Variable Dielectric Delay Lines in Liquid Crystals for Phased Array Feeds

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Outline

PHAROS

- General description
- Vivaldi array, beam former
- Noise temperature test setup and results

Liquid crystal delay line

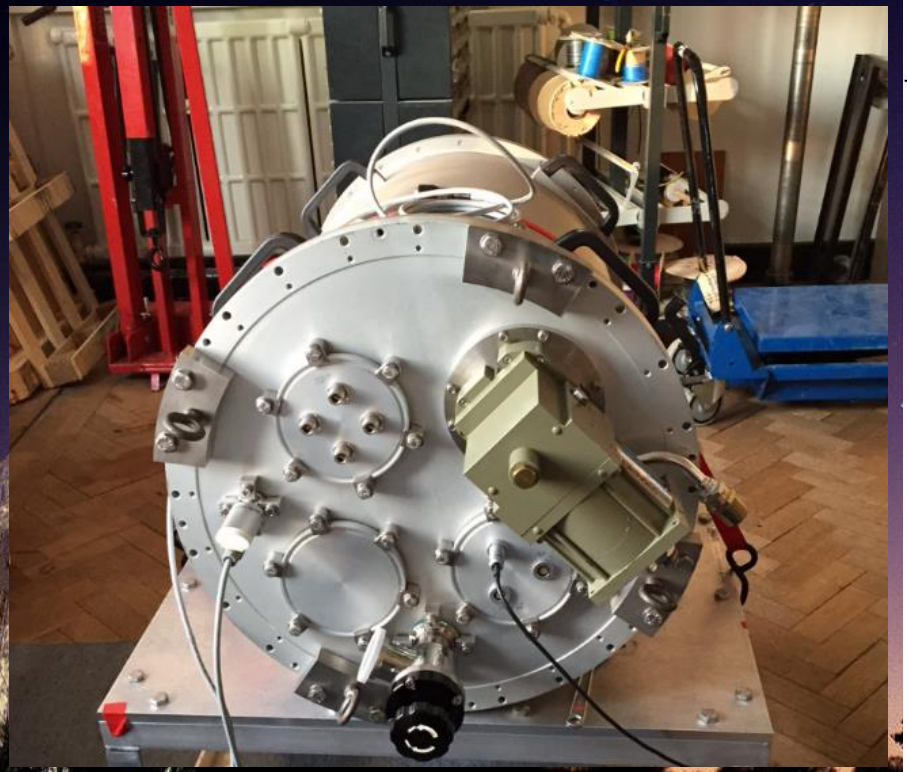
- General description
- First generation
- Second generation
- Third generation

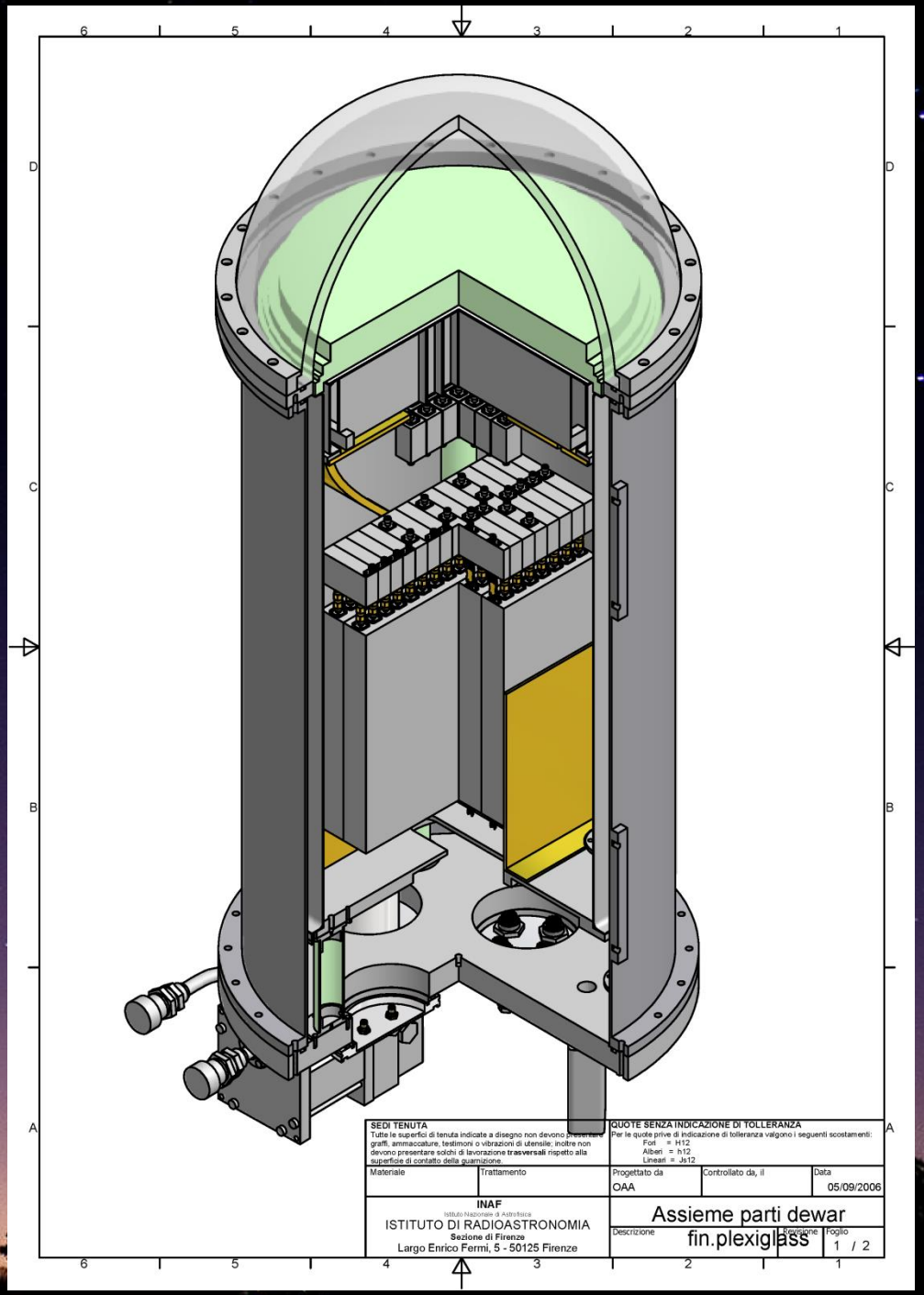
Conclude and future plan

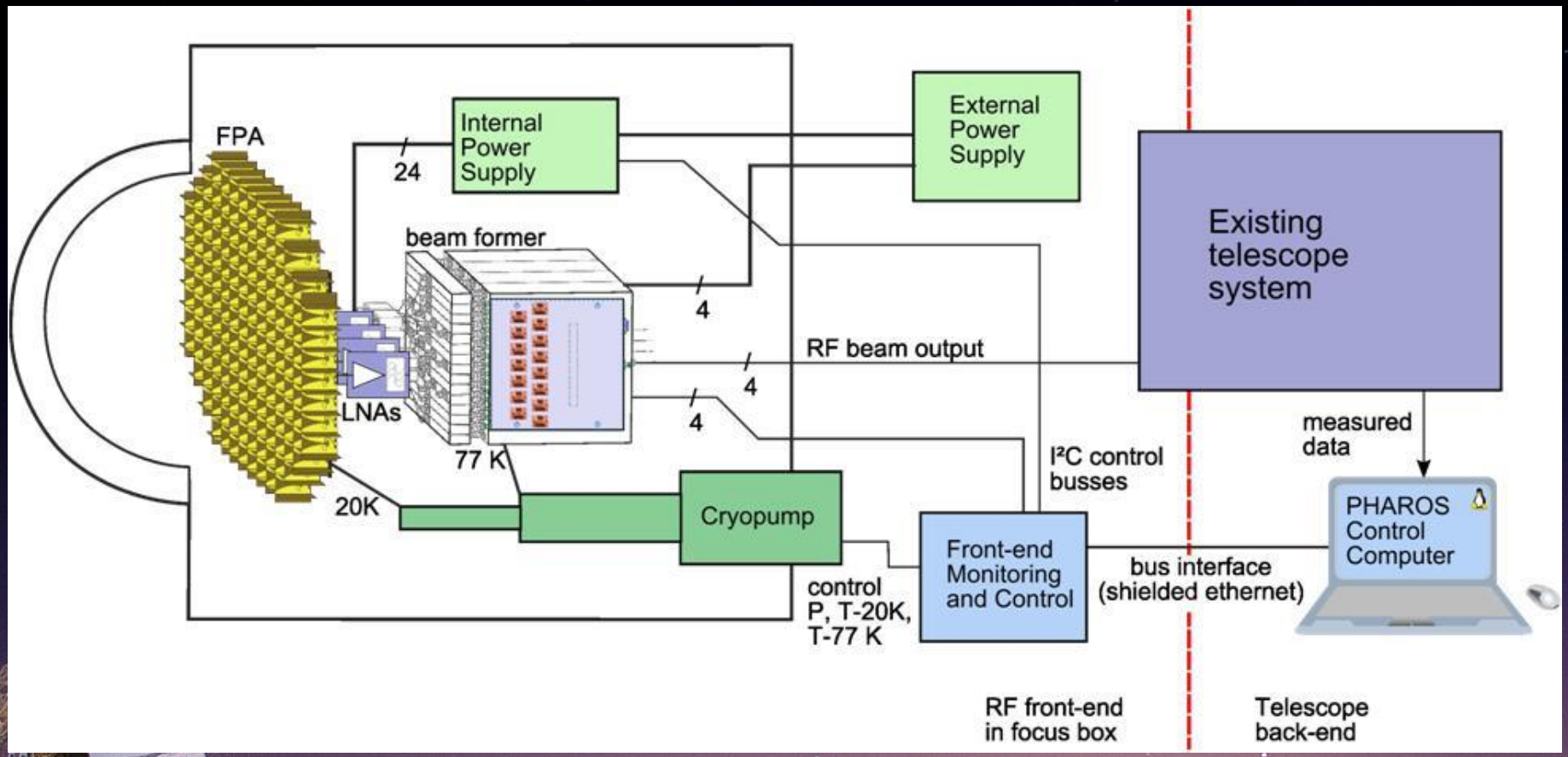
PHased Arrays for Reflector Observing Systems (PHAROS)

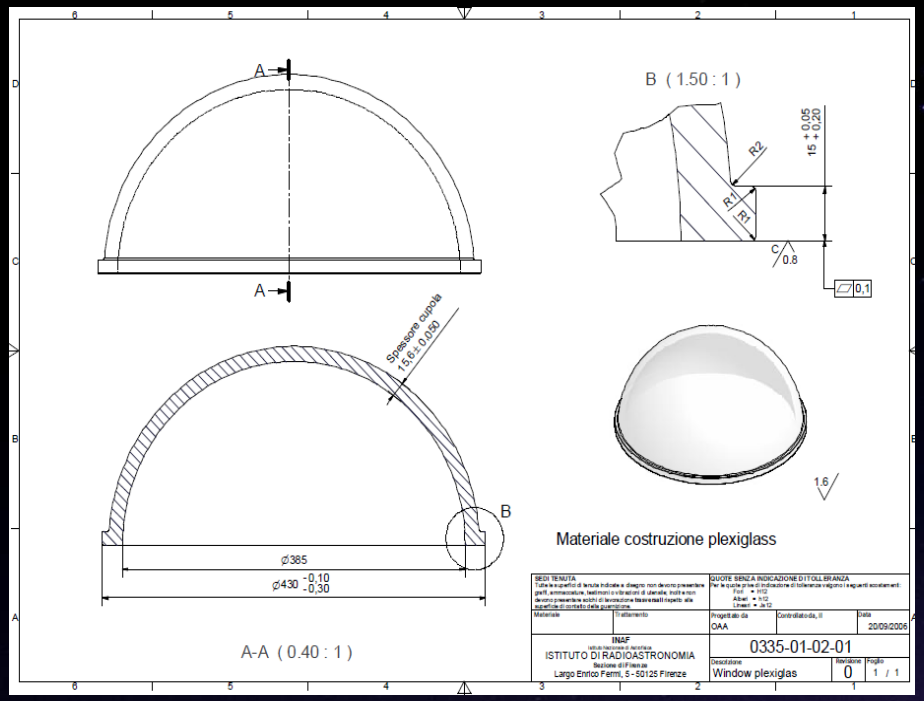
- The key objective of PHAROS is to continue, and bring to fruition, some of the strategic research, begun in the FP5 RTD programme FARADAY (HPRI-CT-2001-50031)
- The partners in PHAROS are Jodrell Bank Observatory (JBO), University of Birmingham, Istituto di Radioastronomia (INAF), Microw ave Engineering Centre for Space Applications (MECSA), Nicolaus Copernicus University (TCfA, Commenwealth Science and Industrial Research Organization (CSIRO) and Netherlands Foundation for Research in Astronomy (ASTRON

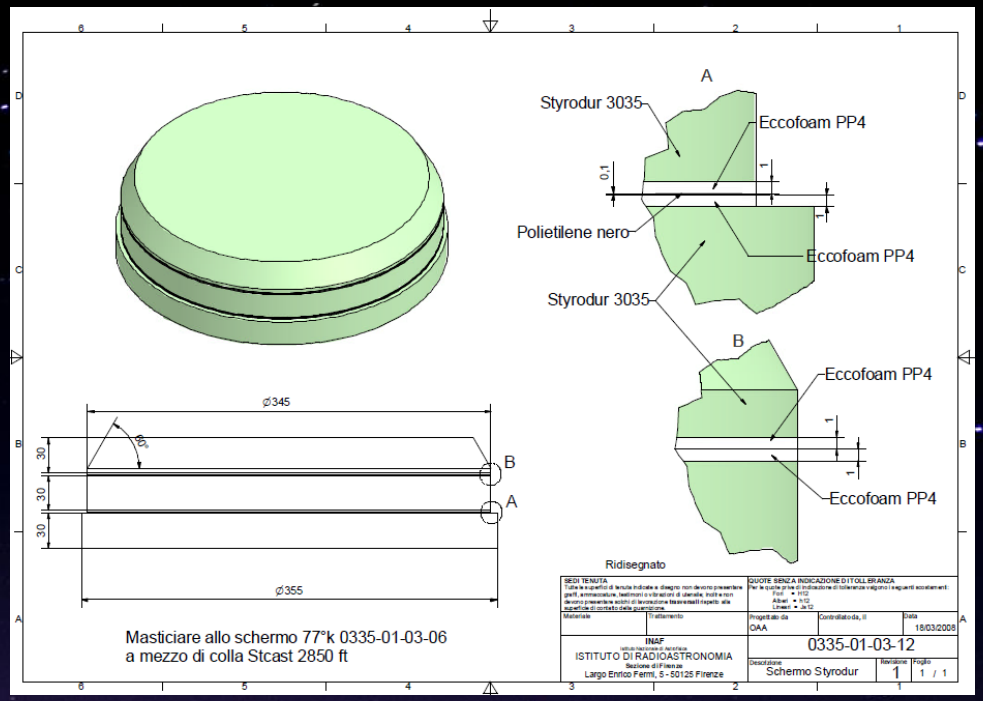
What PHAROS looks like

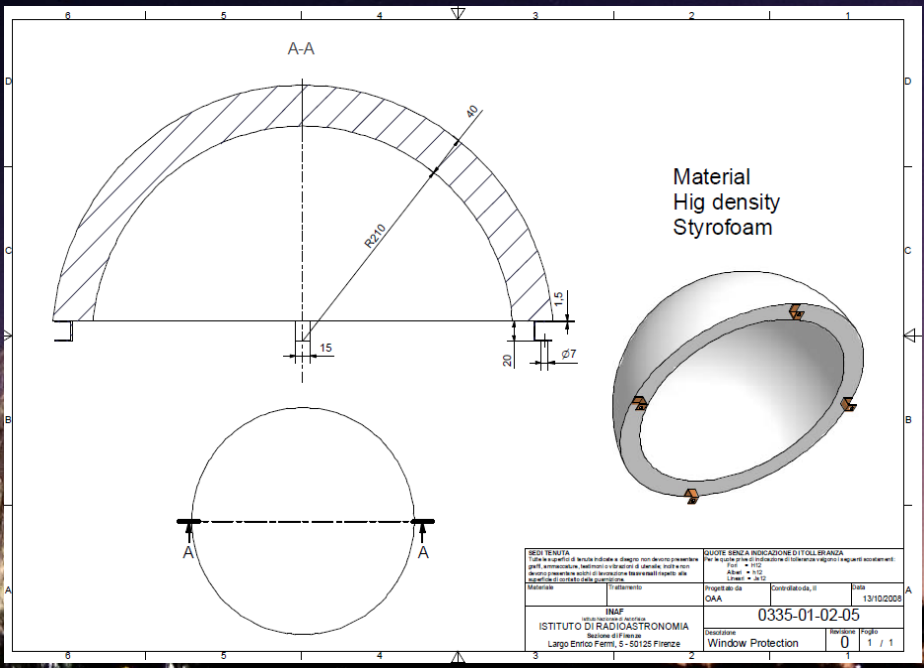




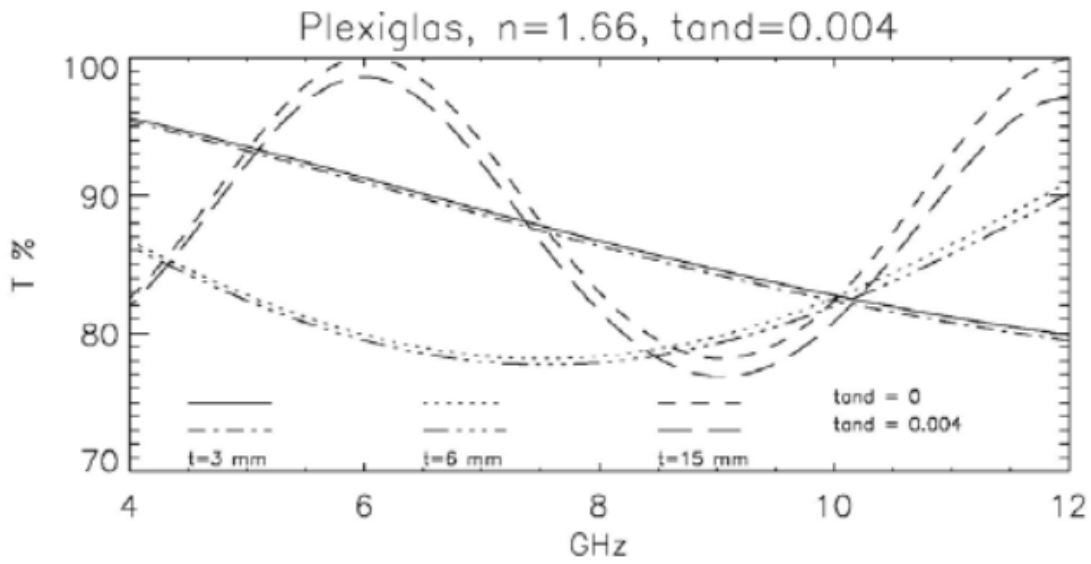

FPA
24
Internal Power Supply
External Power Supply
Existing telescope system
beam former
4
RF beam output
4
4
LNAs
77 K
20K
Cryopump
I²C control busses
measured data
PHAROS Control Computer
Front-end Monitoring and Control
bus interface (shielded ethernet)
control P, T-20K, T-77 K
RF front-end in focus box
Telescope back-end

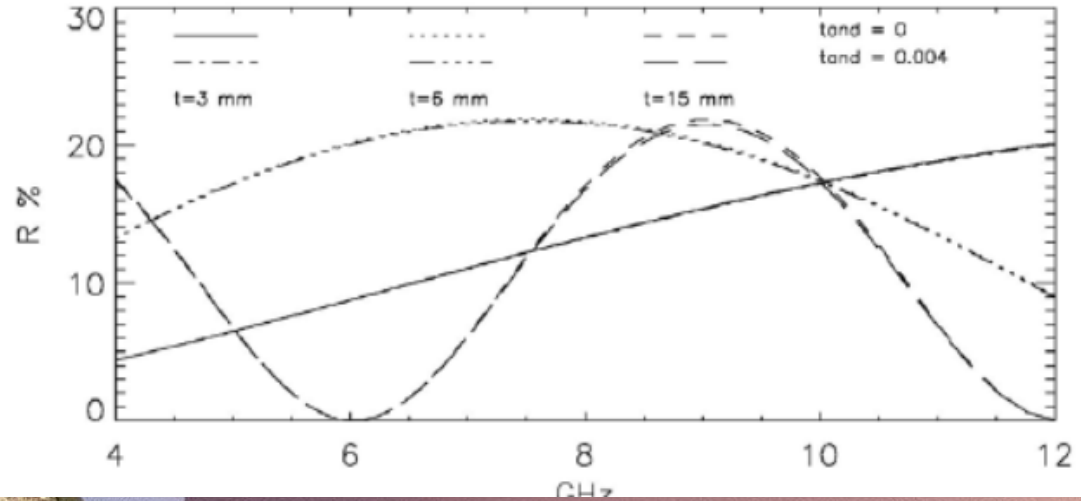






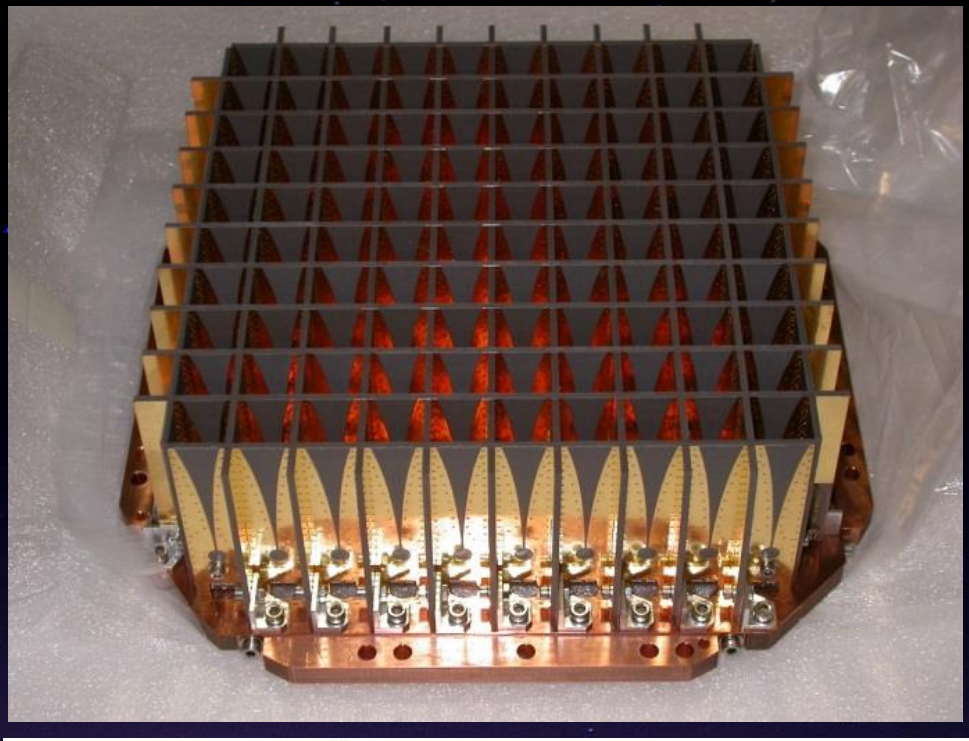
Material	e_r	tand x 10^{-4}
Styrodur 3035CS (BASF) (Green IR filter)	1.04	0.3
Plexiglass (Vacuum window)	2.54	45.3
Styrofoam (Vacuum window protection)	1.03	1.5
Nylon 6 (Window ring lockout)	3.1-8.3	6-1900
Black Polyethylene (one layer 0.1mm)	2.7	10
Eccostock PP4 (Total of 5 layer of 1.7mm)	1.06	1
HDPE (about 0.06mm thickness covering the styrofoam)	2.3	1

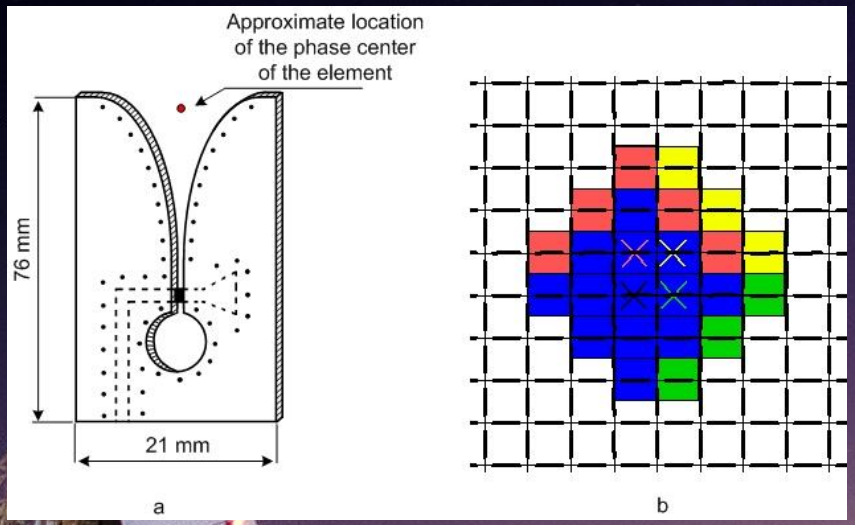




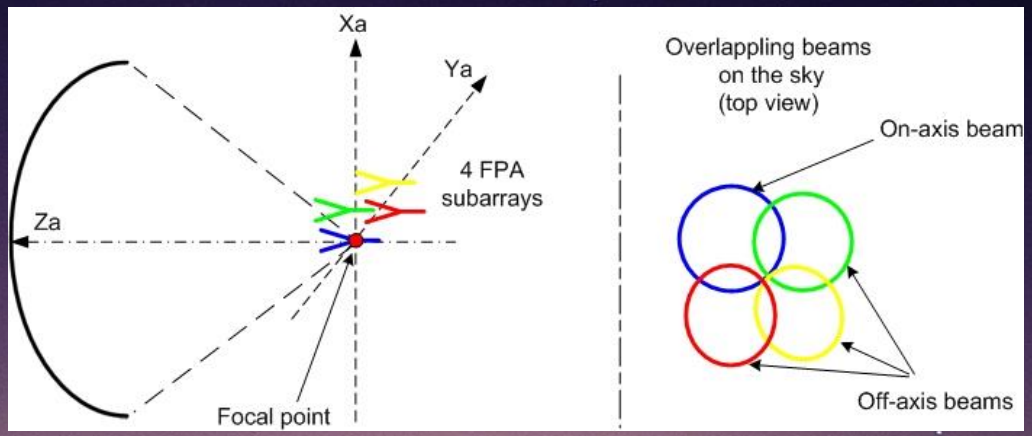
- Transmission and reflection losses
- High epsilon more significant then Tand

Vivaldi array





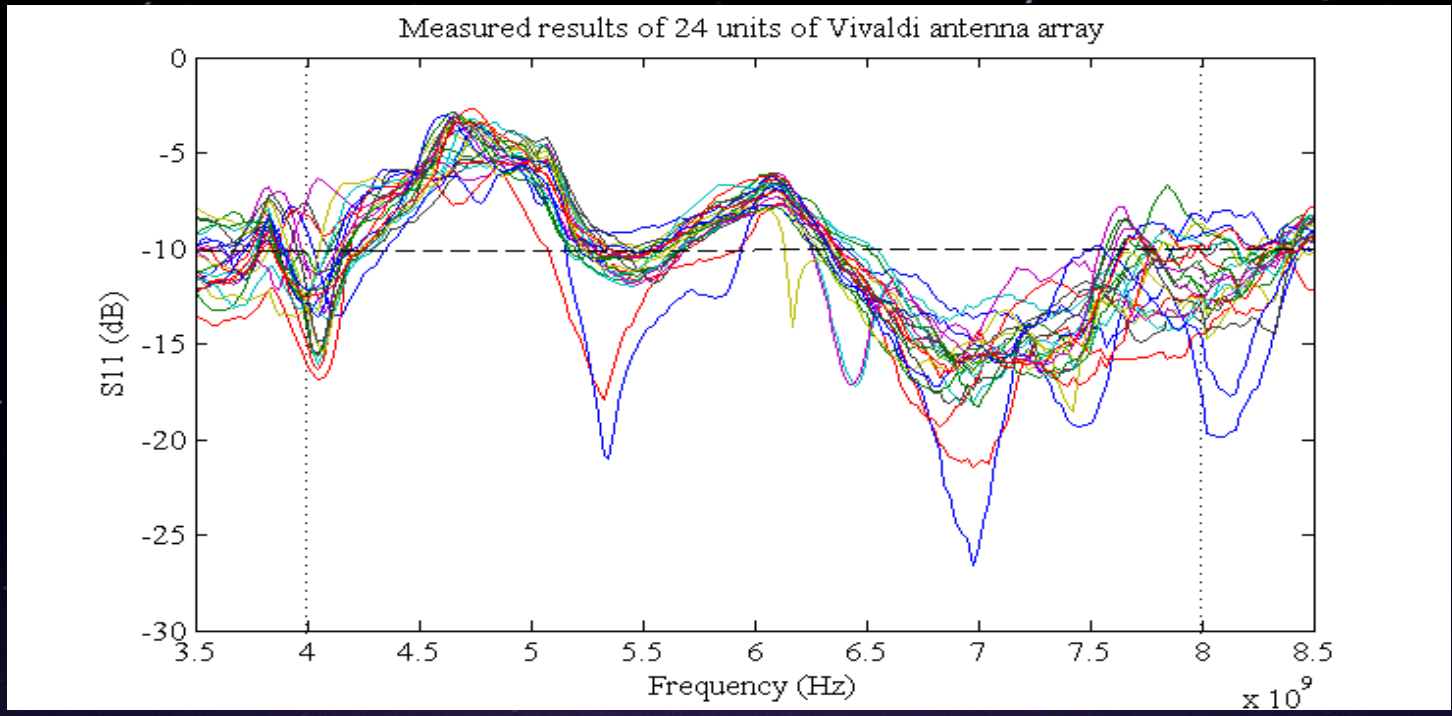
The geometry of the FPA element (a) and schematic of the FPA subarrays (b).



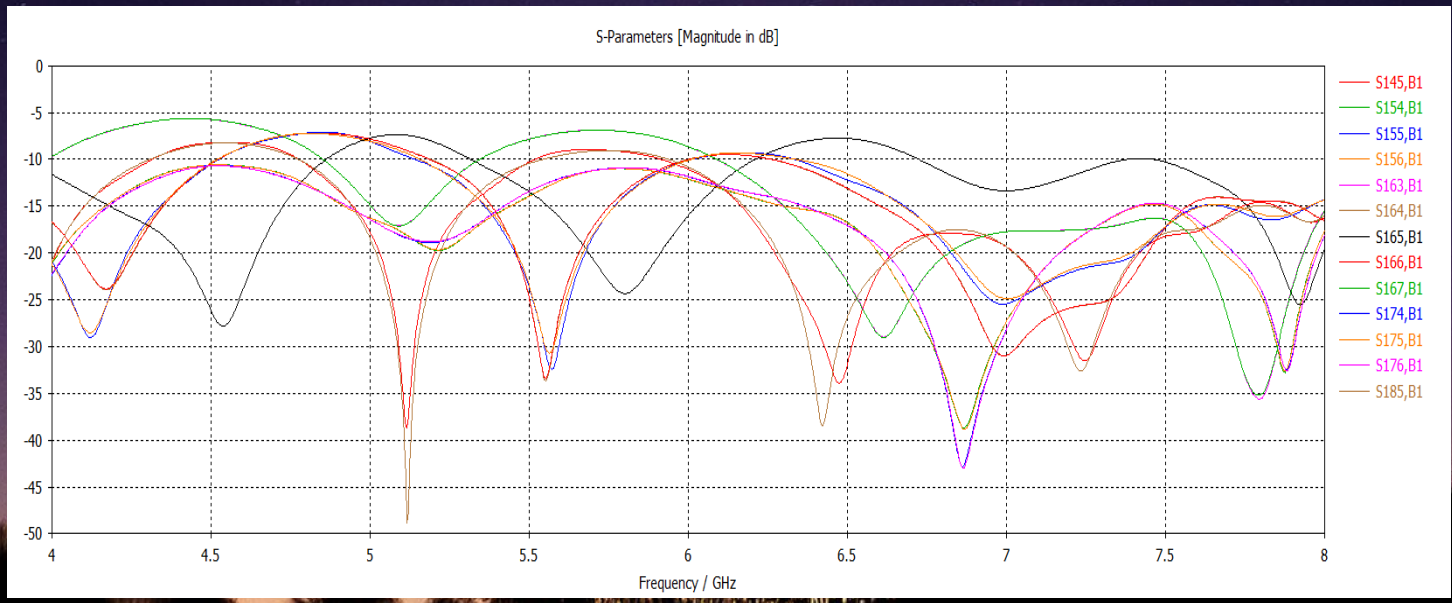
Positions of FPA subarrays in the focal region of reflector and corresponding beams on the sky

S parameter

Isolated ports excite test by VNA

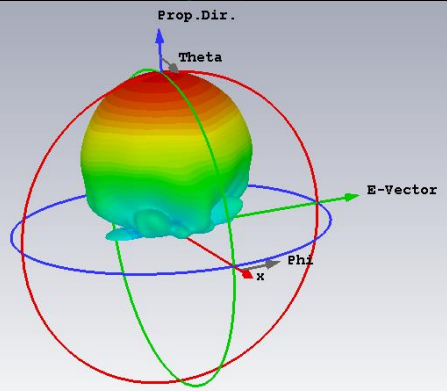


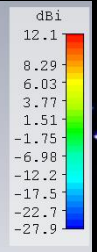
Active ports excite simulation by CST



Farfield pattern 3D plot

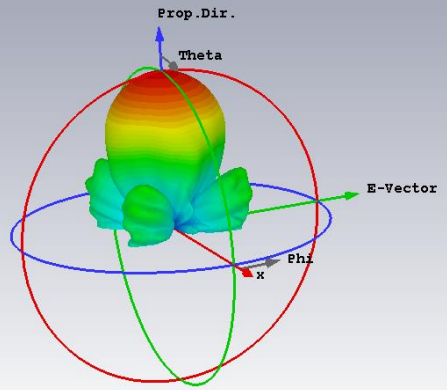
4G

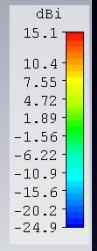




Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=4) [B1]
Component	Abs
Output	Directivity
Frequency	4
Rad. effic.	-0.08122 dB
Tot. effic.	-0.9236 dB
Dir.	12.06 dBi

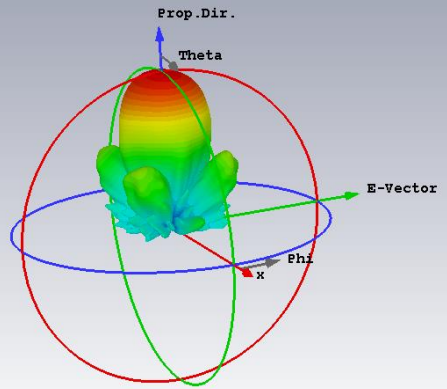
6G

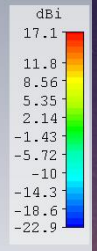




Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=6) [B1]
Component	Abs
Output	Directivity
Frequency	6
Rad. effic.	-0.1053 dB
Tot. effic.	-0.8529 dB
Dir.	15.11 dBi

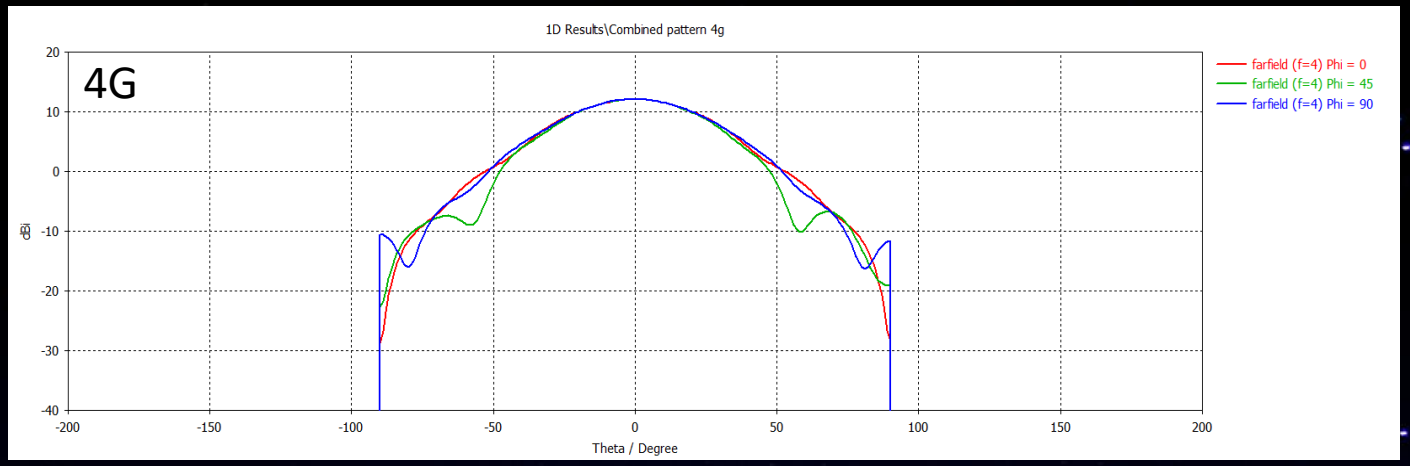
8G

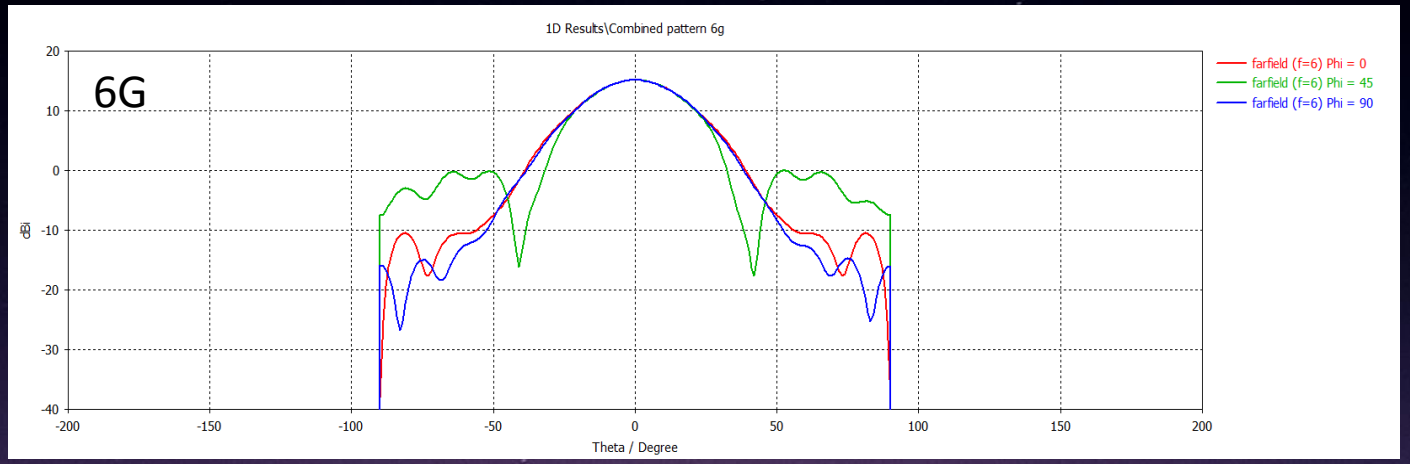


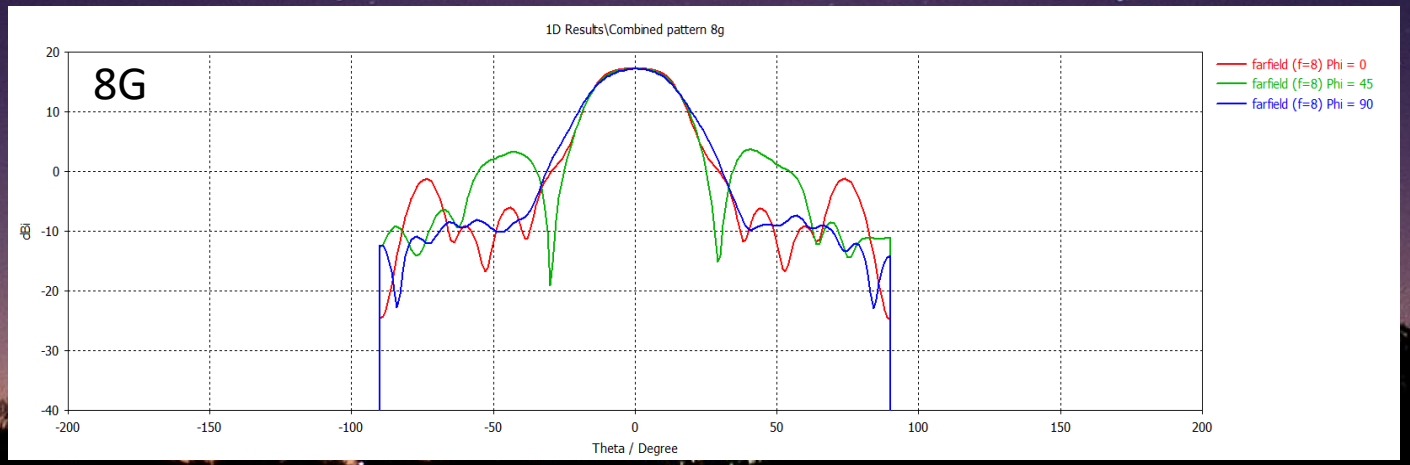


Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=8) [B1]
Component	Abs
Output	Directivity
Frequency	8
Rad. effic.	-0.1575 dB
Tot. effic.	-0.5196 dB
Dir.	17.13 dBi

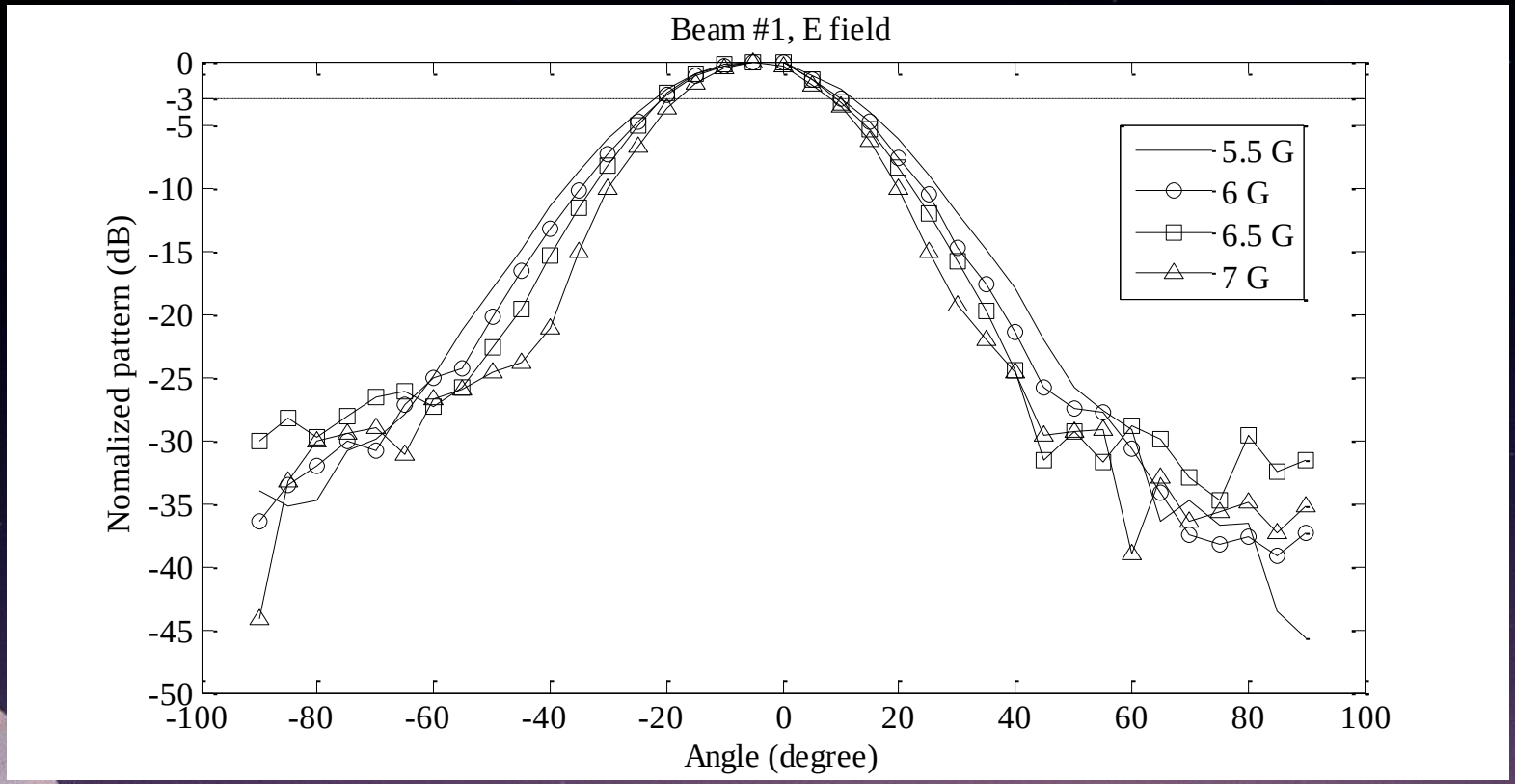
Farfield pattern 2D cut plot
(Phi = 0, 45, 90 degree)



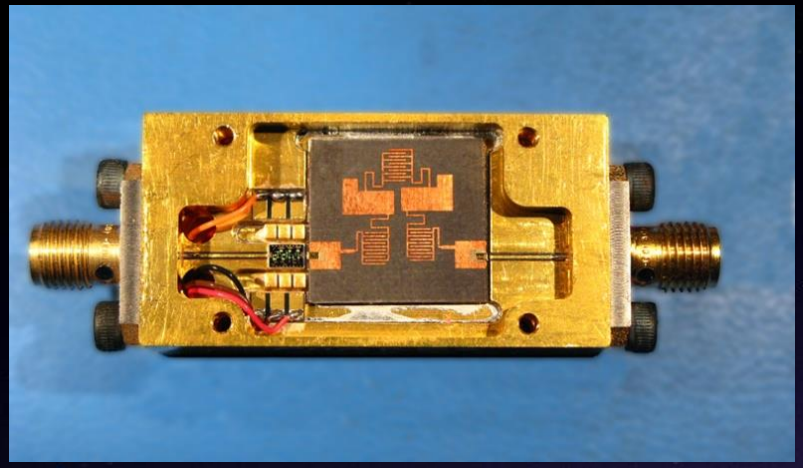


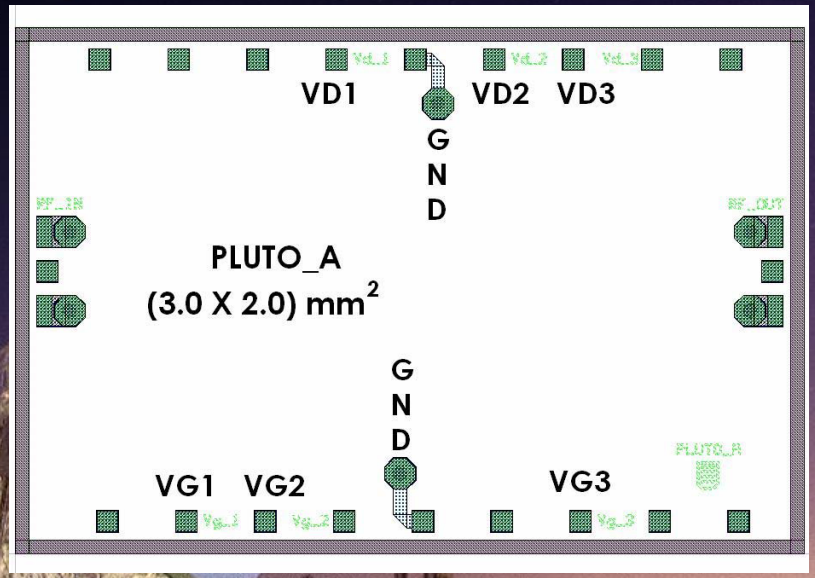


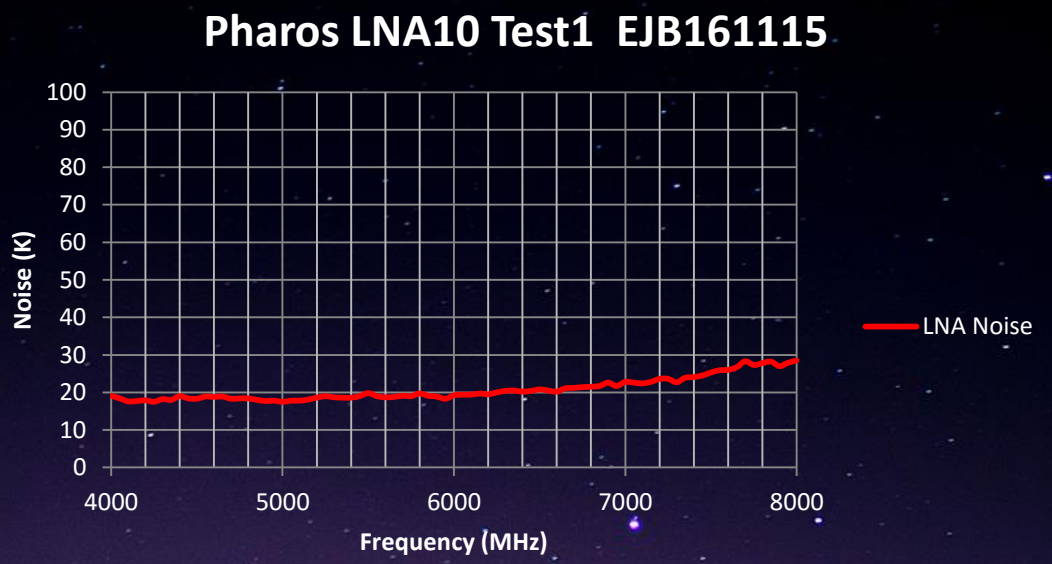
Farfield pattern test at anechoic chamber

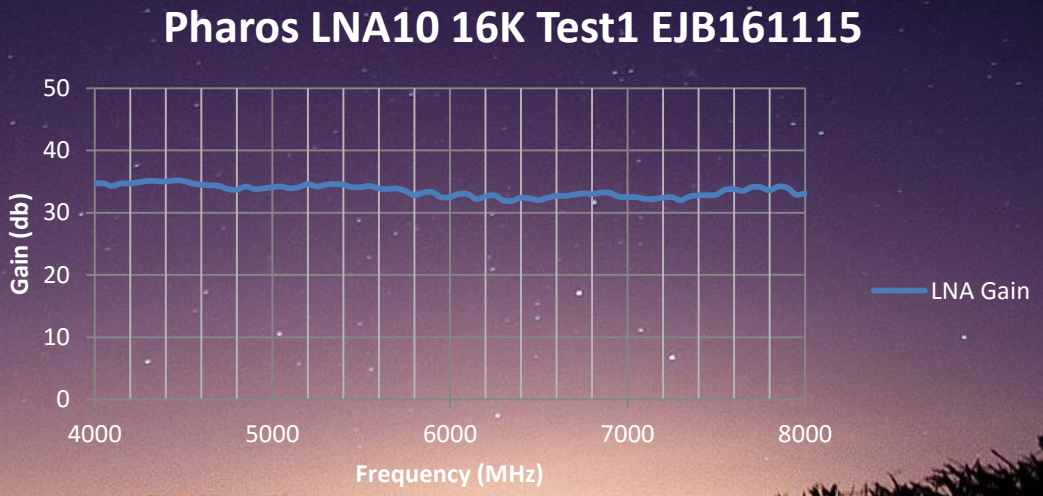


LNA

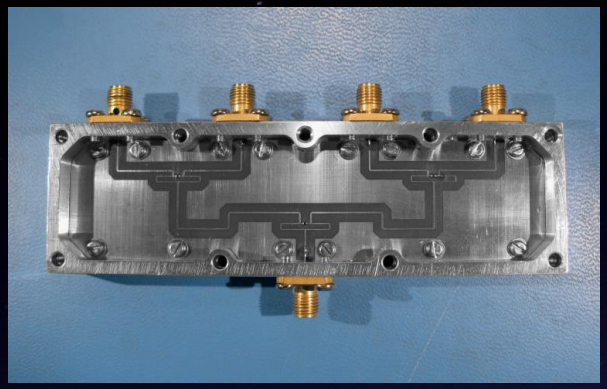


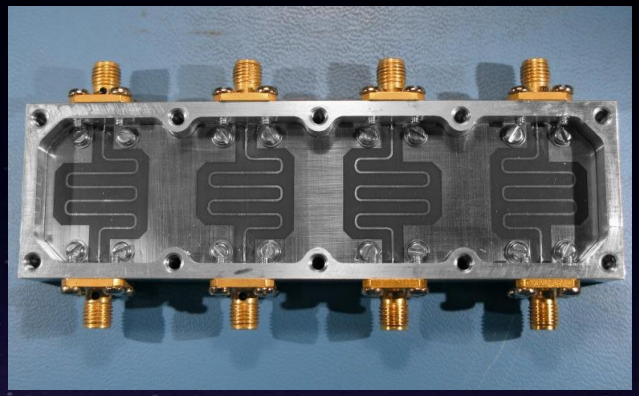

VD1
VD2
VD3
G
N
D
PLUTO_A
(3.0 X 2.0) mm2
G
N
D
VG1
VG2
VG3

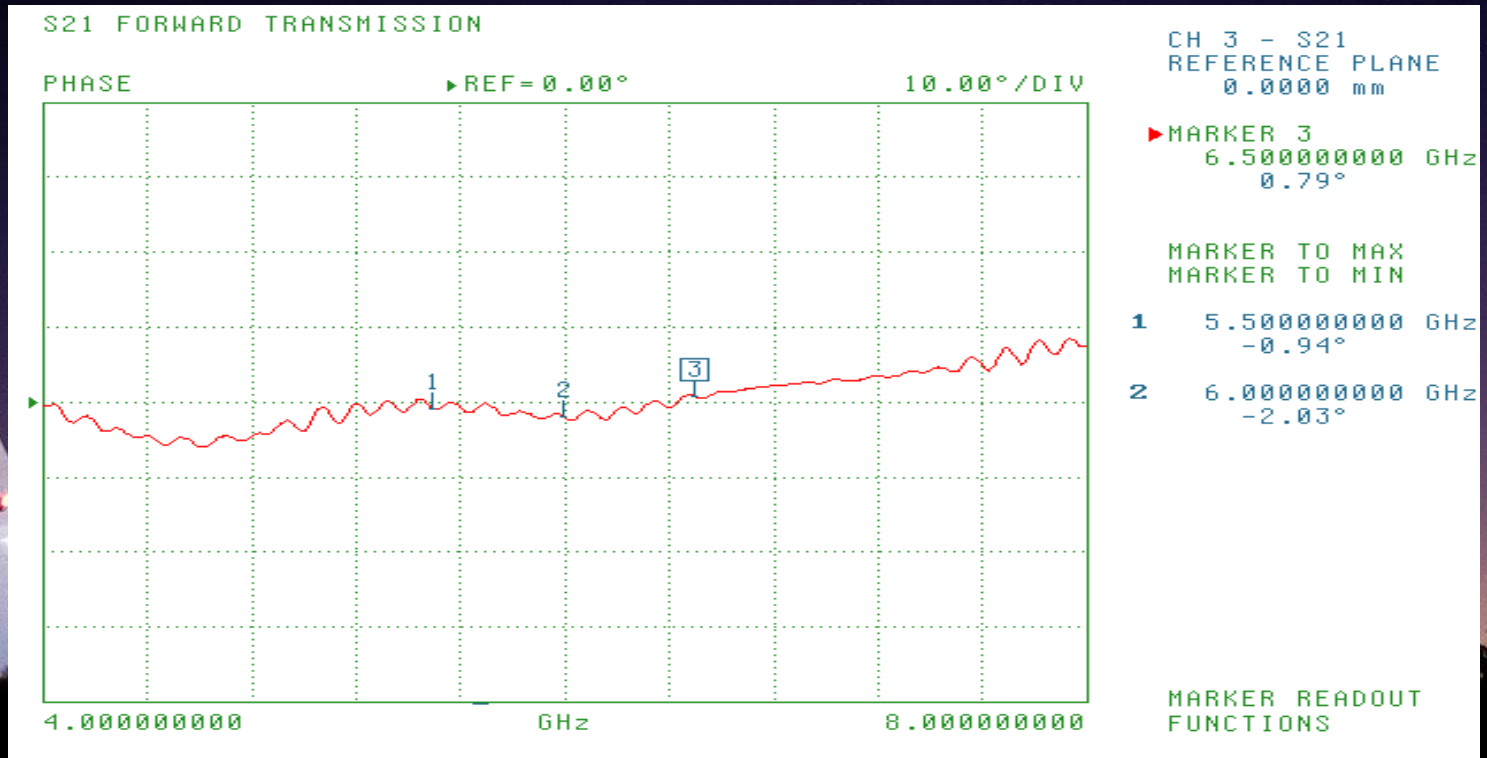

Pharos LNA10 Test1 EJB161115
Noise (K)
100
90
80
70
60
50
40
30
20
10
0
4000
5000
6000
7000
8000
Frequency (MHz)
LNA Noise


Pharos LNA10 16K Test1 EJB161115
Gain (db)
50
40
30
20
10
0
4000
5000
6000
7000
8000
Frequency (MHz)
LNA Gain

Splitter and Delay Line Module

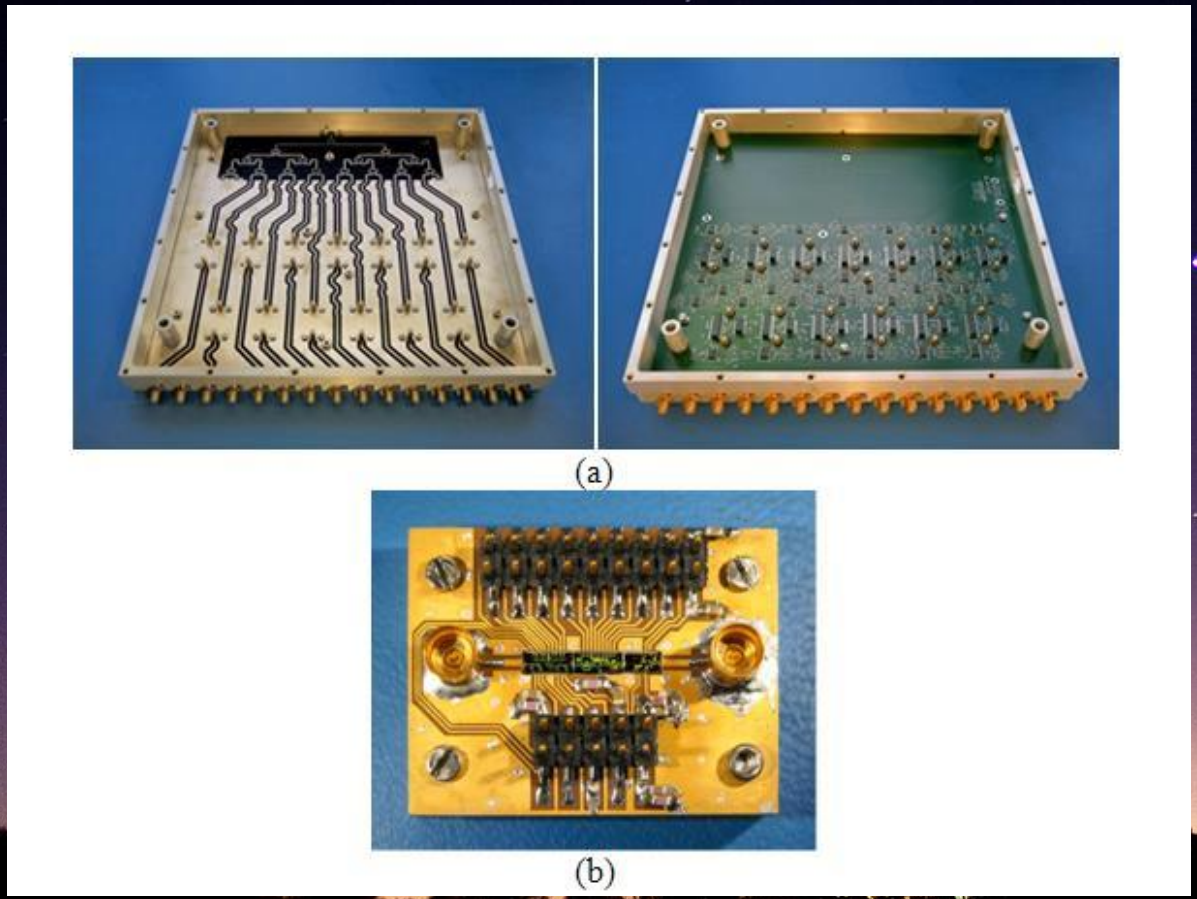




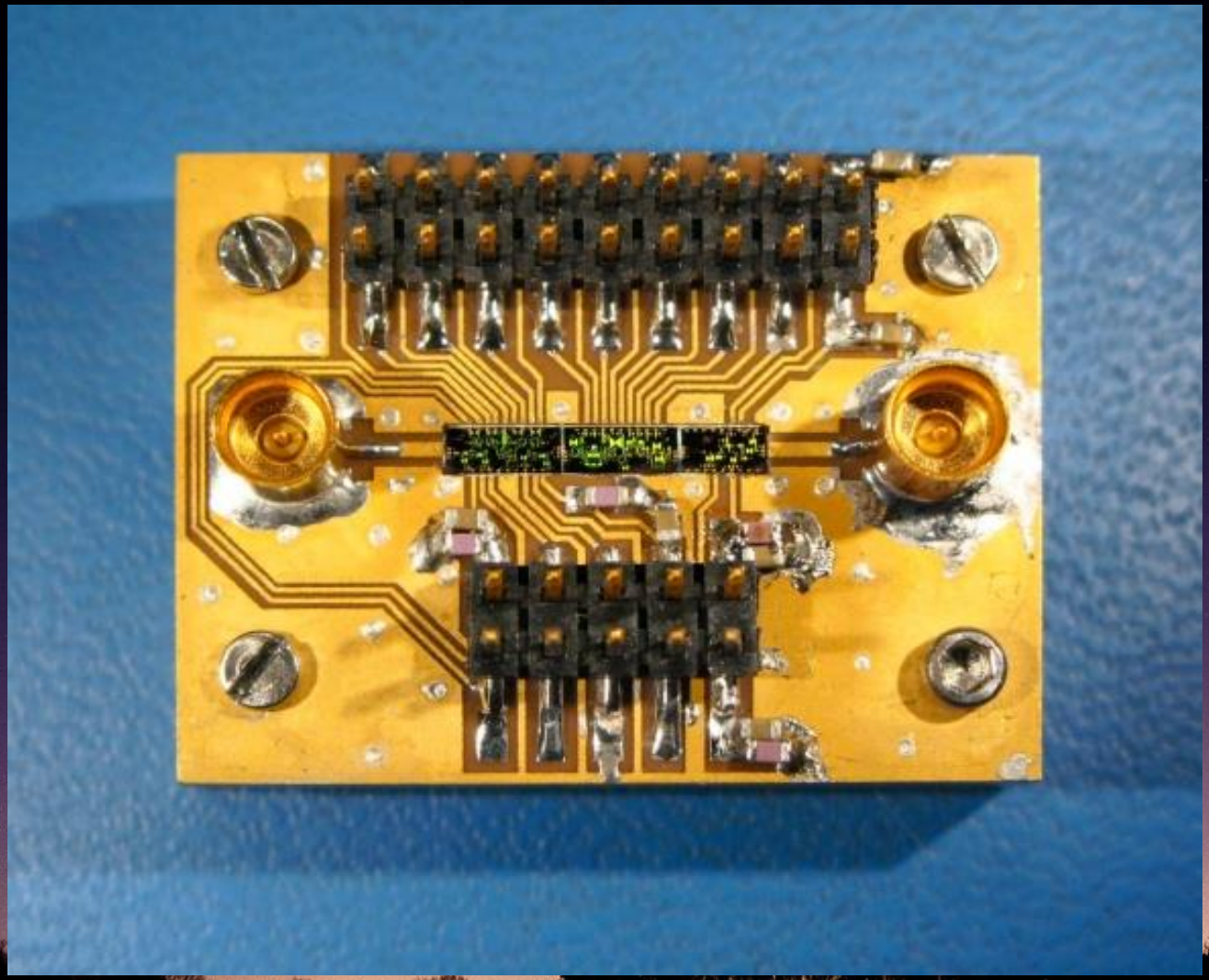


Beam former module

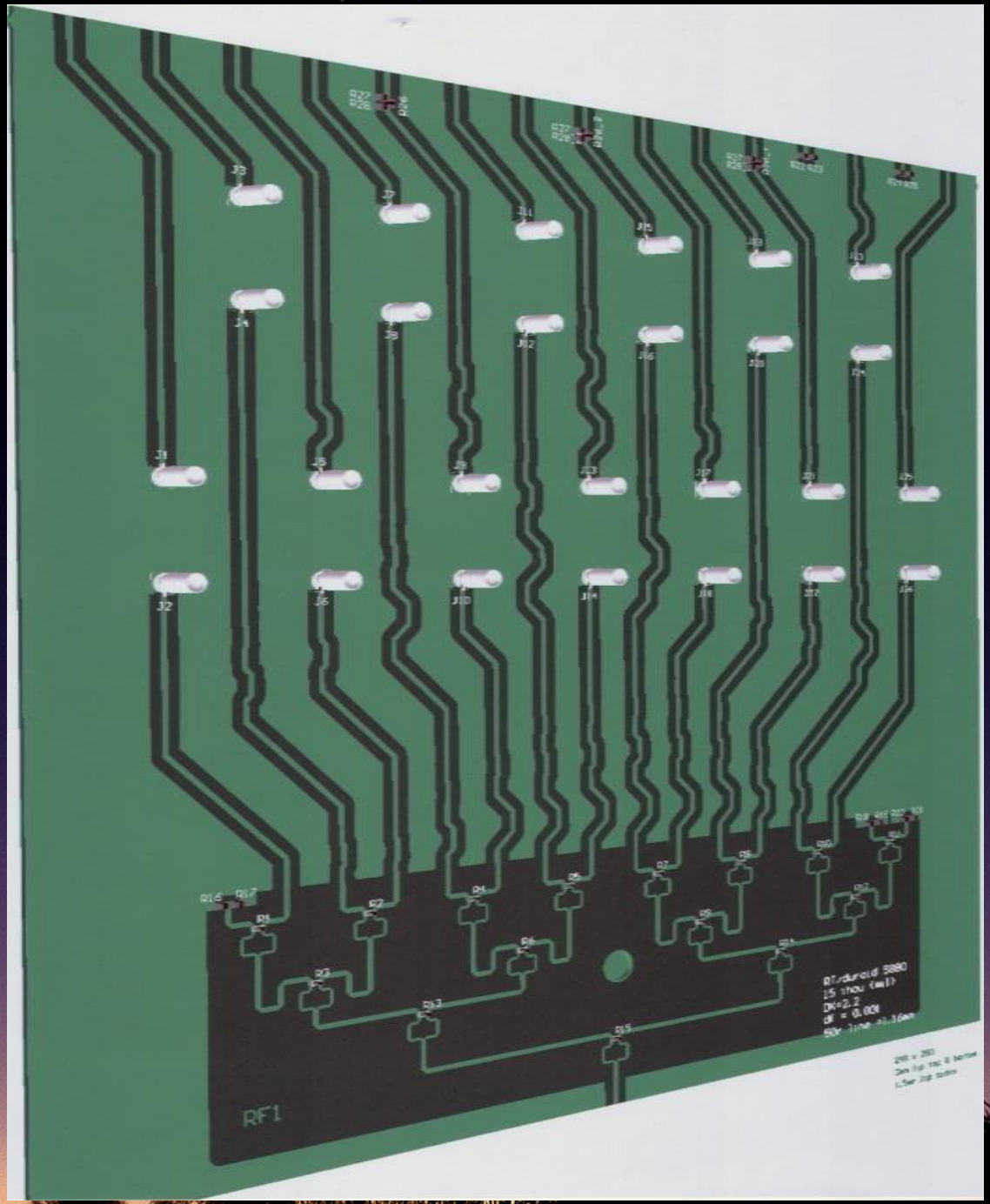
1. RF board
2. Digital control board
3. Phase and amplitude control module (PAC)



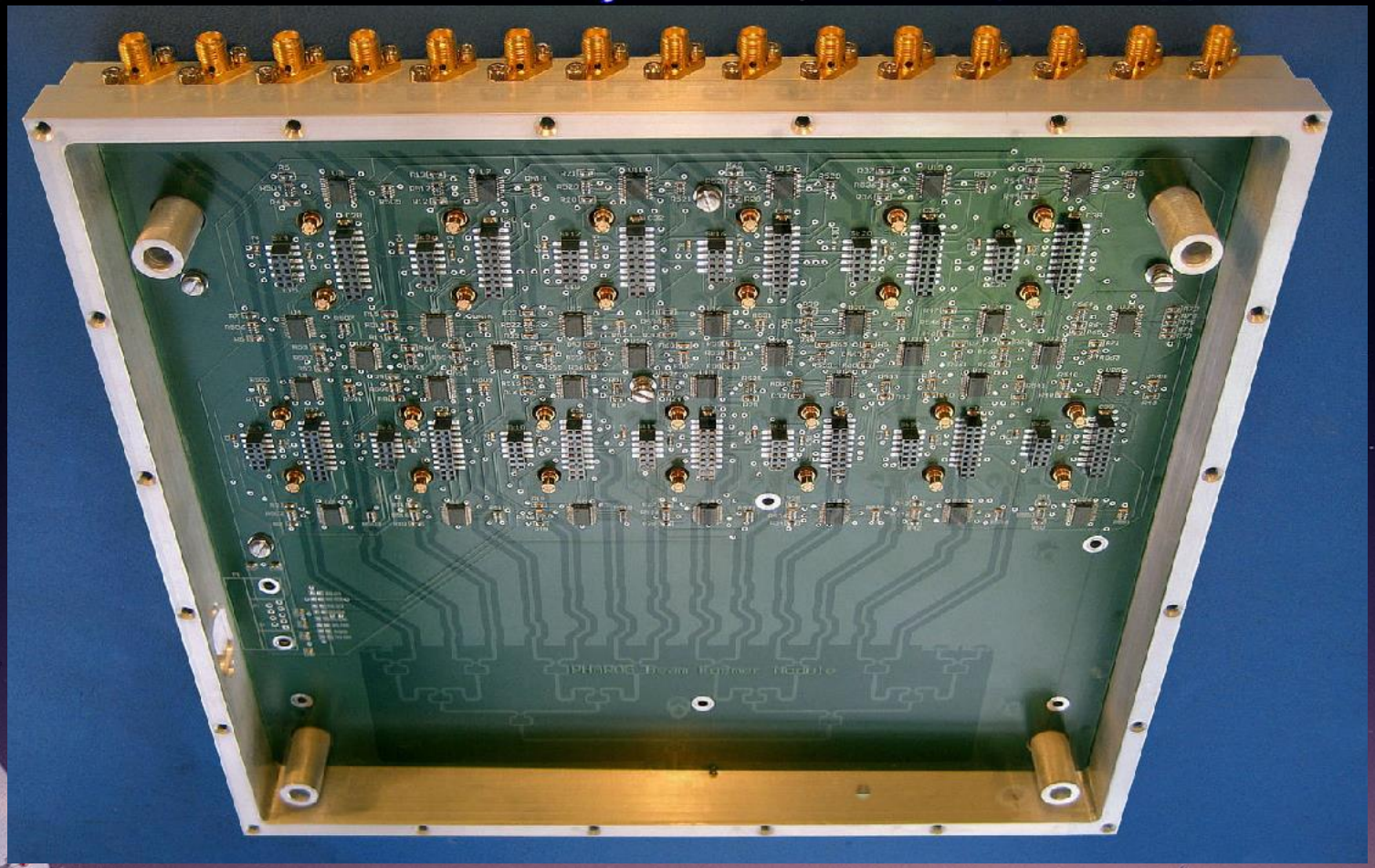
Phase and amplitude control module (PAC)



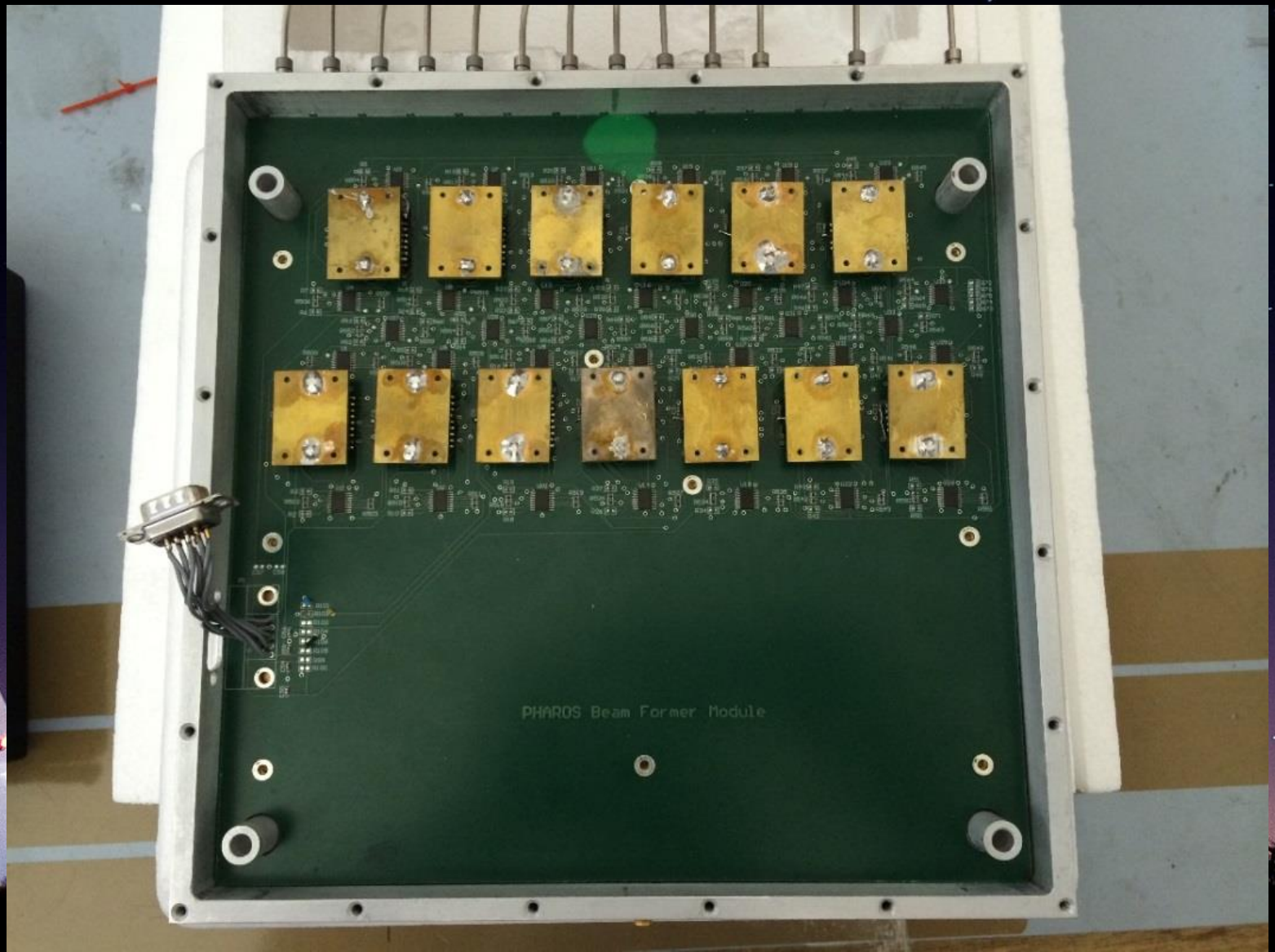
RF board



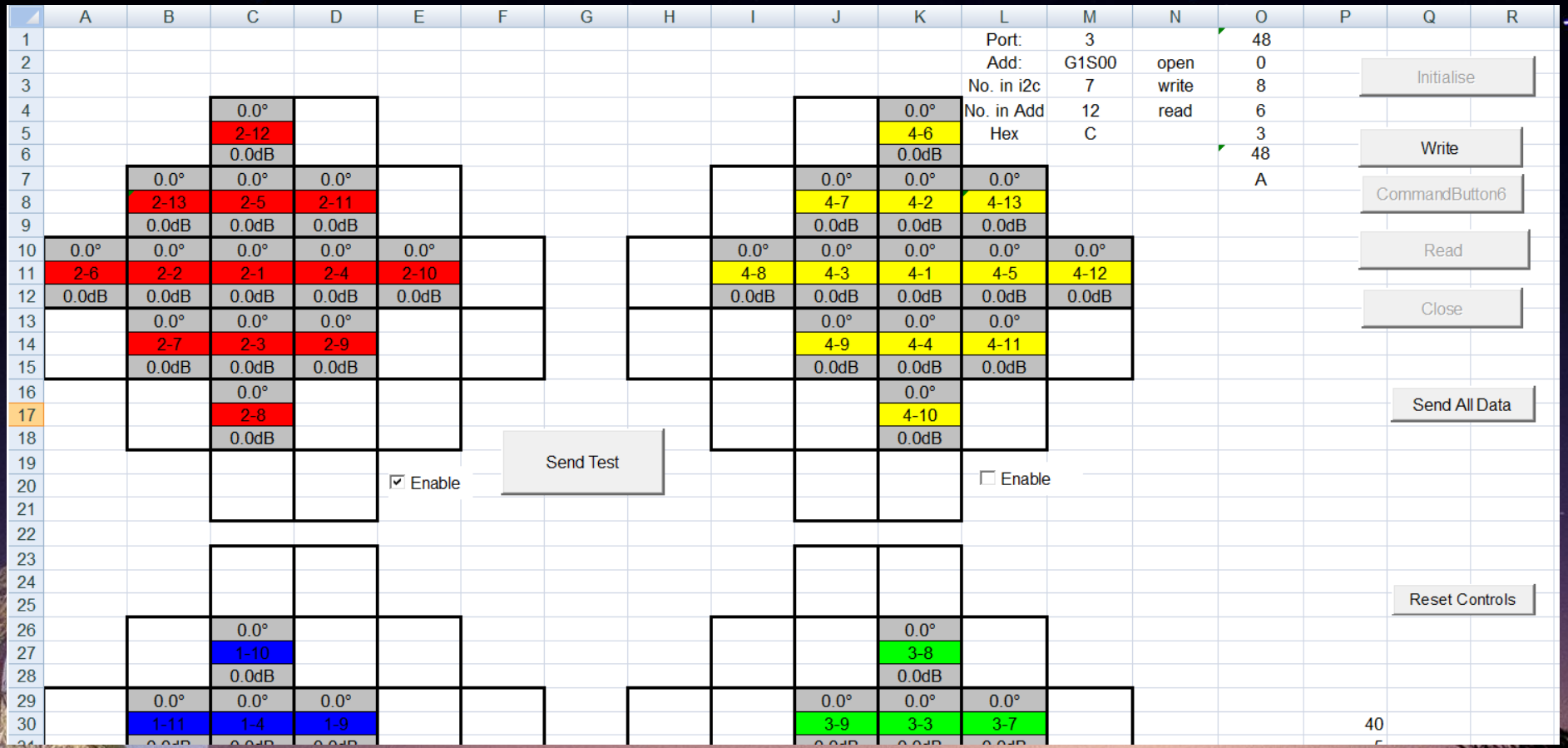
Digital control



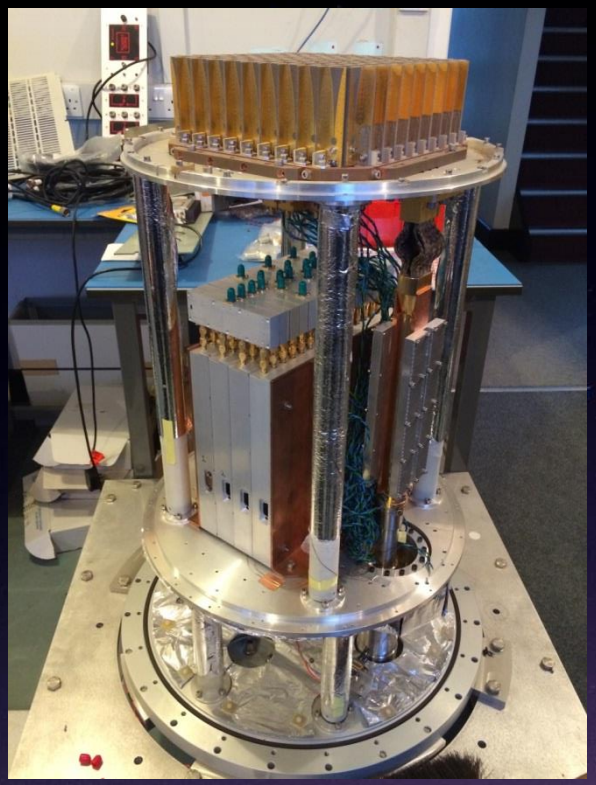
Integrated beam former board



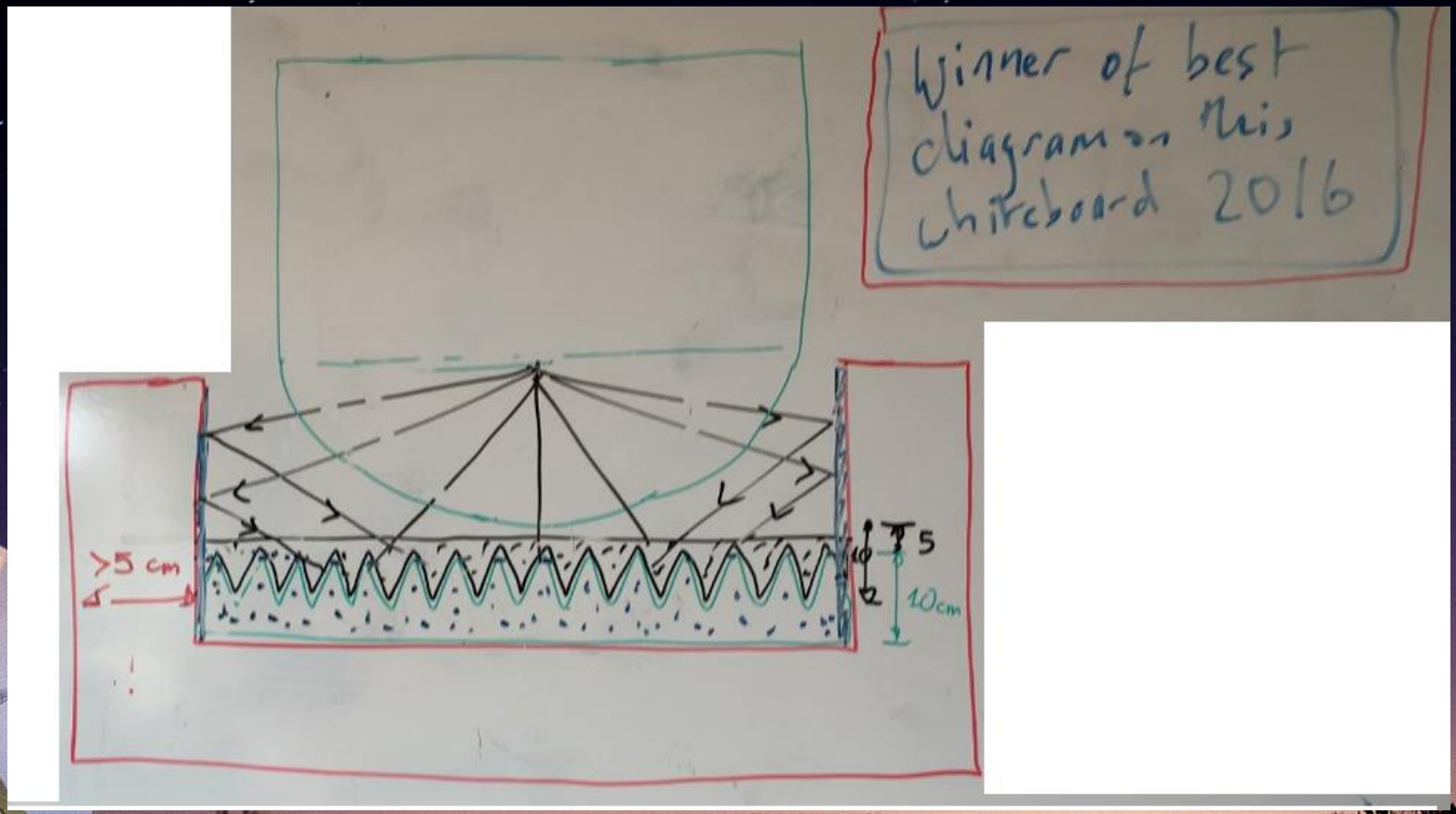
Beam former control UI

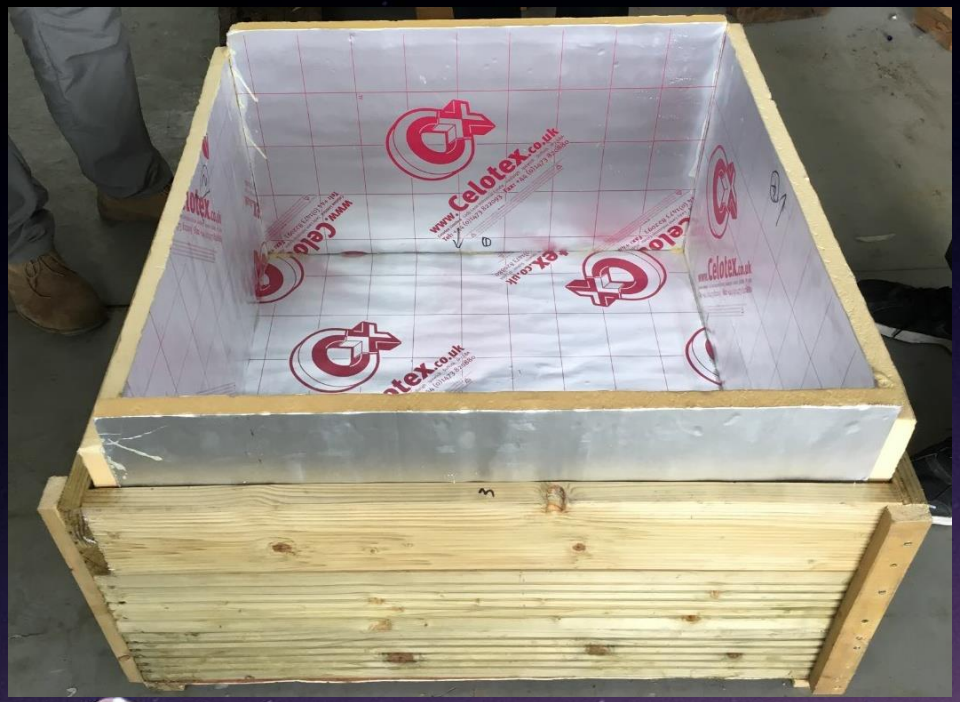


Integration



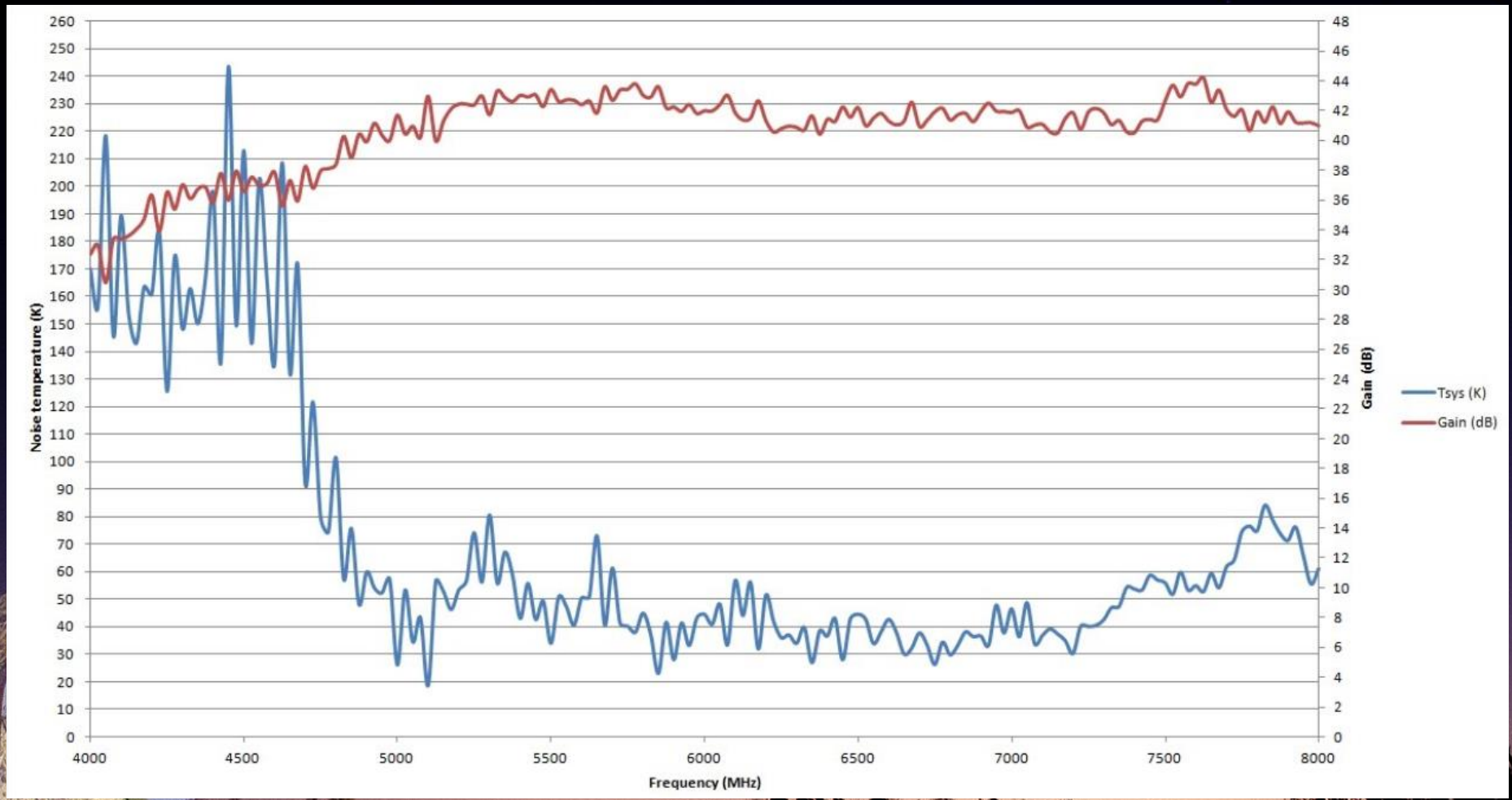
Noise temperature test set up plan a:



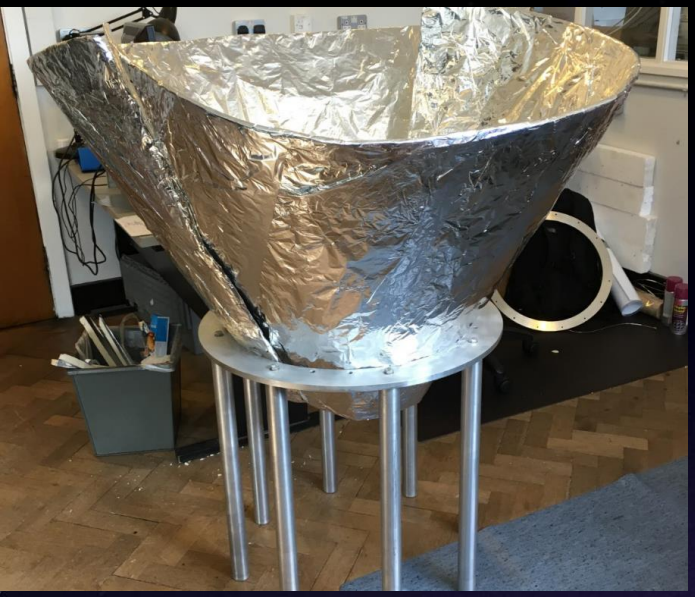

www.Celotex.co.uk


Clarke STRONG-ARM

Noise temperature and gain

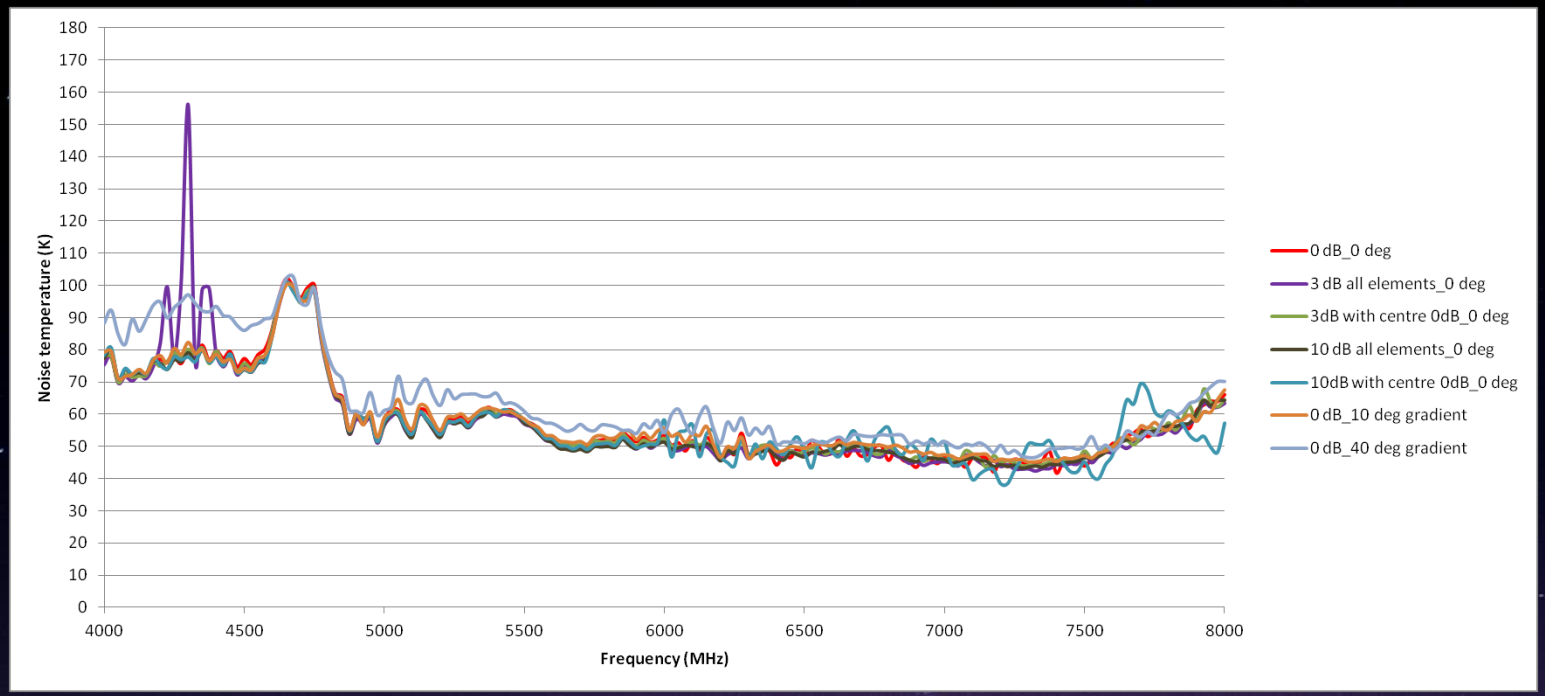


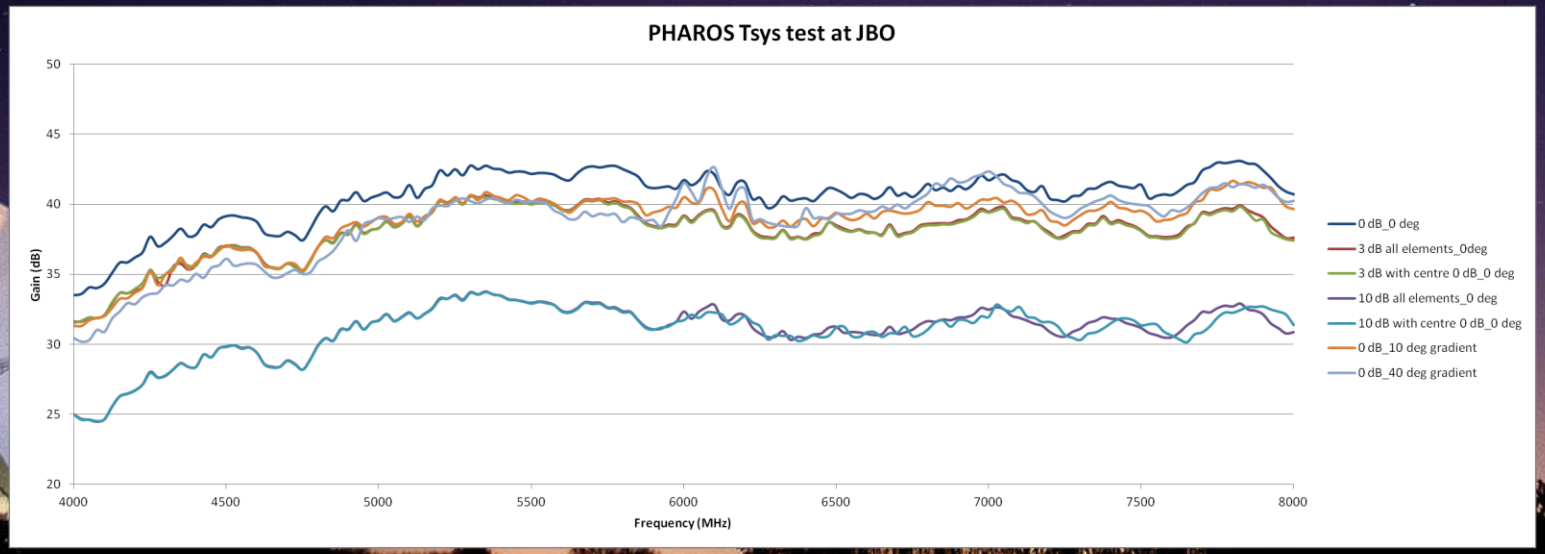
Test set up plan B:



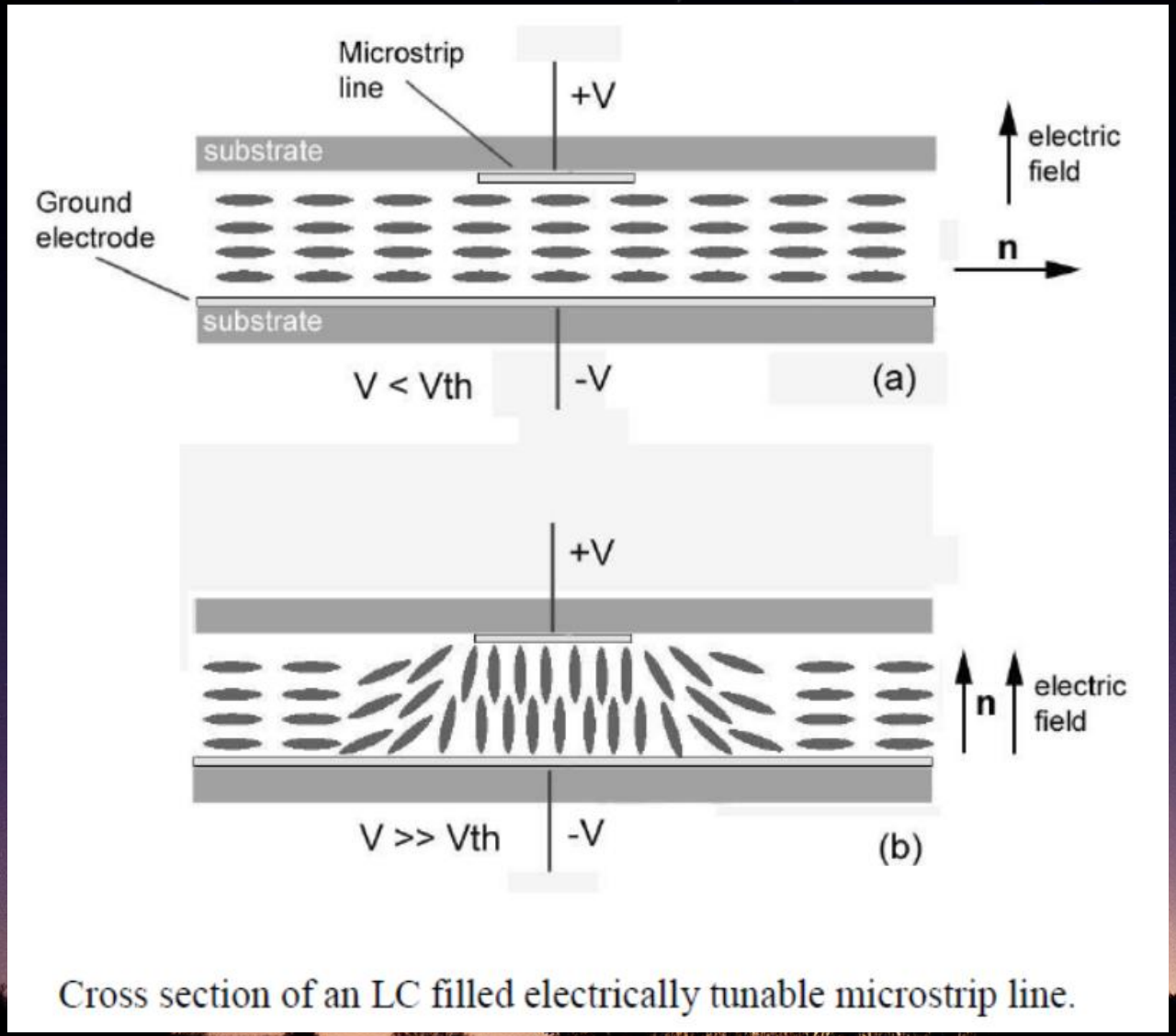
Clear SKY !

Results


Noise temperature (K)
Frequency (MHz)
0 dB_0 deg
3 dB all elements_0 deg
3dB with centre 0dB_0 deg
10 dB all elements_0 deg
10dB with centre 0dB_0 deg
0 dB_10 deg gradient
0 dB_40 deg gradient

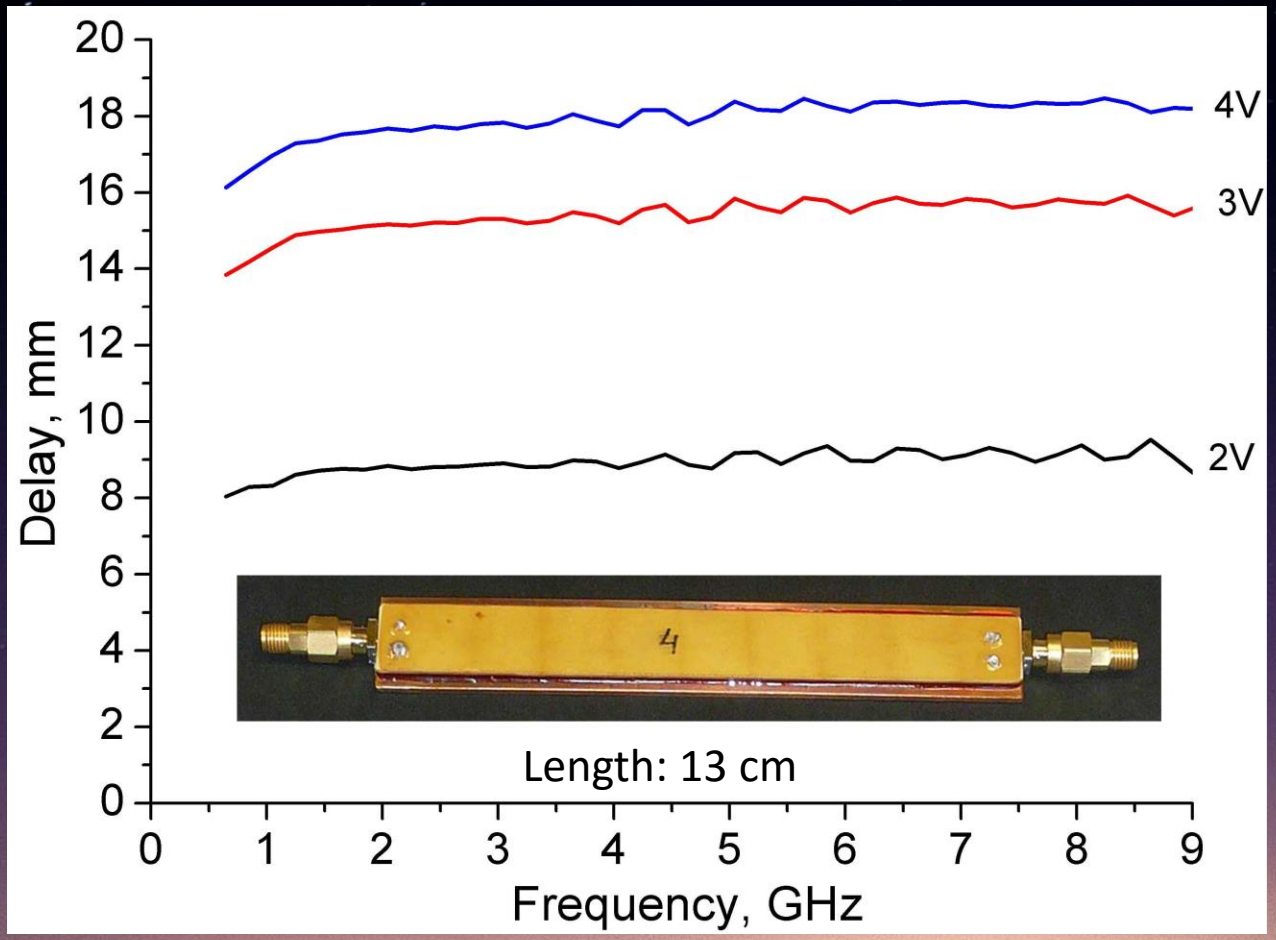

PHAROS Tsys test at JBO
Gain (dB)
Frequency (MHz)
0 dB_0 deg
3 dB all elements_0deg
3 dB with centre 0 dB_0 deg
10 dB all elements_0 deg
10 dB with centre 0 dB_0 deg
0 dB_10 deg gradient
0 dB_40 deg gradient

Liquid Crystal Delay line

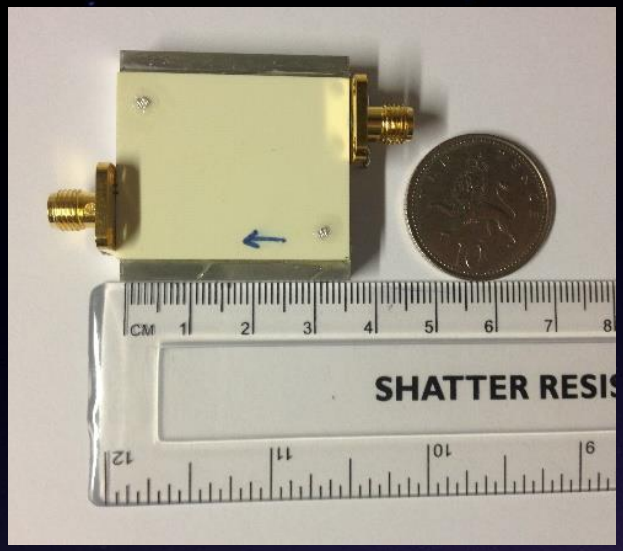


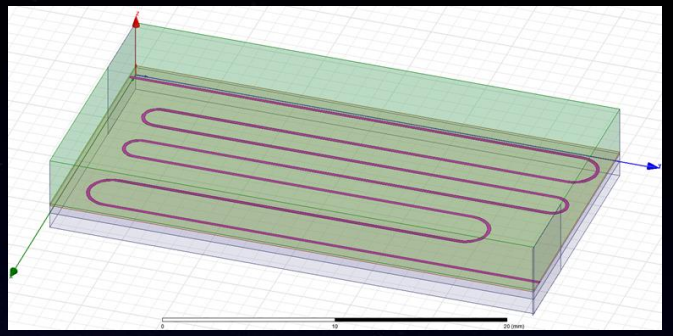
Cross section of an LC filled electrically tunable microstrip line.

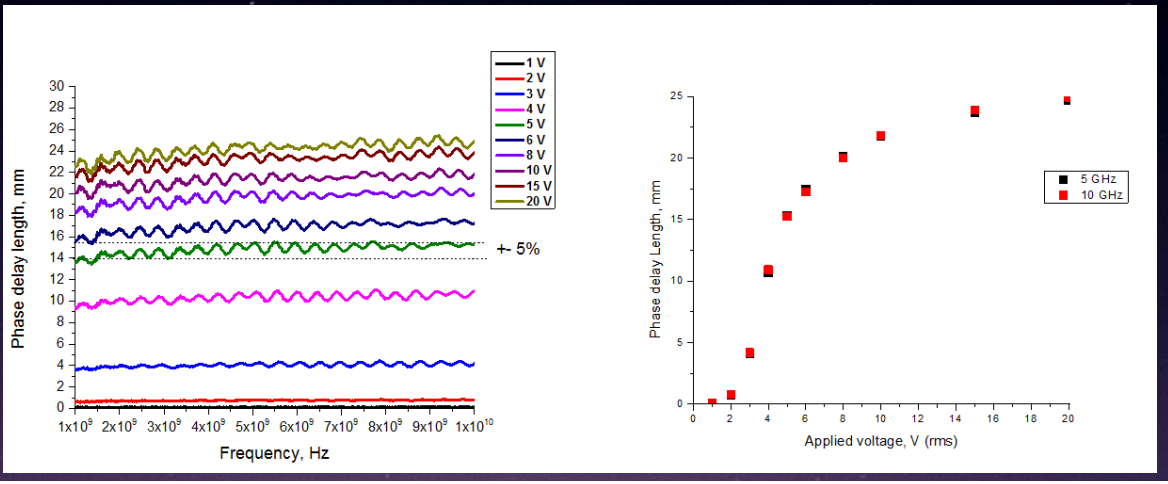
Liquid Crystal Delay line – 1st generation



Liquid Crystal Delay line – 2nd generation

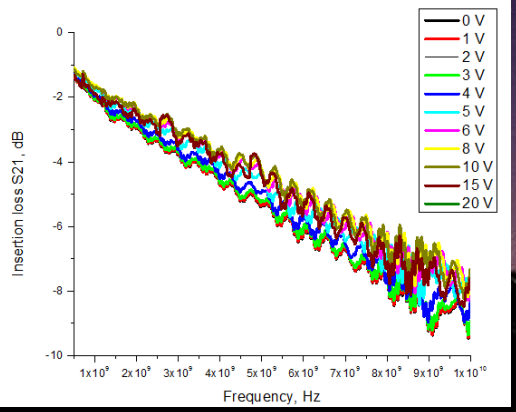




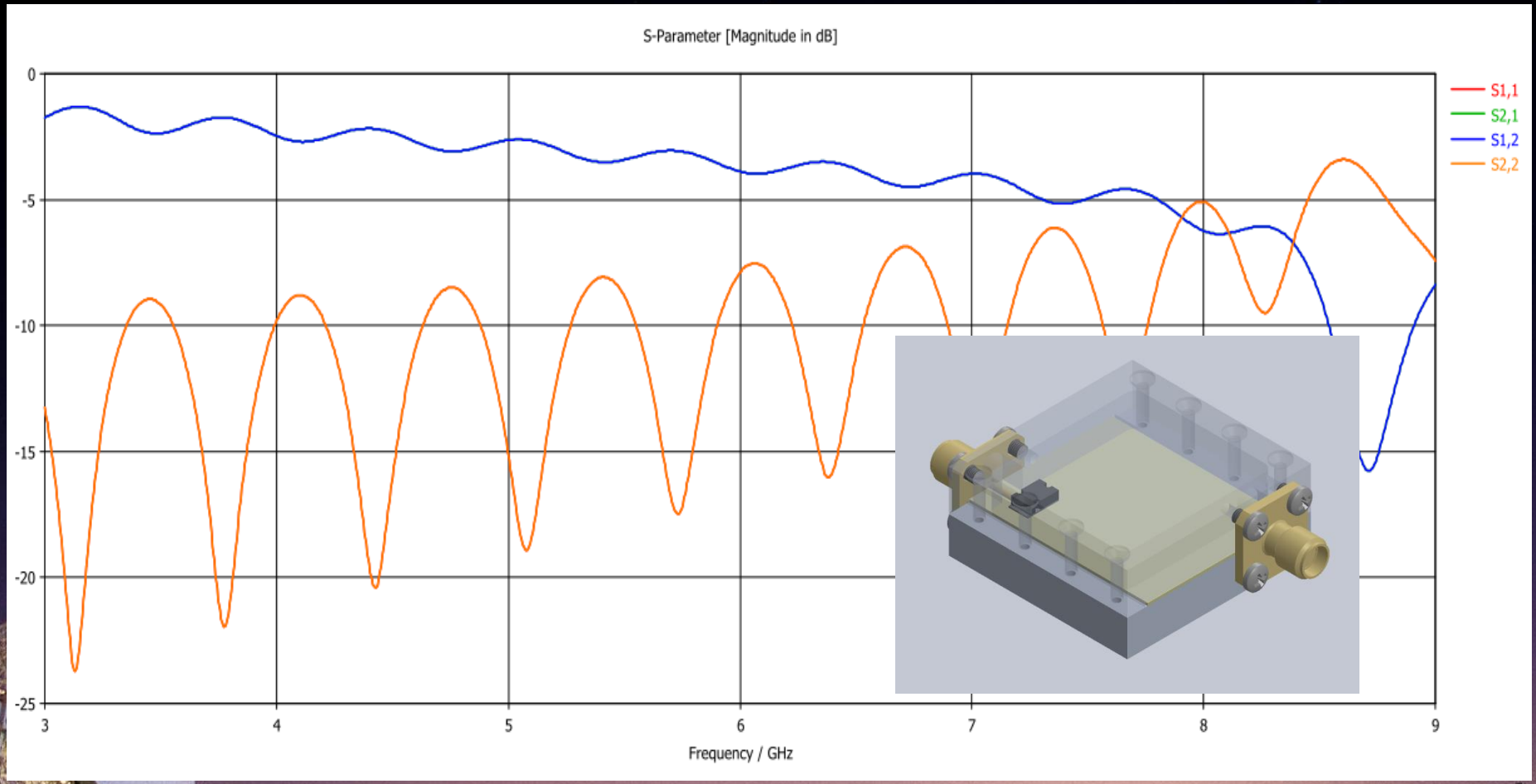


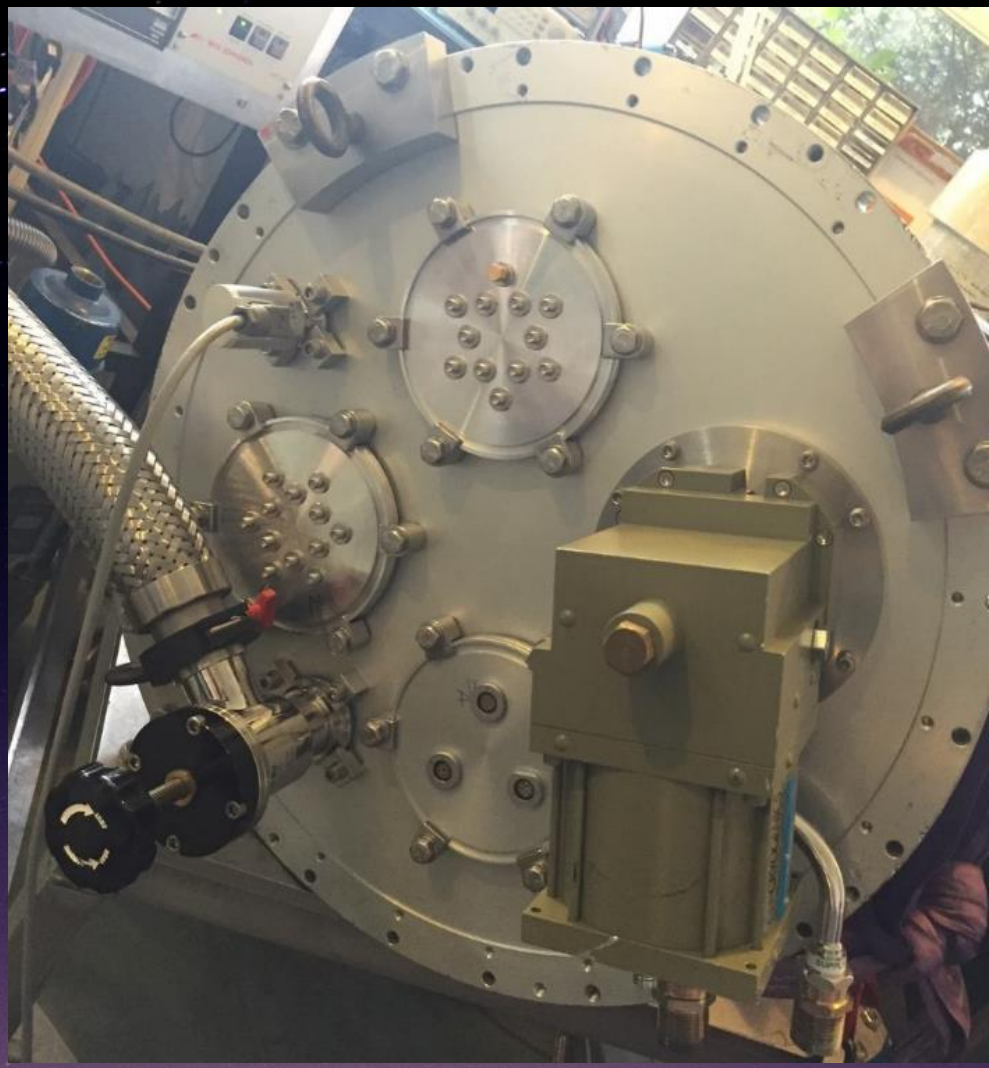
Device performance (0.5 - 10 GHz):

- Delay length ~ 24 mm (20 V rms)
- Insertion loss < -10 dB at freq. < 10 GHz
- Delay length variation < +- 5%



Liquid Crystal Delay line – 3rd generation





Future plan

- More tests on going,
- Mount on Lovell and test,
- New LNAs to reduce noise temperature,
- New structure of liquid crystal lines,
- Extend to more beams.

Thanks !

Groups:
JBO, Manchester.
Cavendish lab, Cambridge.
CAPE, Cambridge.