Irregular array of Log Periodic Dipoles

Andrew Faulkner
for Eloy de Lera Acedo

Why irregular sparse using LPD?

- Wide bandwidth LPD antenna elements
- Good matching can be achieved over the band
- Irregularity ensures grating lobes are smeared out
- More sensitivity *per antenna* (gain and size) than dense at **all** freqs - especially at low frequency

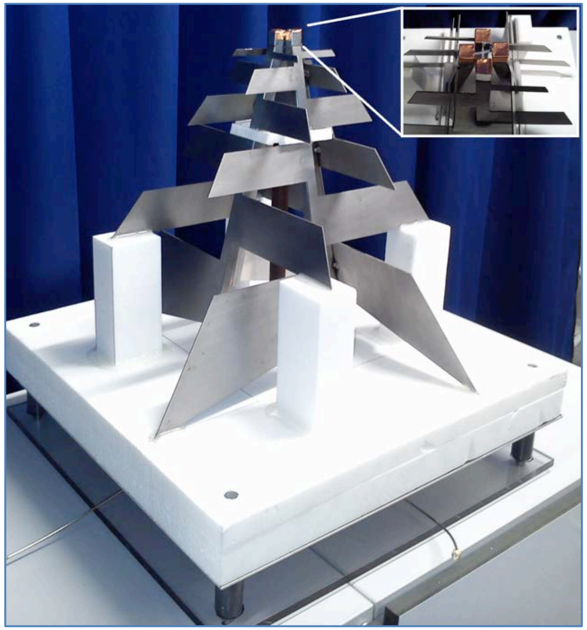
~33% of the number of antennas of a dense array

Reduced # of antennas: makes “All-digital” **realistic** …

- LPDs are highly predictable (e.g. instrumental wideband antenas)

Evolution, so far ….

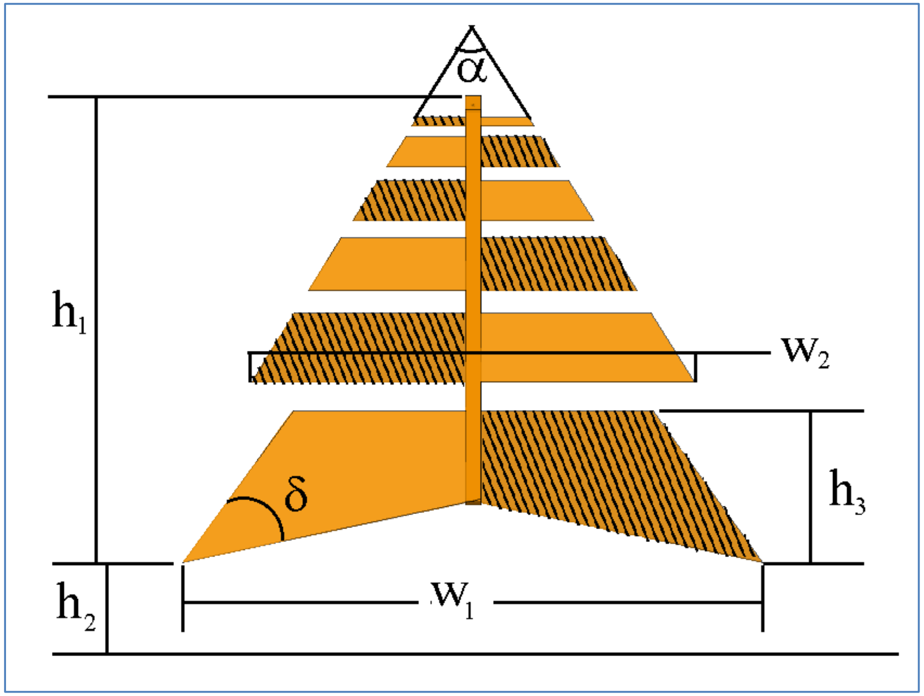
First prototype.
Differential feeding



Second prototype
Single ended feed

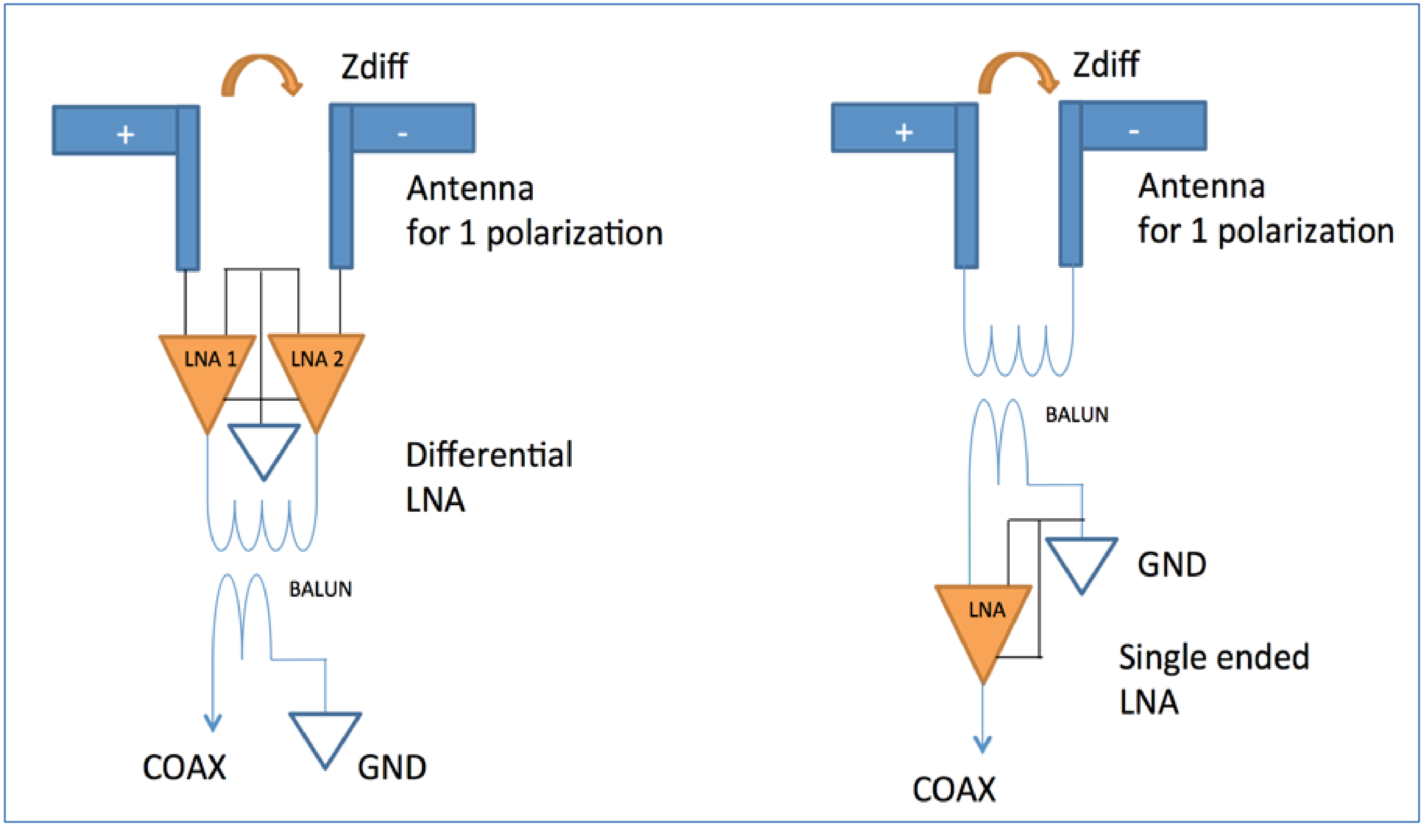
Third prototype
Single ended feed

Current design LPD



Dipoles	6
Geometric ratio (τ)	0.59
Width of the slot ($\sigma = \sqrt{\tau}$)	0.76
Outer aperture of the teeth (α)	62.5°
Inner aperture of the teeth (β)	3°
Separation between arms (ψ)	26°
Scaling of teeth width	0.7
Antenna height (h_1)	30 cm
Distance from the last dipole to the GND plane (h_2)	5 cm
Bowtie bottom dipole (h_3)	7.1 cm
Antenna width (w_1)	37.5 cm
Log-periodic progression width (w_2)	28.5 cm
Bowtie dipole angle (δ)	45°

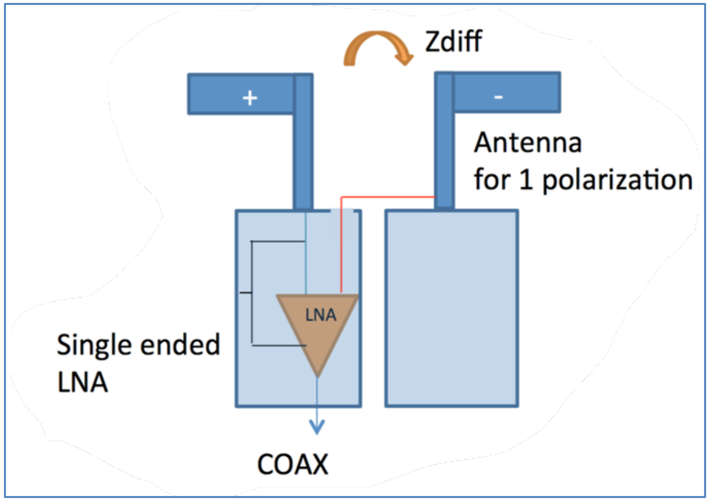
LNA feed - Differential

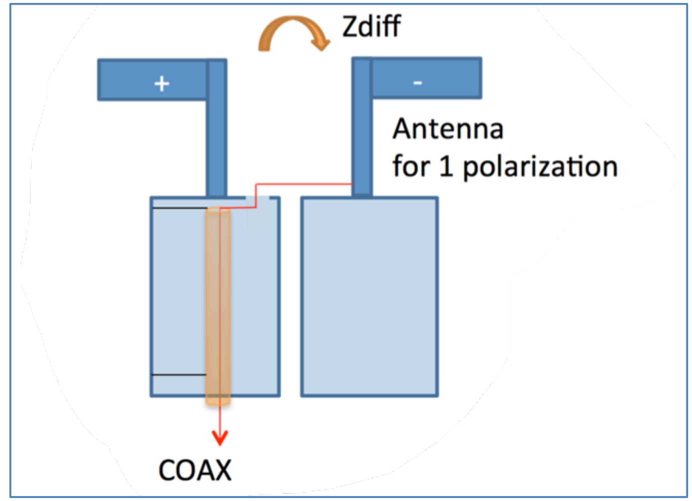


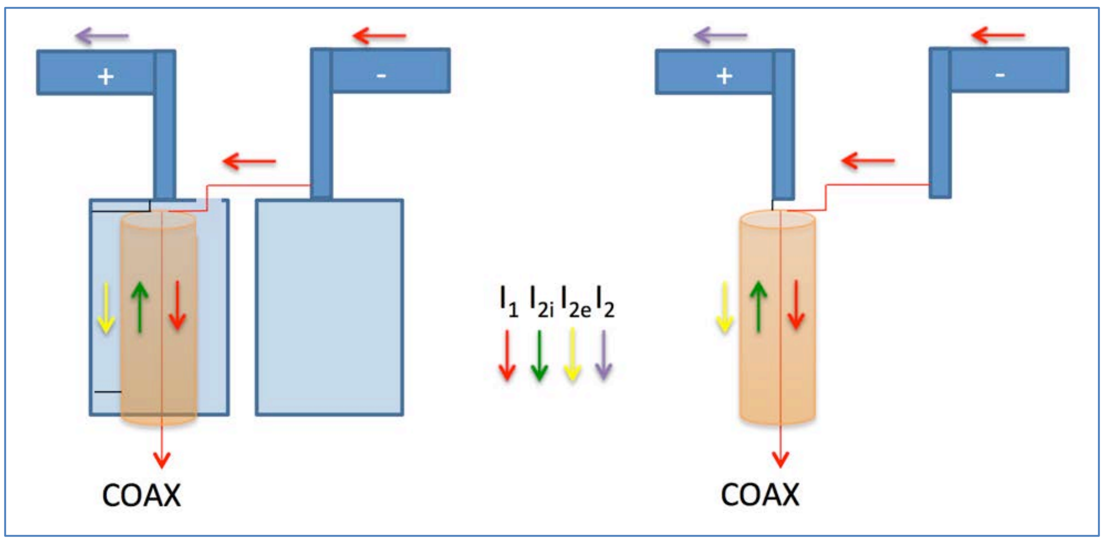
Pseudo differential LNA

Balun at the antenna

LNA feed – single ended





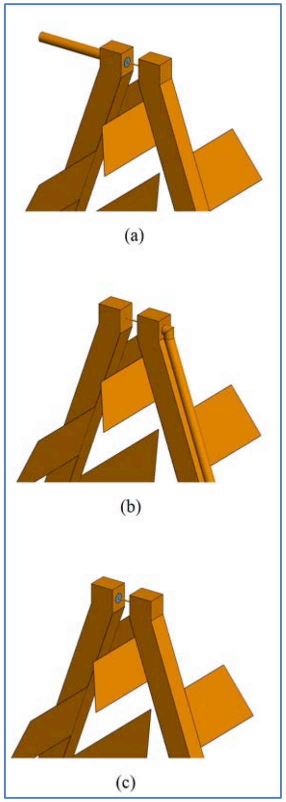


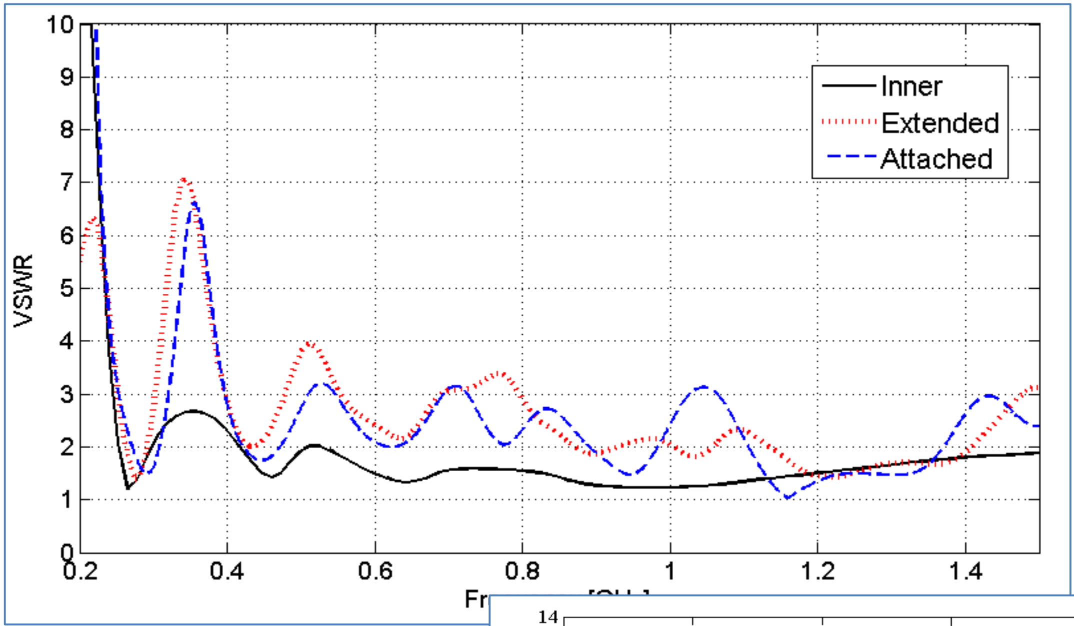
Current balancing:

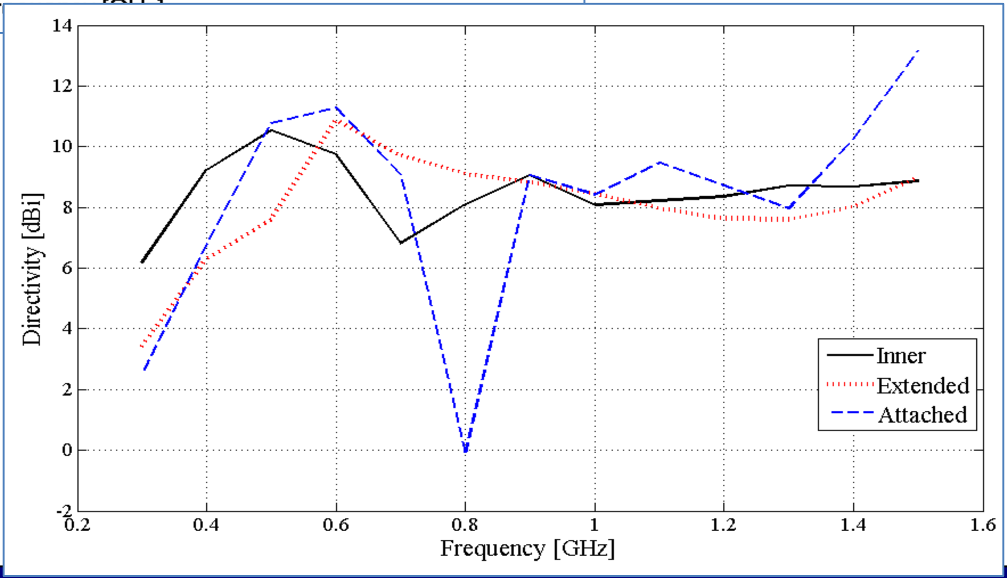
$I_2 = I_{2i} + I_{2e}$ & $I_2 = I_{2i} - I_{2e}$

so: $I_1 = - I_2$

Simulations of single ended feeds







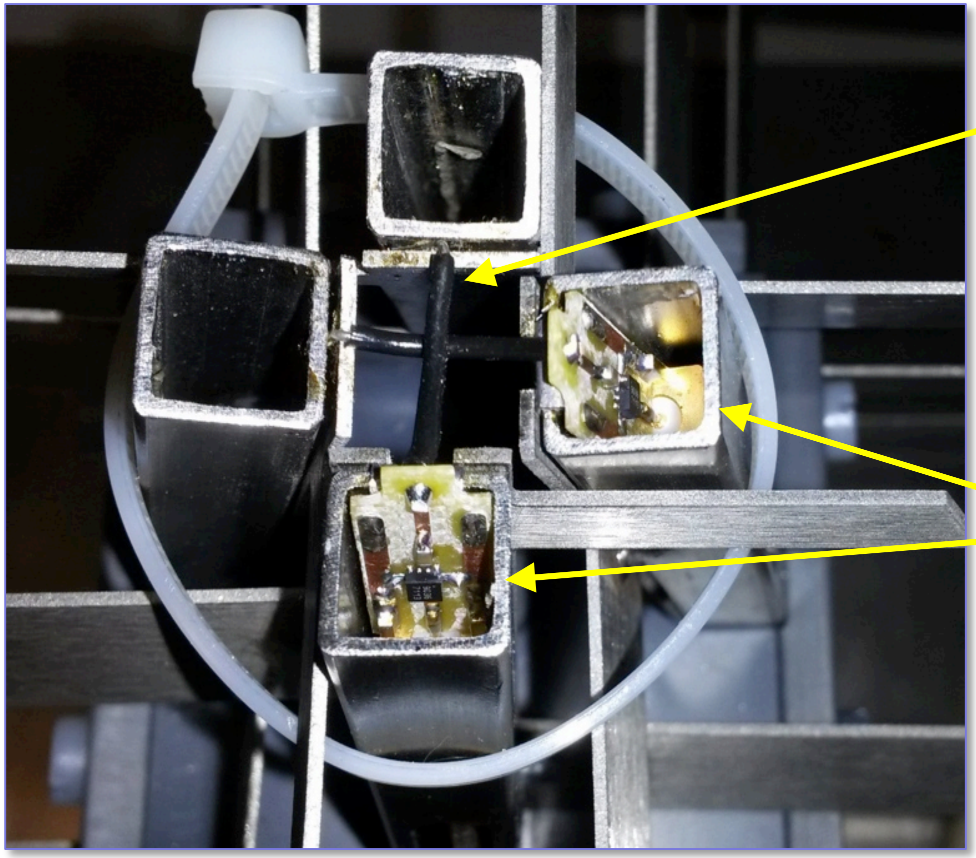
Antenna simulations with coaxial cable:

a) Extended,

b) Attached

c) Embedded on the antenna arm.

Single ended LNA implementation

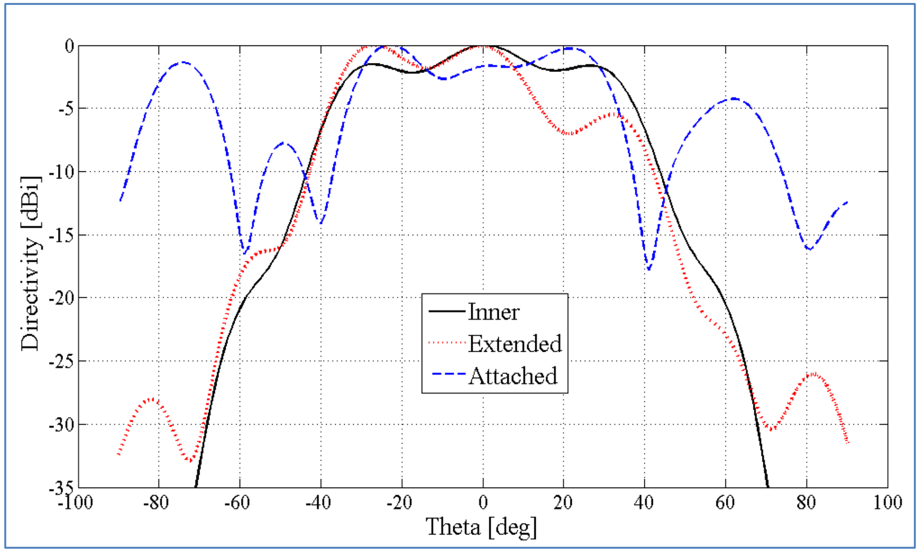


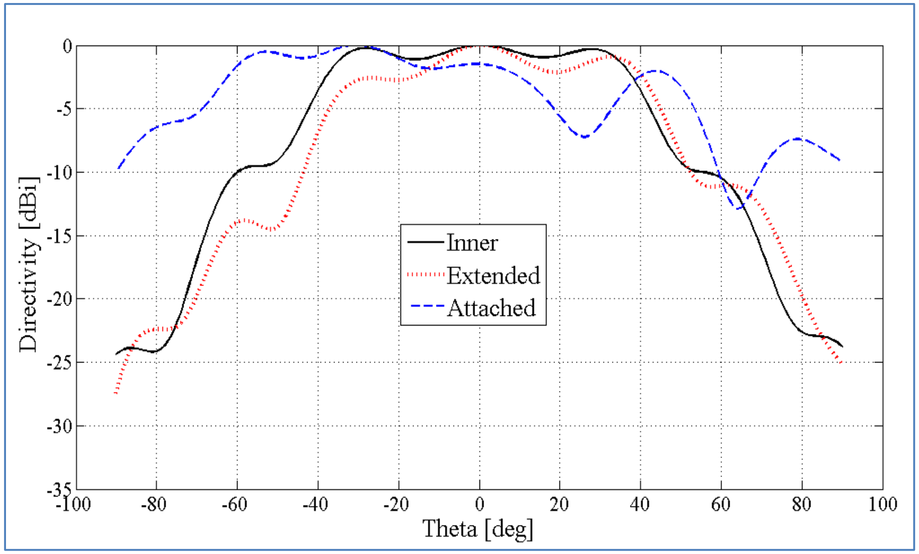
Feed from “other” arm

LNAs inside the spine tubes.

All local electronics to be built into spine: shielded and environmentally sound

Beamshape



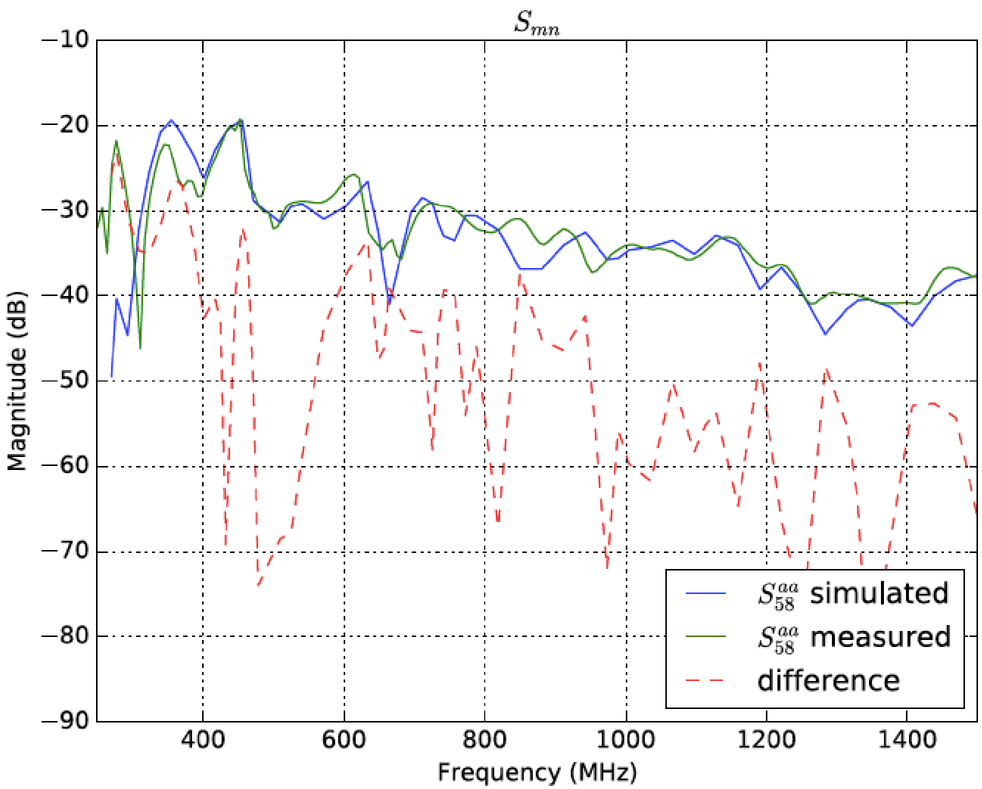


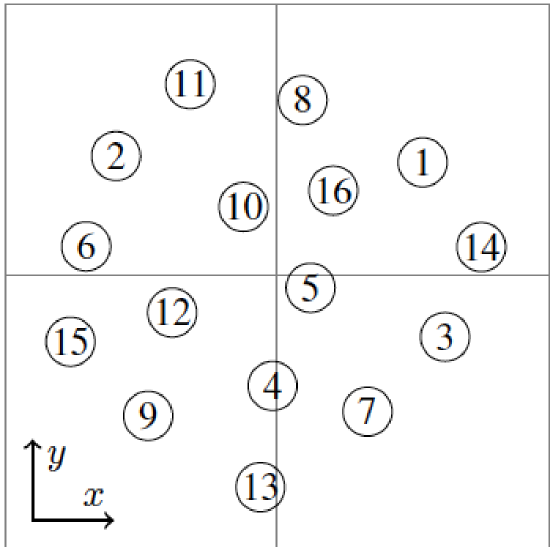
Patterns at 1 GHz for each coaxial configurations.

left: E plane and right: H plane.

16-element model

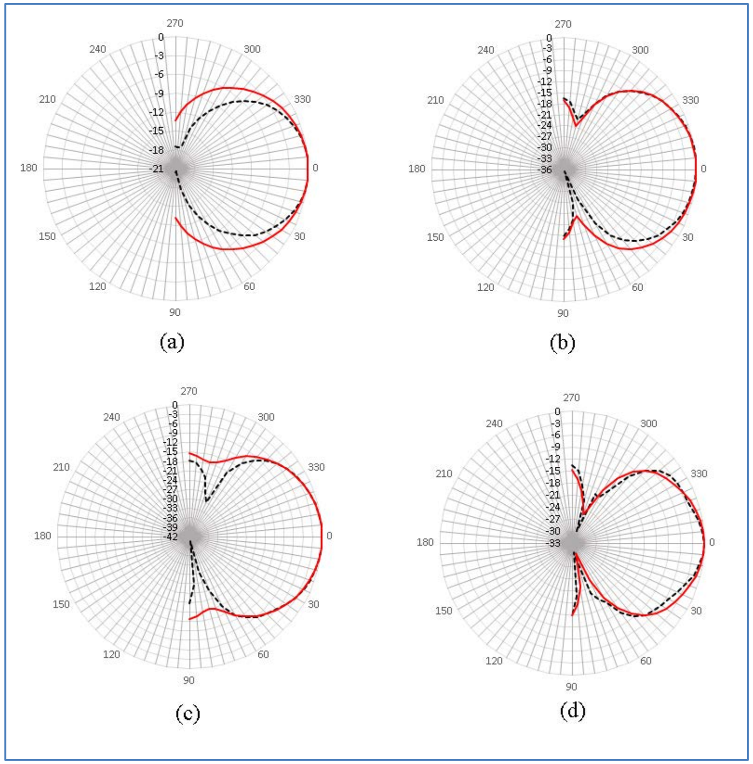
16-element results

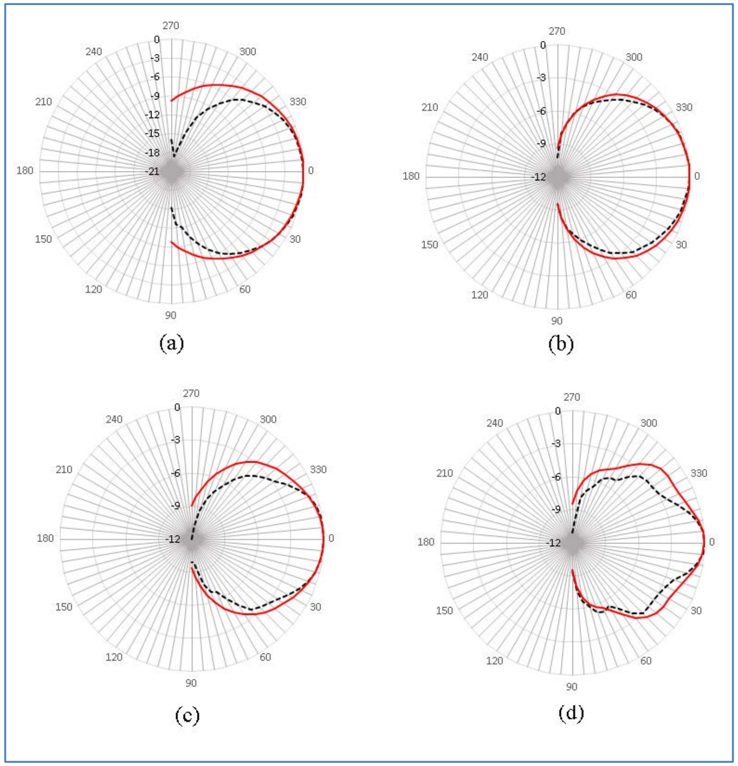




Comparison of simulation and measurement for mutual coupling. The average difference is −44.5 dB.

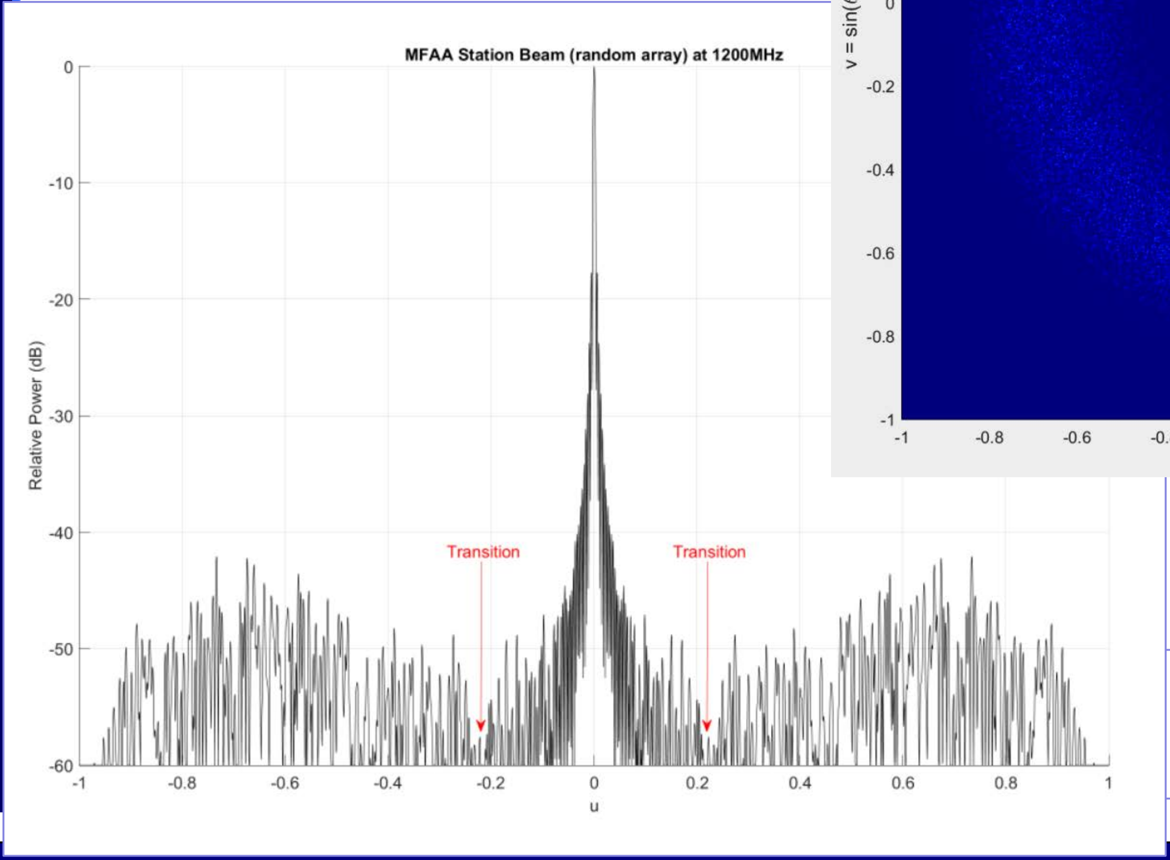
Beamshapes

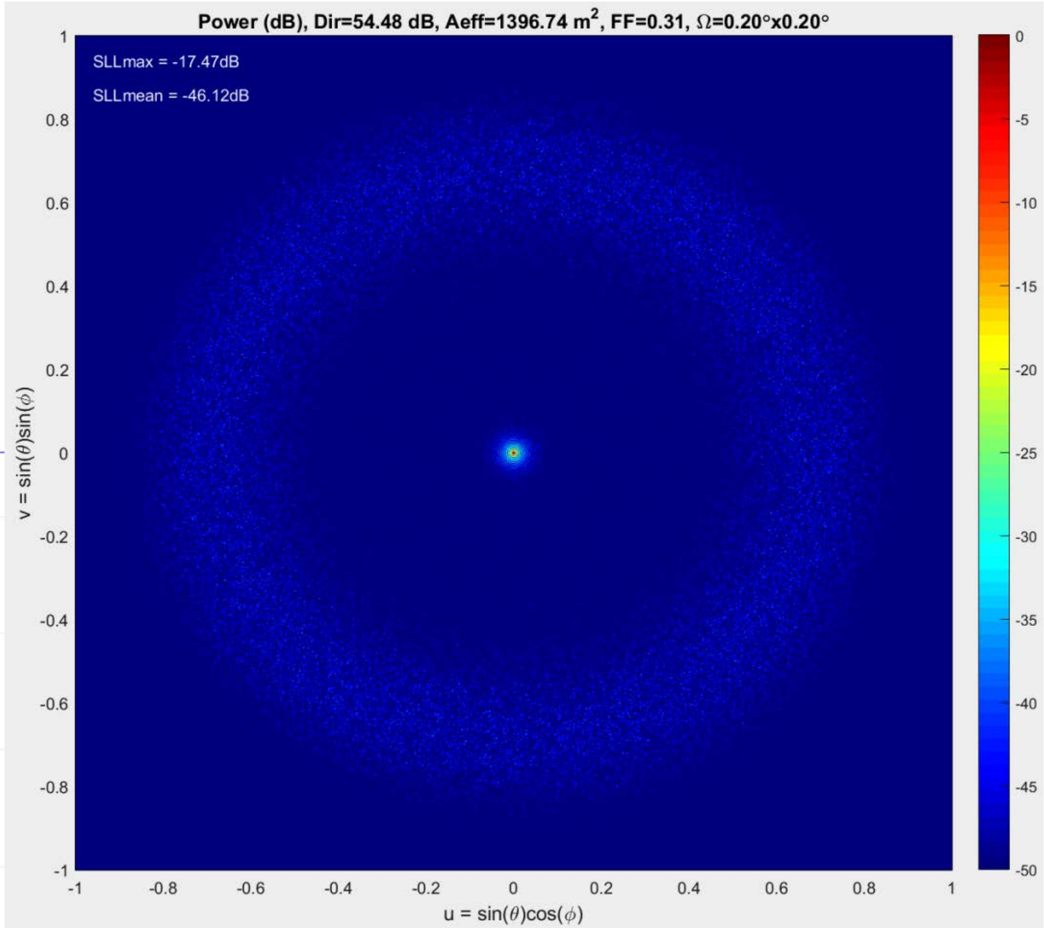




Simulated and experimental E plane (left) and H plane (right) radiation patterns at:
a) 300 MHz, b) 700 MHz, c) 1100 MHz and d) 1450 MHz.

MFAA Station Simulation





1200MHz
32,000 ant.

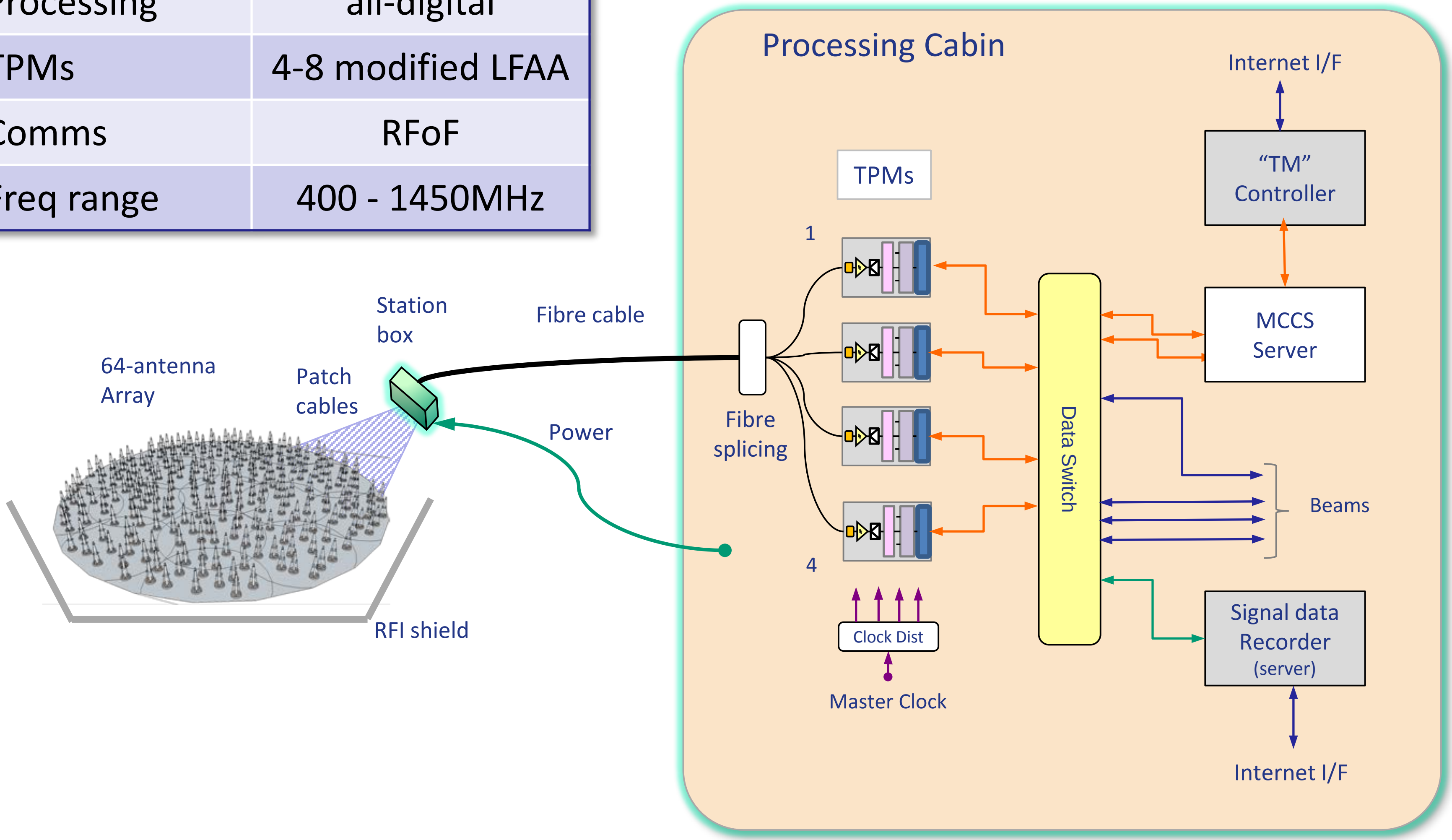
Development: small mass production

- The next step for 100's – 1000's antennas
- Fundamentally low cost
  - sheet metal or wire bending
  - A couple of small mouldings
- Intrinsically environmentally protected
- Electronics in the field shielded in spines
- Optically linked for multiple antenna muxed

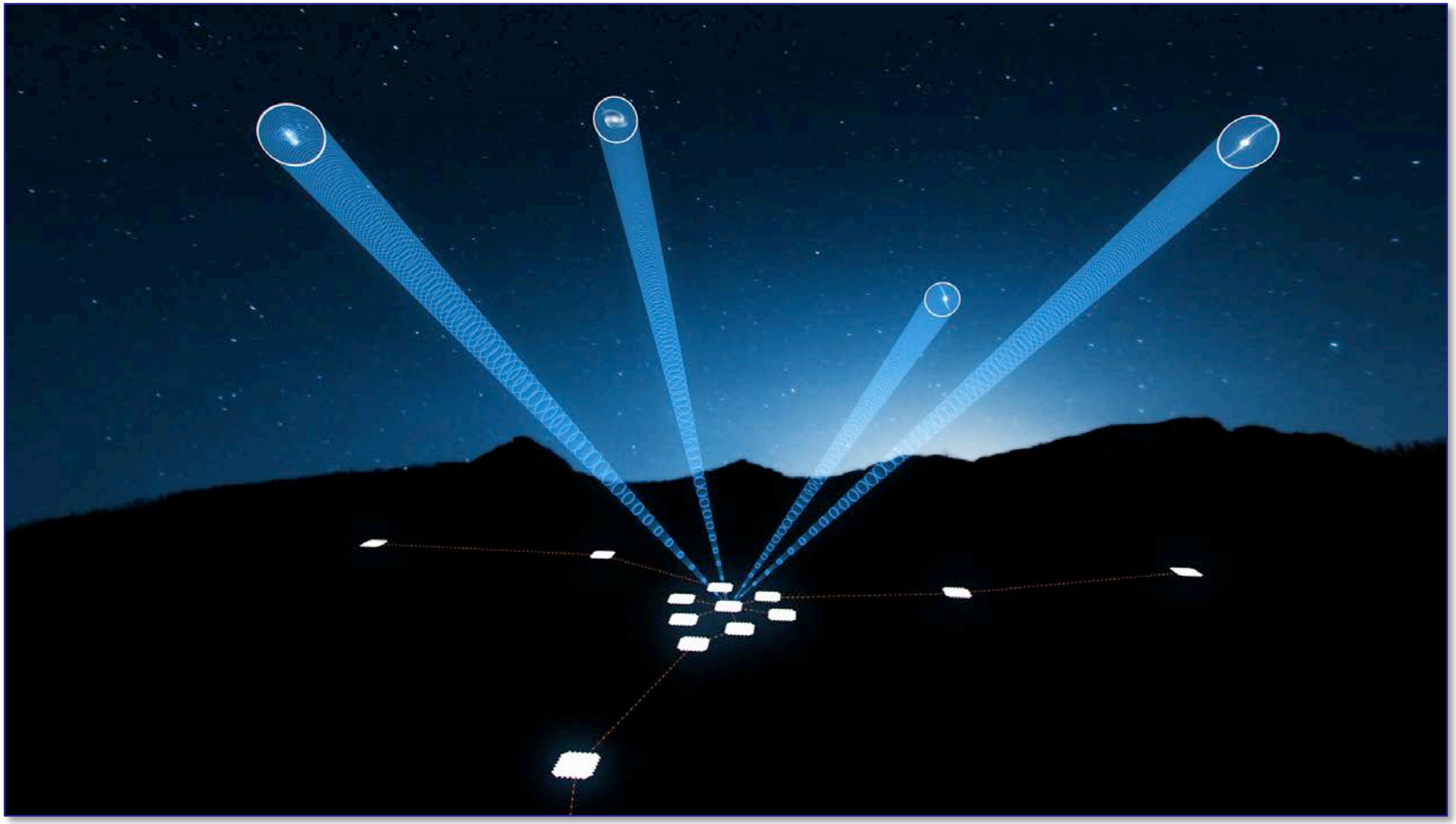
Contract placed with DfM experts…

Demonstrator at Lord's Bridge

# antennas	64 - 128
Processing	all-digital
TPMs	4-8 modified LFAA
Comms	RFoF
Freq range	400 - 1450MHz



MFAA - vision

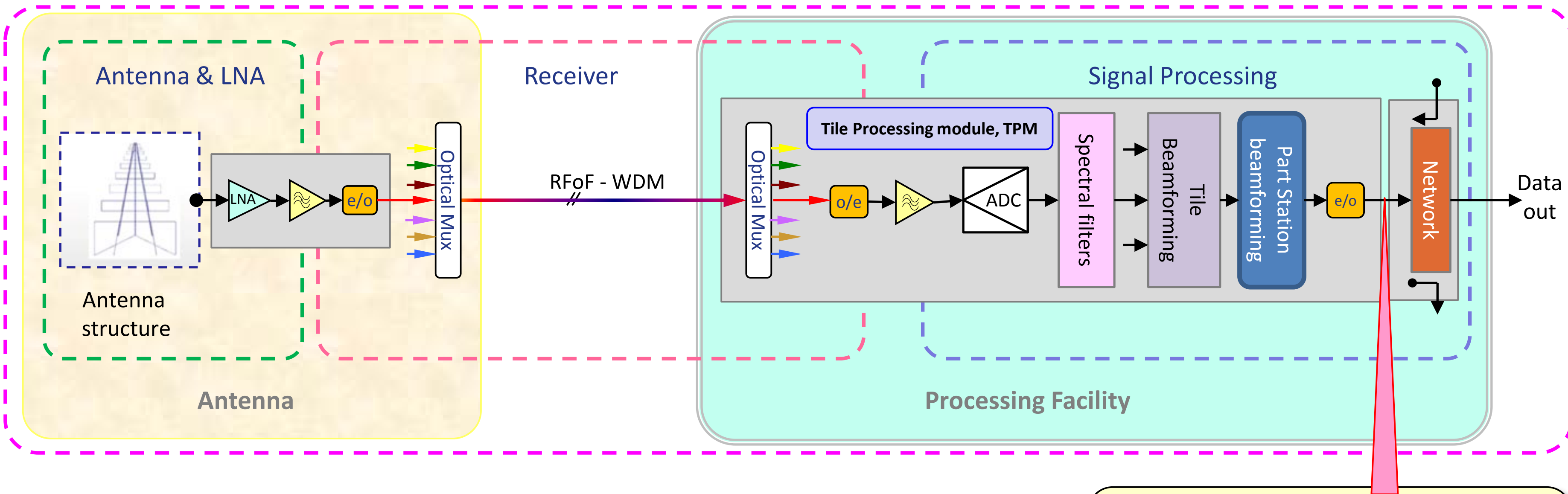


Beams all over the sky…

Outline Specification… with LPD

Parameter	Essential	Desirable	Comments
Frequency – low	450 MHz	<400 MHz	Scientifically the low frequency is for HI at z=3.
Frequency – high	1450 MHz	>1450 MHz	Reach at least HI line; further science at higher frequencies
Polarisations	2-linear 30dB purity	2-linear 40dB purity	Essential to have orthogonal polarisations Purity is post calibration
Sensitivity	10,000m^2/K @ 800MHz	10,000m^2/K @ 1GHz	Sensitivity may be higher at lower frequencies Sensitivity is at zenith, will reduce with scan angle.
Optical FoV	100deg^2	**>±45° from zenith**	More FoV (at narrower BW) gives better survey speed and is important for transients
Bandwidth (max)	1000MHz	>1000MHz	Should be capable of having beams of the full bandwidth
Beams*bandwidth Product	>50GHz	>250GHz	Data rate determines telescope performance. Likely limited by post processing capability.
# of beams (max)	Fill optical FoV	Fill ±45° from zenith	Depends upon bandwidth required. Beams should be completely configurable for BW/Number etc.
Beam precision	<2% error at all freqs	<1% error at all freqs	This requires accurate analogue calibration; good beam prediction sims; ability to "measure" the beam on-line.
Buffer	100 sec	1000 sec	Element/tile level buffering, flexibly applied, at some B/W
Configurability	Beams/BW	Station size Station location	Modify processing across the array – new approaches. Station size and location can tune for experiment

Signal path - sparse

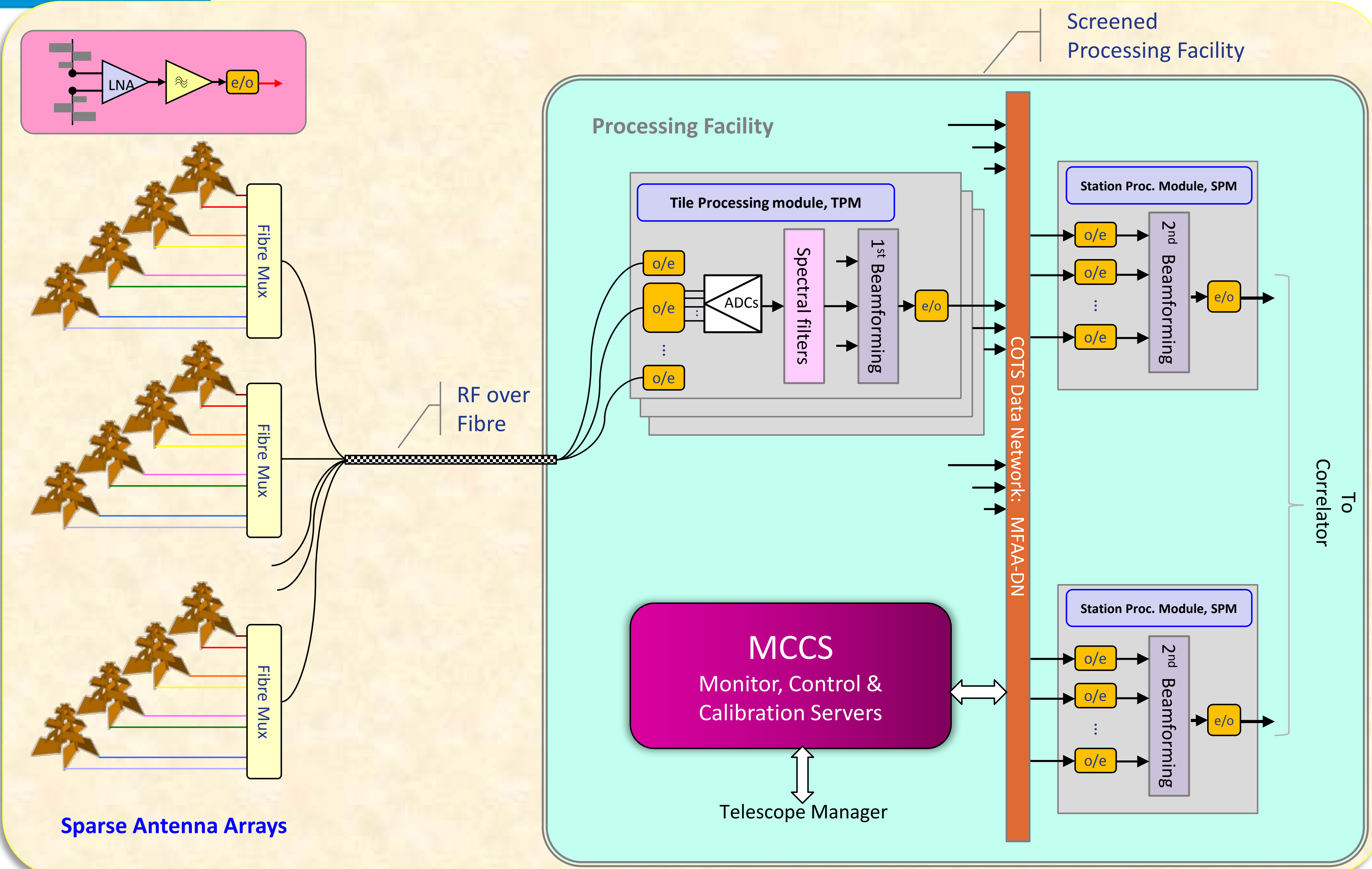


- Control data
- Calib. coefficients
- Partial beam in #x..
- Partial beam in #2
- Partial beam in #1

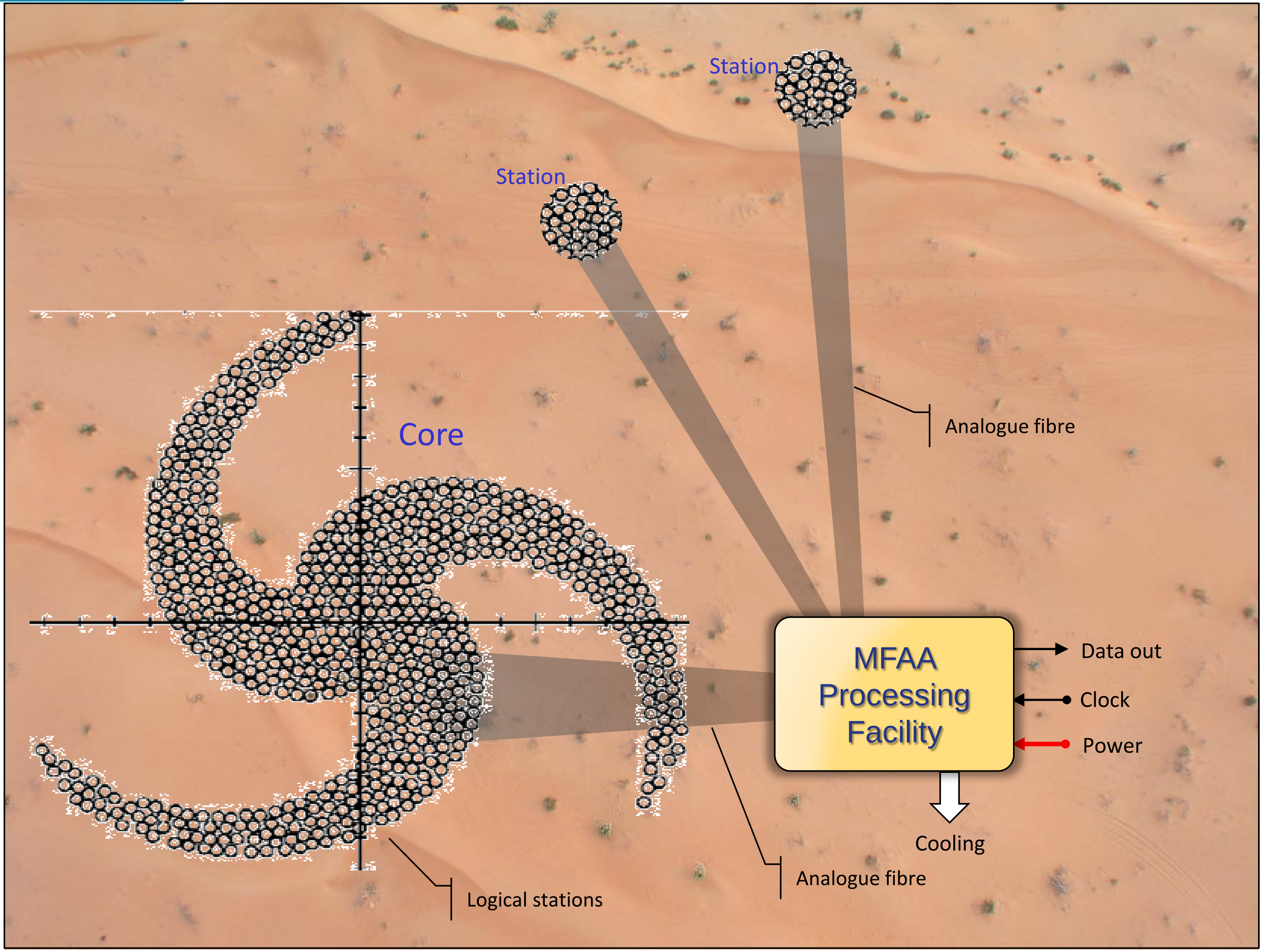
Data Network

- Beam out #1 *(Partial)*
- Beam out #2 *(Partial)*
- Beam out #x.. *(Partial)*
- Data for calibration
- Tile monitoring data

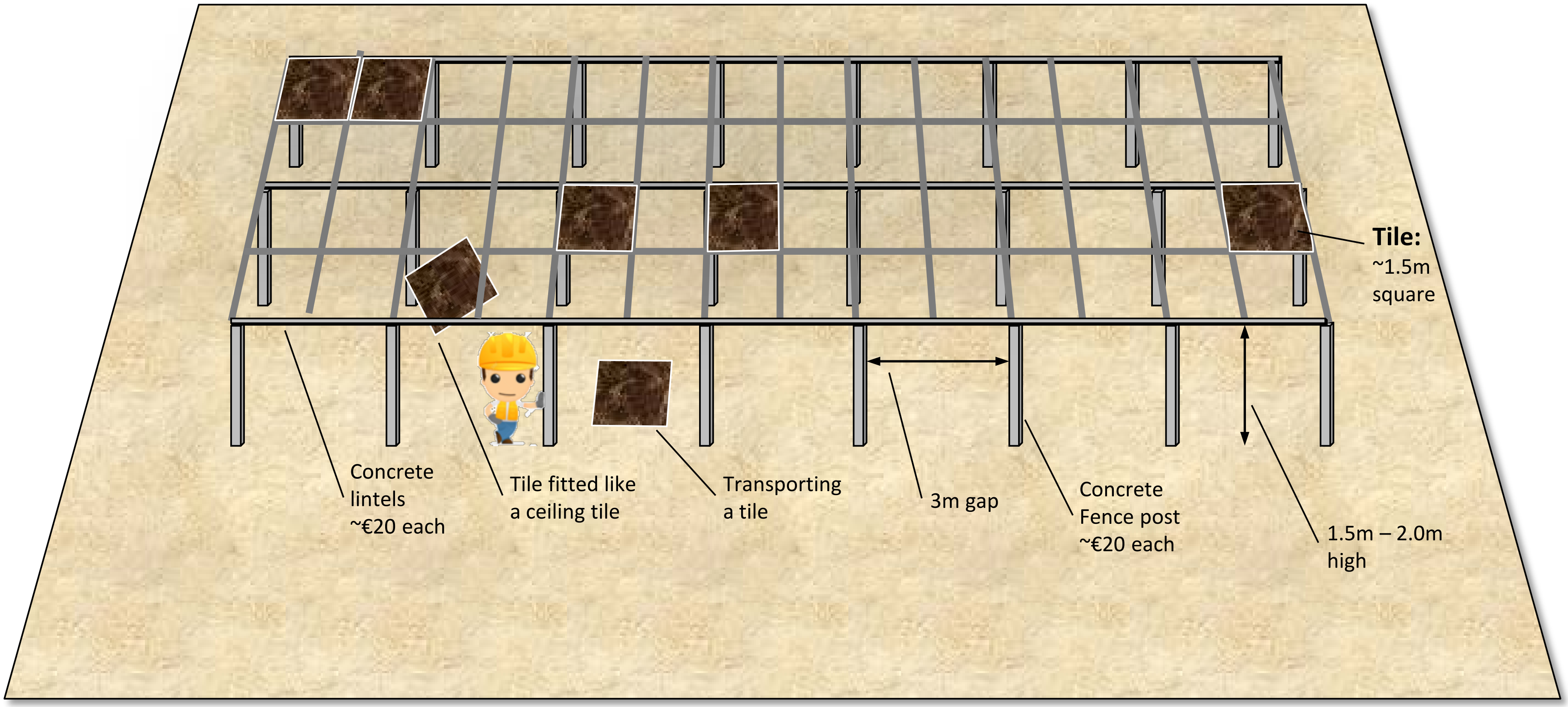
System architecture (all-digital B/F)



Possible configuration



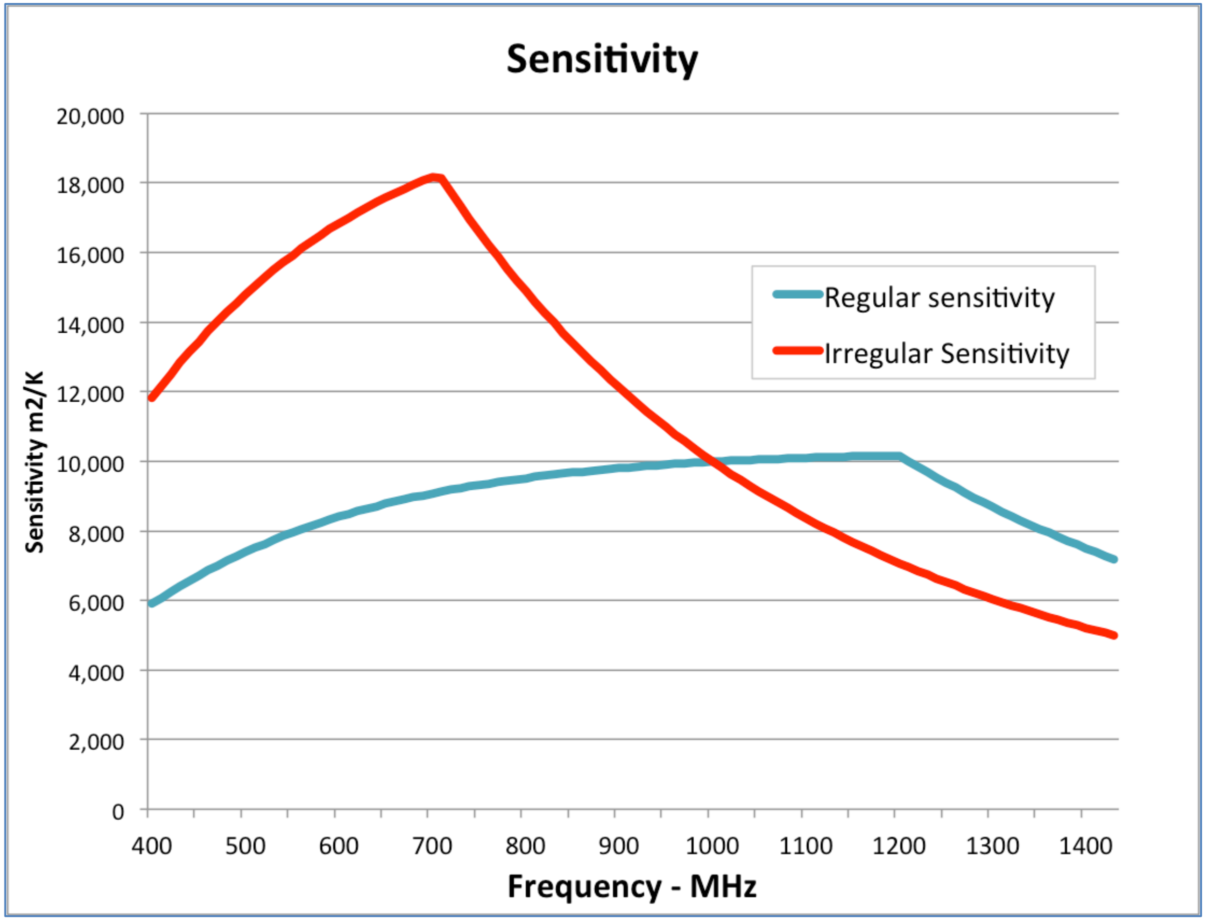
Construction suggestion for MFAA



Sample array designs…

	Sparse	Dense
Frequency range	400MHz – 1.4GHz (2.0GHz)	450MHz – 1.4GHz
# of stations	256	256
Diameter of station	60.5m	42.3m
T_{sys}	35	35
Beamforming	**All digital**	RF for 16 elements Digital thereafter
# Digital channels (2-pol)	16 million	~3 million
Optical FoV	±45 deg from zenith	~200 sq deg
Antennas/station	32,000	90,000
Antenna spacing	300 mm	125 mm
Total # of antennas	**8 million**	**23 million**

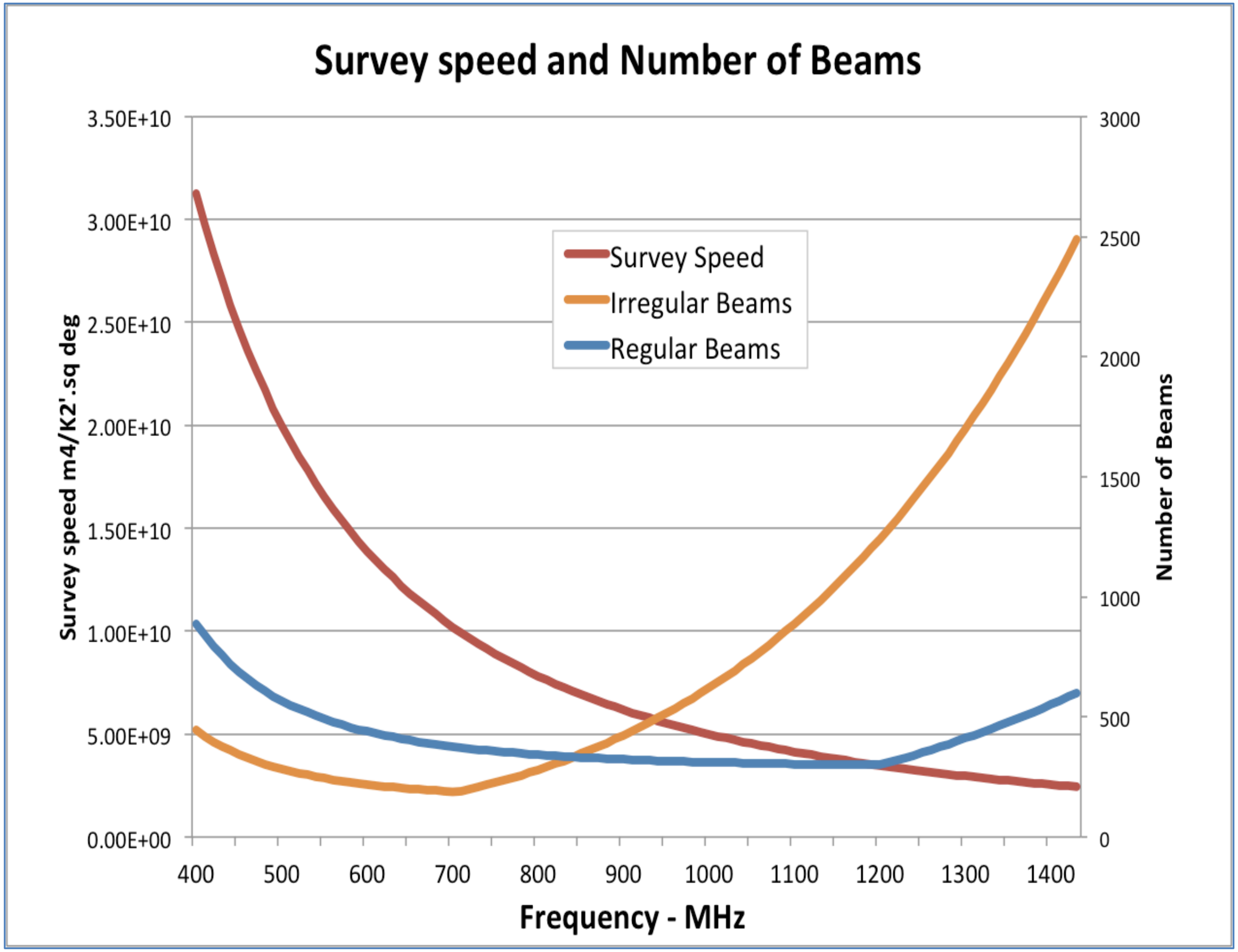
Sensitivity



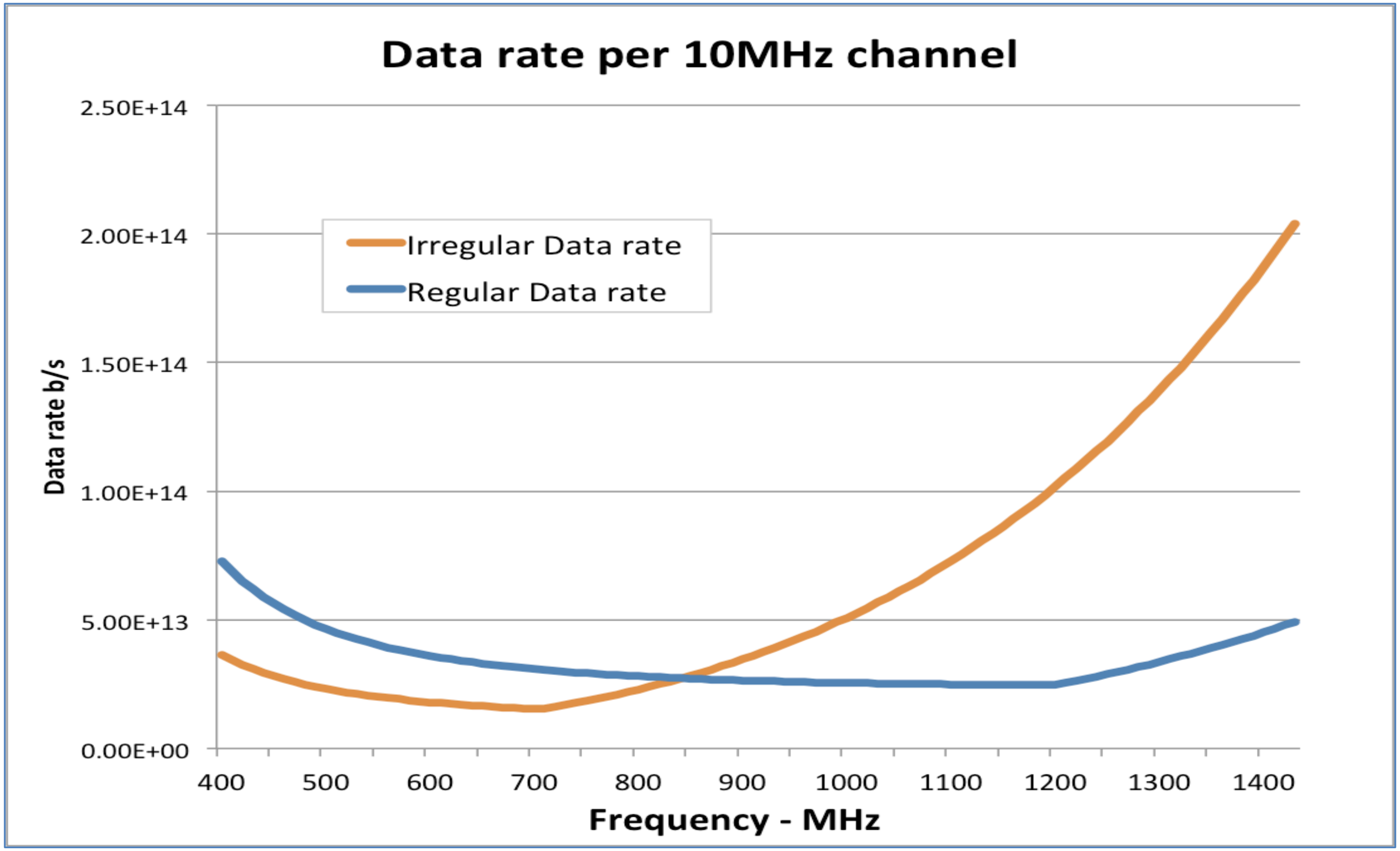
The A_{eff} of the LPD is: $\sim\lambda^2/2$ – where sparse enough.

Max is the physical area typ. $\lambda^2/4$ (dense regime)

Survey speed



Data rates



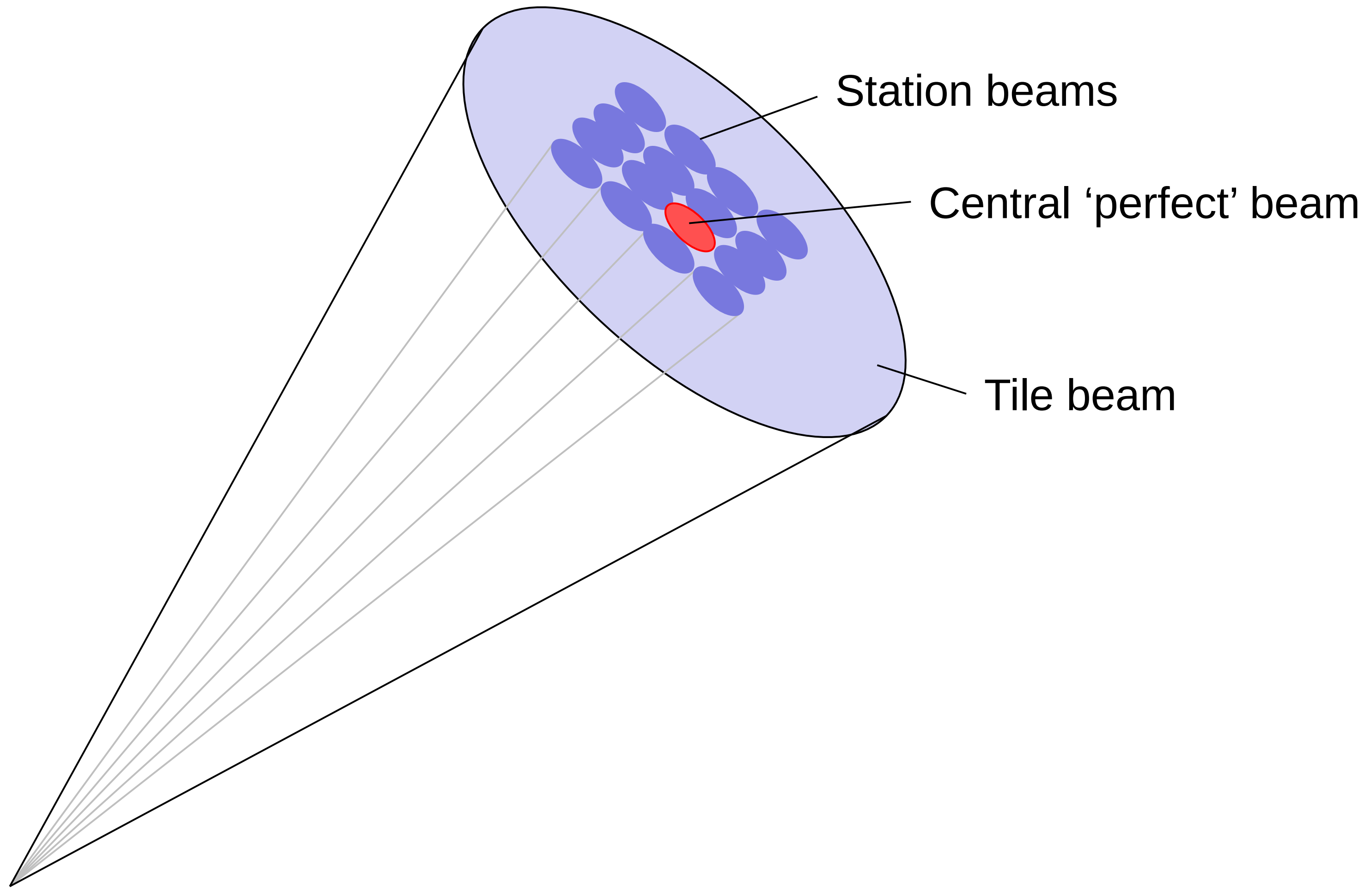
Data rate per 10MHz channel
2.50E+14
2.00E+14
1.50E+14
1.00E+14
5.00E+13
0.00E+00
Data rate b/s
Irregular Data rate
Regular Data rate
400
500
600
700
800
900
1000
1100
1200
1300
1400
Frequency - MHz

Power and cost estimates using sparse…

Quantities		Power			Cost	
			Each	Total	Each	Total
2^{23} Antennas	2^{13} Ant/station	Antennas	1 W	8 MW	€30	€240M
2^{16} TPMs	2^{10} Station proc.	TPM	150 W	10 MW	€2500	€160M
2^{10} stations	2^{10} Racks	SPM	1 kW	1 MW	€10,000	€10M
2^{7} Ant./TPM	2^{6} TPMs/rack	Switches	250 W	0.5 MW	€5000	€10M
2^{5} Fibres/TPM	2^{2} Ant./fibre	Servers	1 kW	1 MW	€5000	€5M
2^{11} Data switches	2^{10} Servers	**Total** (inc.25% losses)		**25 MW**	(inc. 30% for INFRA etc.)	**€550M**

8million antennas
1024 racks

2-stage beamforming



Tile Beamforming