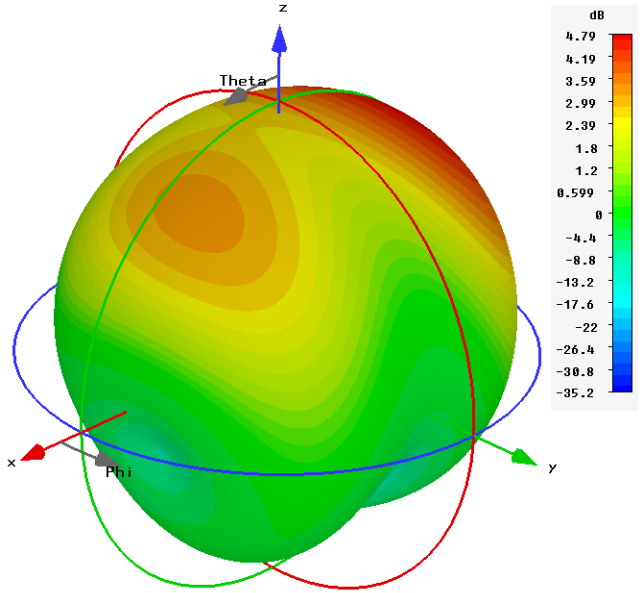
BW@-10dB = 4.5GHz

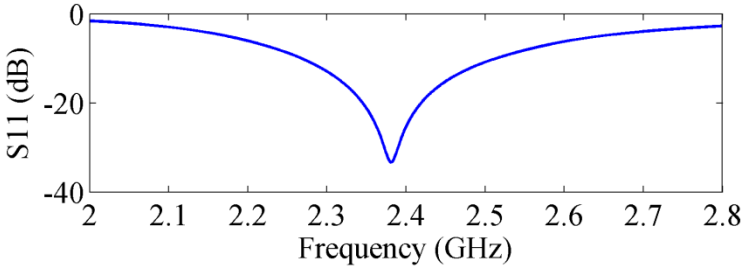


V-band "Bull's eye" and 2.4GHz PIFA module

- **2.4GHz PIFA**
  - Omnidirectional pattern that allows point-to-point contact during manoeuvre phases

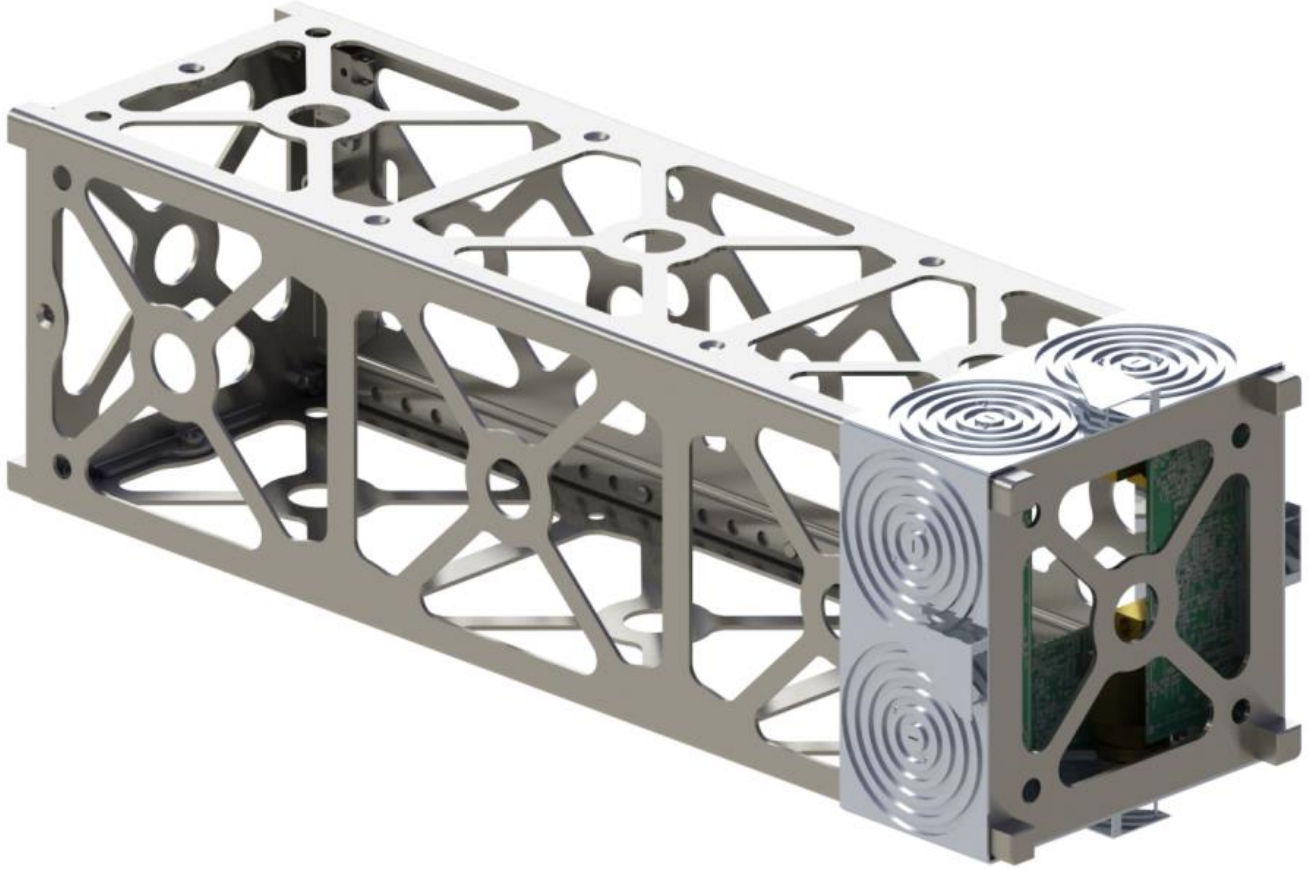






V-band Bull's eye and 2.4GHz PIFA module

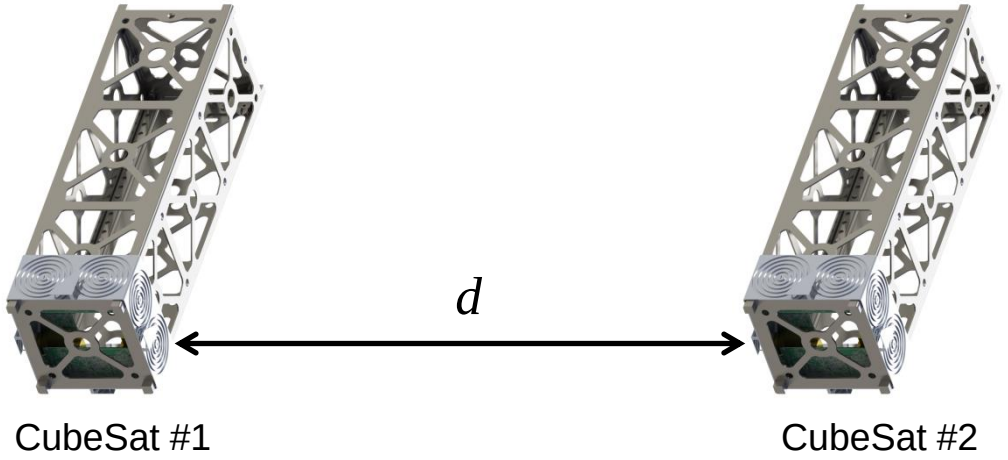
- Integration onto a 3U CubeSat

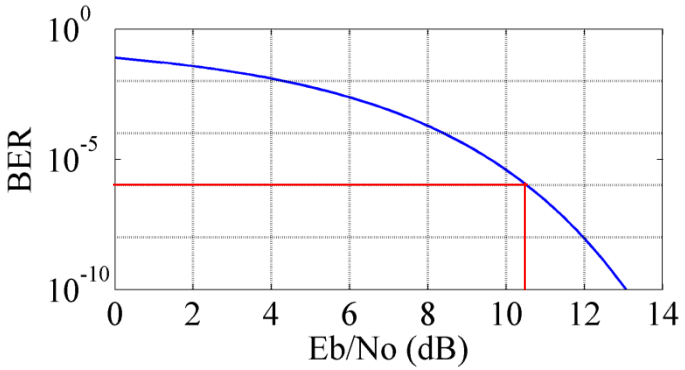


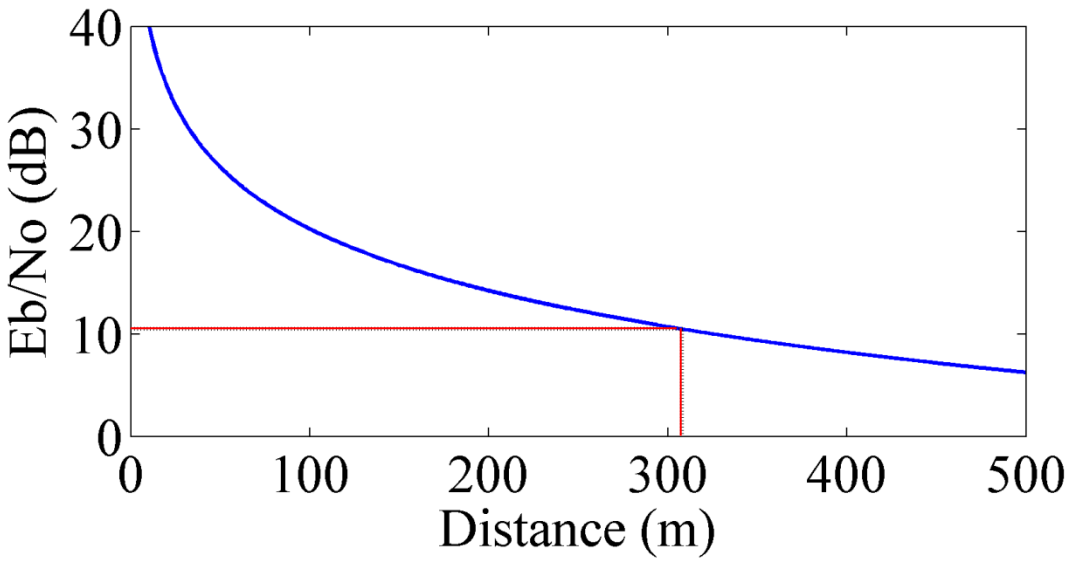
What can we expect from that?

Link budget

- **TX/RX characteristics**
  - Antennas gain=18.0dBi
  - RF power=10mW
  - NF=6dB
  - Data rate=500Mbps / BPSK







Conclusion

- Some space-based observation mission can be achieved only by using clusters of CubeSats (e.g. OLFAR).

- The V-band provides more 12GHz of bandwidth using the inter-satellite service:
  - The small wavelength (5mm) allows design of small, directive antenna
  - Inter-CubeSat links can benefit from the mass production of RX and TX modules for current terrestrial applications at those frequencies (e.g. Wireless HD)

- The “Bull’s eye” antenna offers a low profile, high directivity alternative to bulky horn antennas or lossy dielectric-based array of patch antennas.

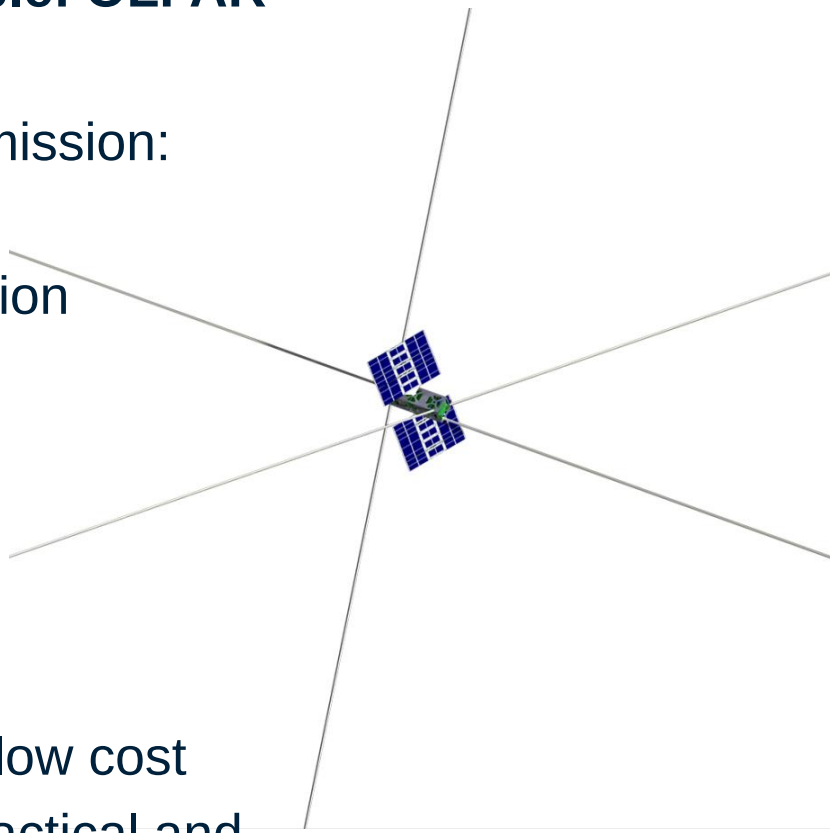
Thank you for your attention.

Questions…?

Interplanetary CubeSat cluster mission example: OLFAR

Orbital Low Frequency Array

- 0.3-30MHz CubeSat-based radio-observation mission:
  - Wavelength of ~10-1000meters: apertures of several kilometres required for high resolution
    → **Distributed aperture needed**
  - Ionospheric scintillation (<30MHz) and ionospheric opaqueness (<15MHz)
    → **Space-based instrument needed**



- CubeSats can offer a solution because of their low cost and capabilities: A cluster formation is the only practical and affordable solution.

Credit: OLFA, Delfi Space