Wide-band Receivers and EVN future upgrades

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- DISCLAIMER – my personal view – not of EVN as a whole, which will come out of future science vision/technology roadmap process.

1) Science case of ultra-broad band versus conventional octave receivers

CONS

- At given frequency lose sensitivity relative to octave (but can be acceptable - 10%.-15% -see later)
- May be more susceptible to RFI (but now no band is safe, and can mitigate with blocking filters)

PROS

Ultra-wideband case best if there backend that we can process the additional frequency range allowed by the broad band receiver.

Also when there is not one killer science goal demanding highest possible sensitivity at a single frequency - (i.e. VLBI case different from SKA case).

PROS (cont)

- 1) Increase total BW around desired frequencies to more than compensate continuum sensitivity at each band

- 2) Get excellent ‘filled’ MFS uv coverage image at any desired frequency within the receivers

- 3) Get multiple bands in one observing run, further improving sensitivity - achieve ‘Holy grail’ of EVN frequency agility

- 4) Get position-aligned images at multiple frequencies - get high quality continuum spectral index information

- 5) Get broad spectral properties of fast transients (i.e. extend recent Breakthrough Listen dynamic spectra 4-8 GHz to wider frequency range)

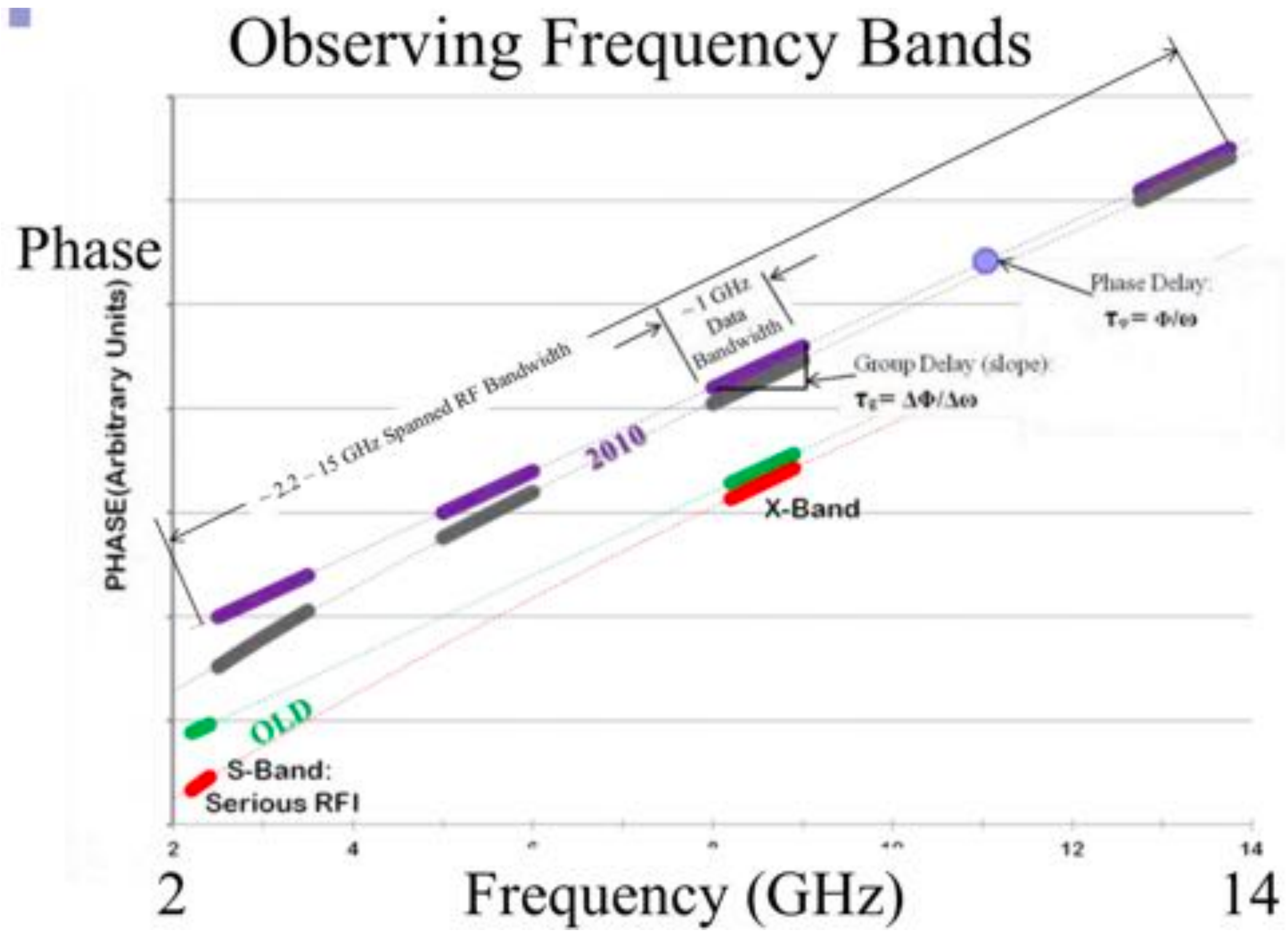
- 6) Replacing existing octave receiver with wideband receiver give station access to new frequency regions e.g. 15GHz

- 7) Lower maintenance costs including calibration time. Especially for new stations - cheaper to buy one receiver compared to three.

- 8) Compatible with geo-VLBI VGOS antennas.

- 9) Extrapolate atmosphere solutions at low frequency to high frequency to extend coherence time at high frequency and image weaker sources

2) Leveraging existing technical developments for geodetic -VLBI + SKA



VLBI Geodesy Observing System (VGOS) observing concept

- need ultra-wide band to get accurate group delays- = derivative of phase versus frequency – needs large lever arm in frequency

VGOS Fast Slewing Telescopes

Wetzell, Germany

Onsala Twin Telescopes

Ishioka (JP) Courtesy Y. Fukuzaki

Yebes (Spain)
(August 2013) Courtesy:
J.A. Lopez

Badary (RU)

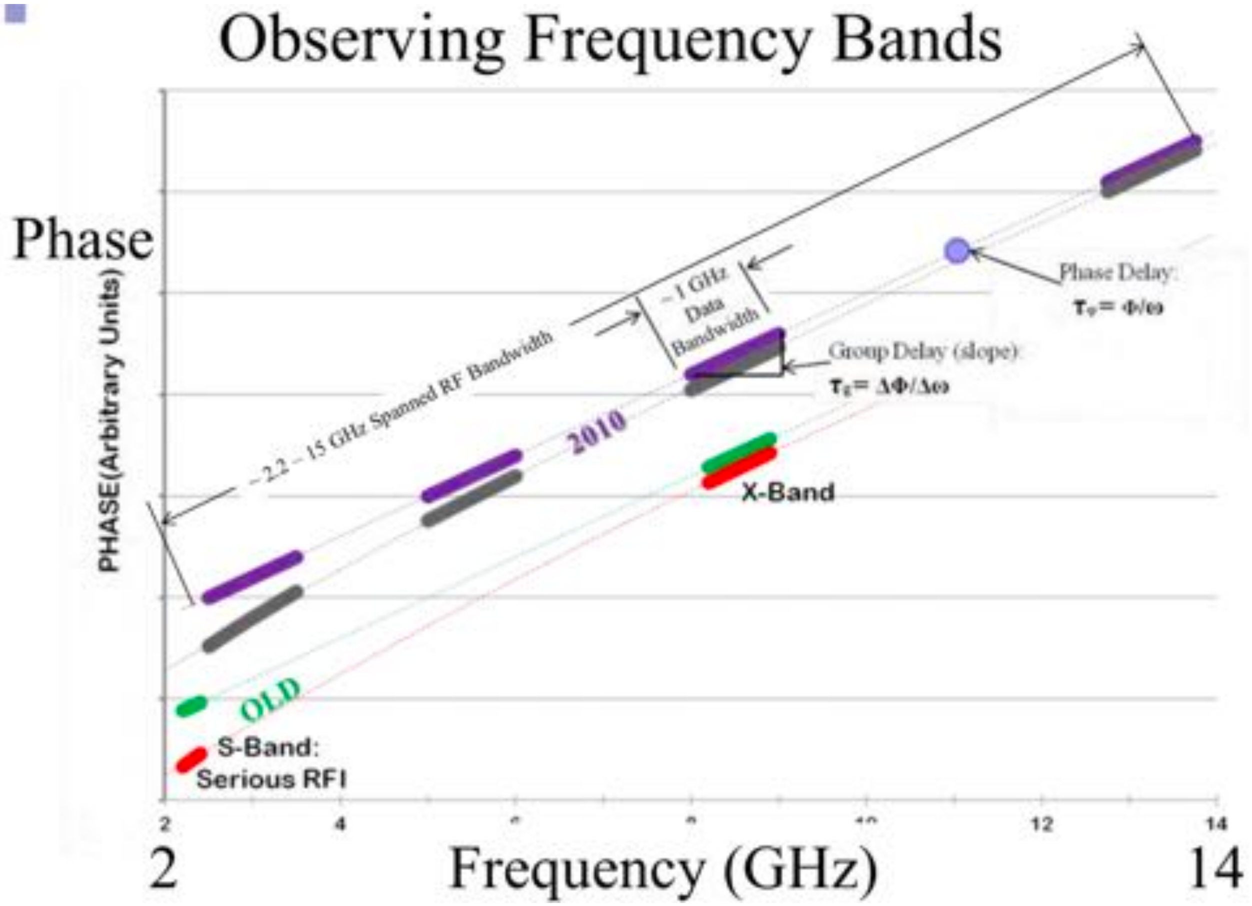
Zelenchukskaya (RU)

GGAO (US)

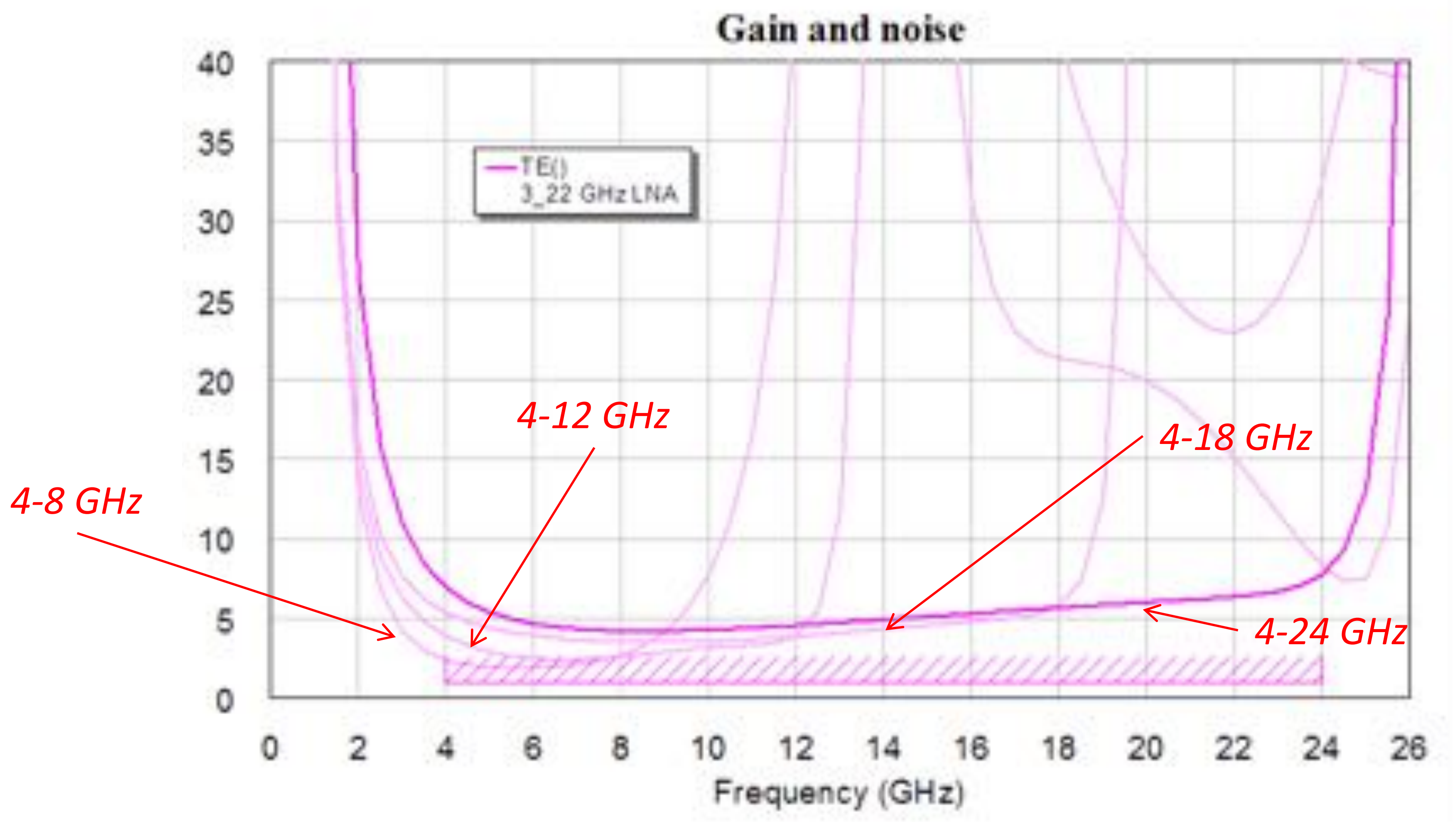
Santa Maria (Eastern Azores)
(Sep. 2014) Courtesy: F. Colomer

VGOS also Requires

1) Broad Band LNAs
2) Wide band data acquisition and recorders
3) Wide band feeds



Broad Band LNA, only modest Tsys penalty for wide bands



- Modelling of Low Noise Factory LNA's made in Chalmers University clean room. Four different designs for four different bandwidth- the noise for 4-12 GHz only about 0.5 K - 1.0 K higher than for 4 – 8GHz.

Backend

- DBBC3 in production – **can already cover 4 x 1GHz bands dual polarization**. → output 32 Gbps
- Units deployed at Onsala and other VGOS antennas and at Event Horizon Telescope (EHT) telescopes
- Development has been funded by VGOS and EHT – can be exploited for cm VLBI needs

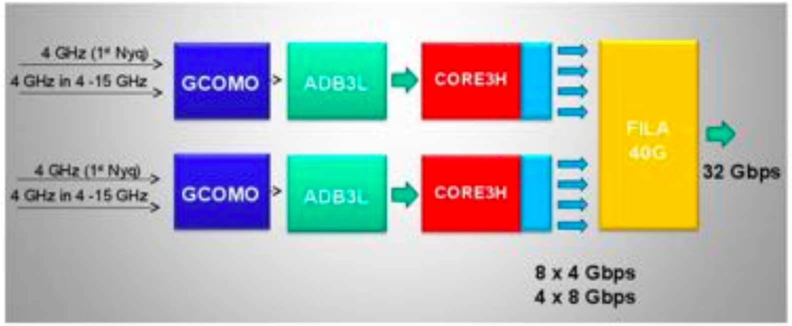


Fig. 1 DBBC3 block diagram.

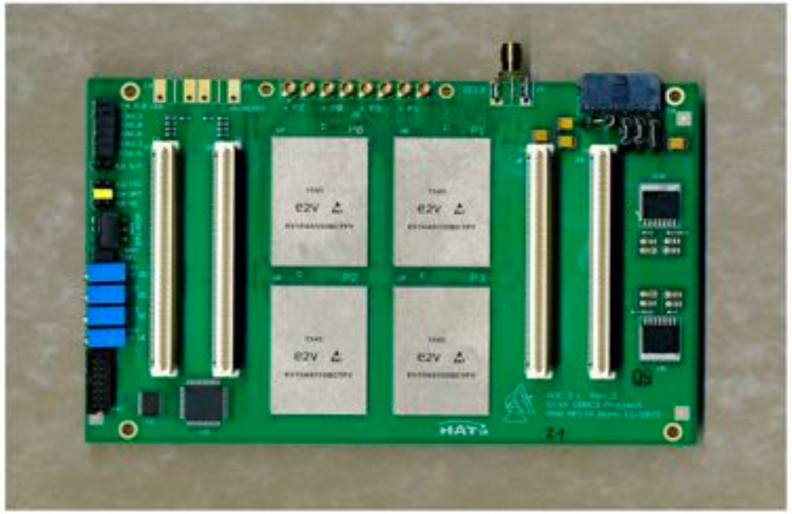
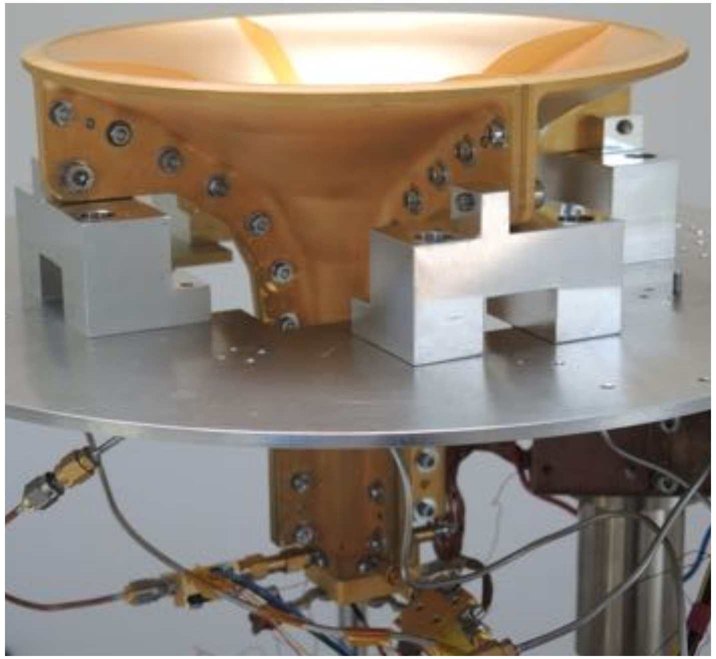


Fig. 2 ADB3L sampling board.In the centre the four sampling chips can be seen.

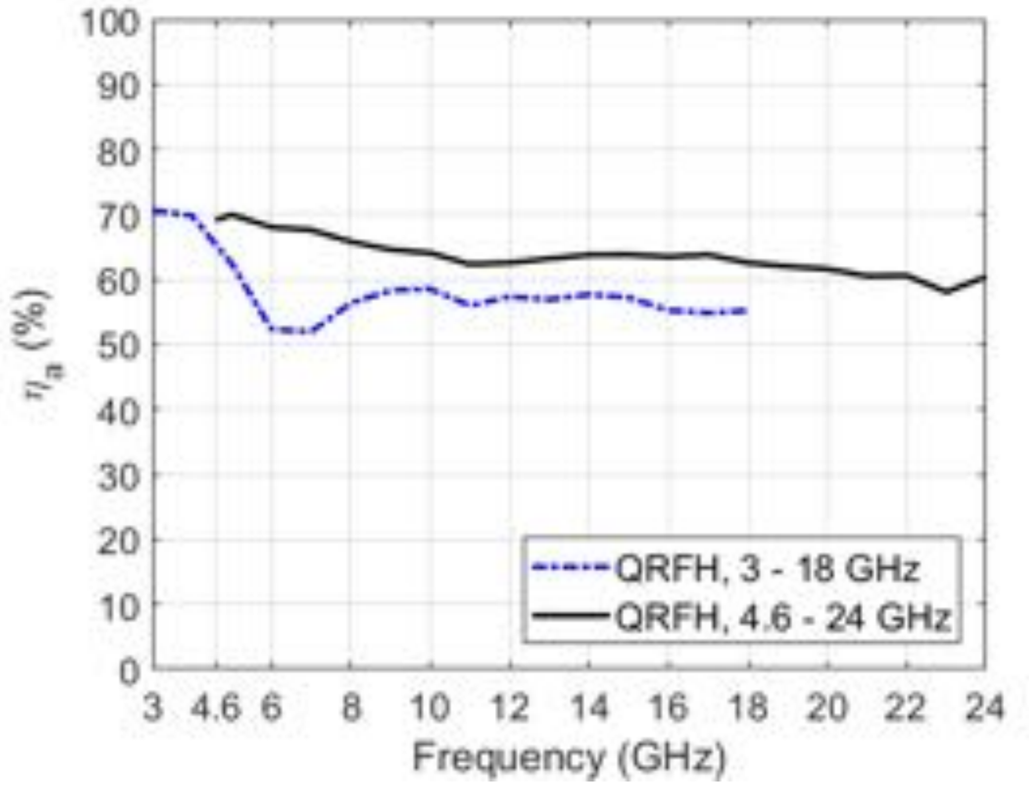
Broad Illumination Angle Broad Band Feeds - Quad-Ridge Flared Horns

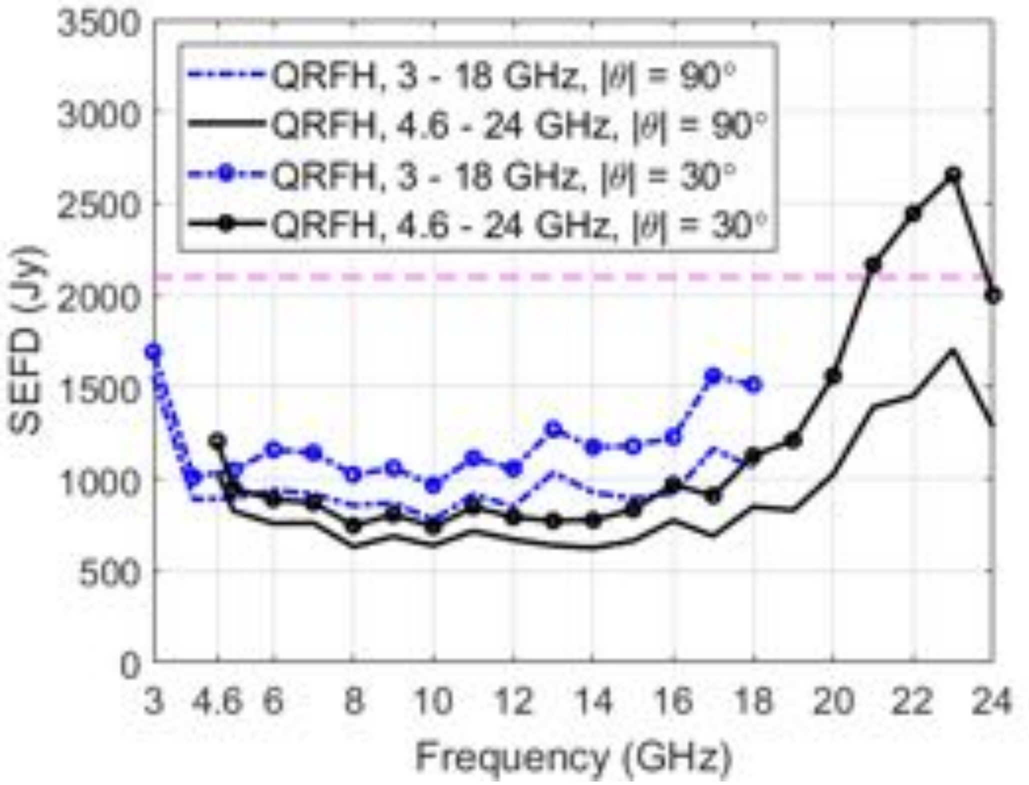
Caltech feed – deployed on
OTT telescope.



4.6 – 24GHz feed developed
for SKA WBSPF AIP

Expected Performance of Onsala Twin Telescope



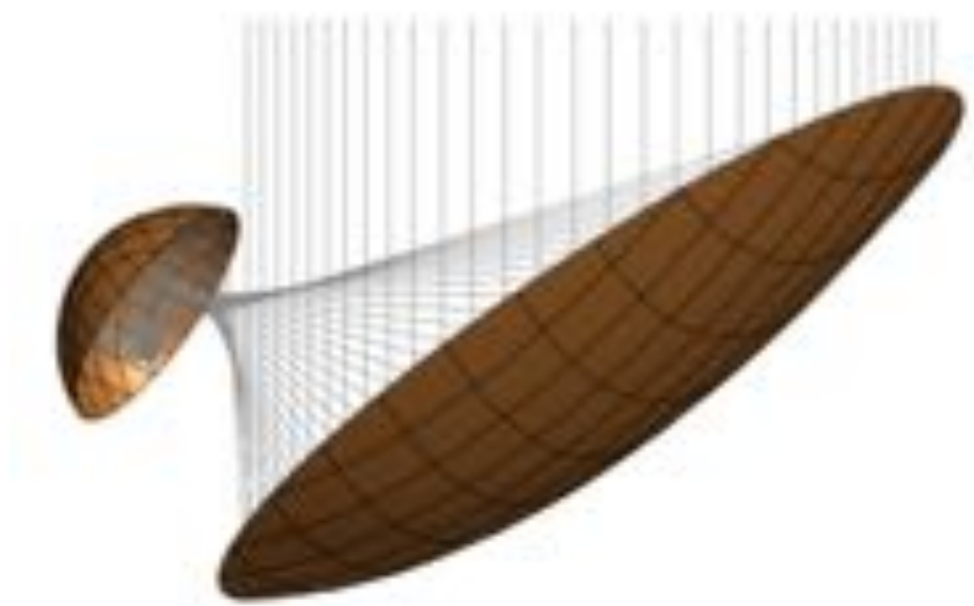


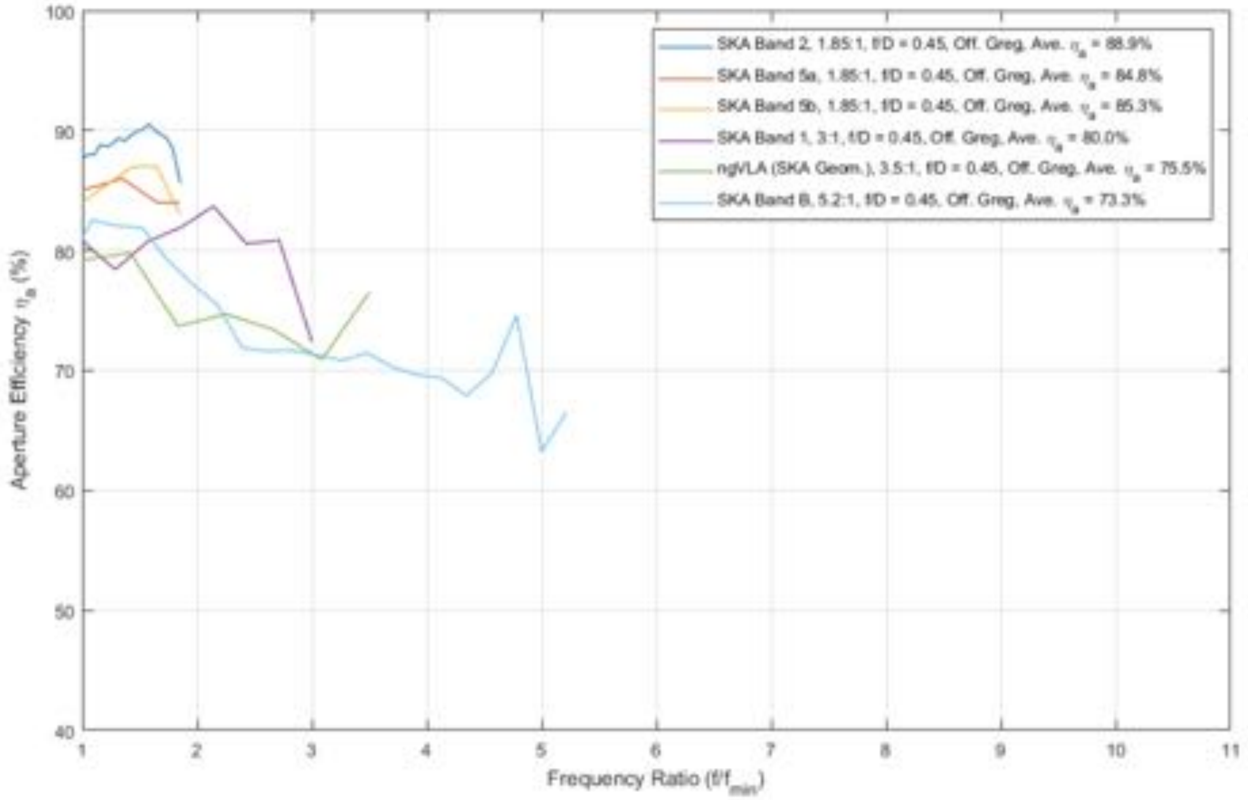
Blue lines – Caltech feed on OTT –simulated performance
Black Line - SKA feed in OTT – simulated performance, mean 65% aperture efficiency (including blockage) over range 5.2 in frequency

3) BRoad bAND EVN   (BRAND – EVN)

- Radionet JRA – goes beyond VGOS
- WP on Backend (led by IRA) capable of sampling **full band** 1.5 – 15.5Ghz i.e BW= 14 GHz or 3.5 times VGOS bandwidth.
- Work on high temperature **superconducting filters** to block strong RFI regions.
- Further development of broadband LNA’s
- Wideband feeds capable to cover up to 10:1 ratio.
- Go for linear pol – development of new pol calibration method (Marti -Vidal etc developed for EHT) makes old requirement of circular pol for VLBI not needed.

**Unblocked Apertures - ** SKA dish geometry, compilation from Jonas Flygare, OSO



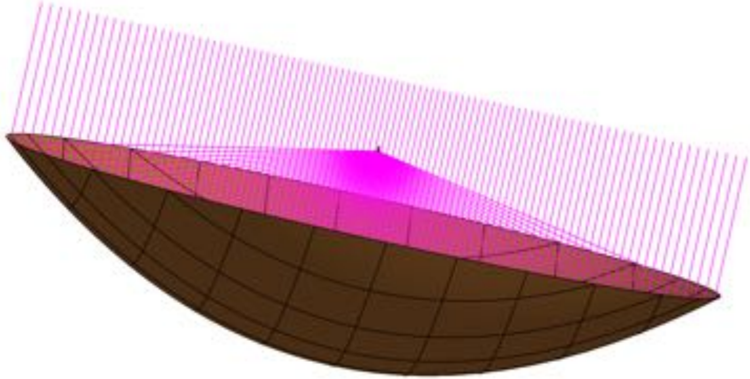


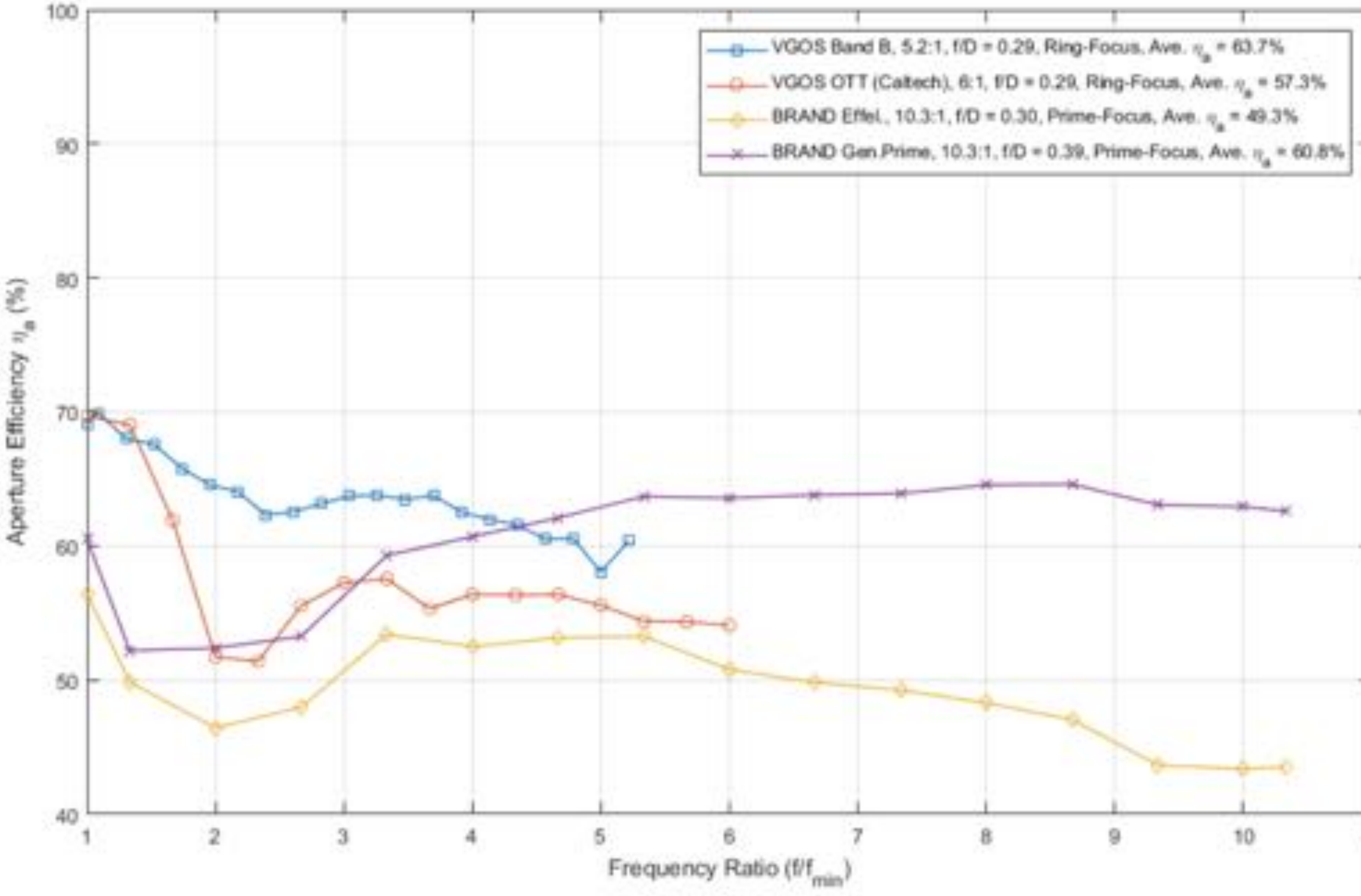
Trade-off between bandwidth and aperture efficiency. Compared to Corrugated horns (1.8:1) lose 10% going to 3:1 and 20% going to 5:1

SKA Band 1, developed at Onsala 3:1, 80% mean aperture efficiency (peak 85%).

Blocked apertures - large illumination angles - as in OTT ring focus and for Prime focus illumination of EVN antennas such as Effelsberg

- BRANd -Effelsberg, Prime-Focus
- $\theta_o \approx 79°$ x 2
- f/D = 0.30
- D = 100 m
- Freq = 1.5 – 15.5 GHz





EVN antenna geometries (incomplete)

	Station	Type of reflector optics	Feed illumination angle (half angle(	Wideband Option
1				
2	Effelsberg	Prime Focus	79	Quadrige, non-optimum
3	Effelsberg	Cassegrain		
4	Onsala 25 m	Cassegrain	14	Smooth Spline
5	Onsala 20 m	Cassegrain	6	Smooth Spline
6	HartRAO 26 m	Cassegrain; unshaped parabola + hyperbola	13	Smooth Spline
7	HartRAO 15 m	Prime focus; unshaped parabola	51	QuadRidge
9	Noto	Cassegrain configuration	19	Smooth Spline
10	Noto	Primary focus configuration	76	Quadridge, non-optimum
11	Svetloe, Zelenchuckskaya, Badary	Cassegrain	21	Smooth Spline
12	Medicina	Cassegrain	19	Smooth Spline
13	Yebes	Nasmyth	4	Smooth Spline
14	Torun	Cassegrain	19	Smooth Spline
15	Sheshan	Cassegrain	20	Smooth Spline
16	SRT	Shaped-gregorian design	12	Smooth Spline
18	Ro70m	Cassegrain	16	Smooth Spline
19	Lovell	prime focus	79	Quadridge, non-optimum
20				
21	MkII	prime focus	53	Quadridge
22	Defford	prime focus	56	Quadridge
23	Cambridge	Cassegrain	17	Smooth Spline
24	Knockin	Cassegrain	18	Smooth Spline
25	Pickmere	Cassegrain	18	Smooth Spline
26	Darnhall	Cassegrain	18	Smooth Spline

Note Quadridge performs best for half illumination angles 45 – 65 degrees, for EVN telescopes relevant for Prime focus..

For most EVN dishes that use secondary focus i-llumination angles are less than 20 deg.

Smooth spline feed as for ATCA 4- 12GHz (3:1) range 14 deg illumination – get similar performance as octave – the max 3:1 ratio limited by OMT – go wider with linear pol.

4) Multi-band receiver systems for 22 – 86 GHz

At high frequency very broad sensitive LNA's covering 22- 115GHz don't present exist (probably could but needs development) – can't in any case sample all the BW in forseeable future.

Given smaller physical scales at high frequencies can instead separate frequencies by dichroic mirrors

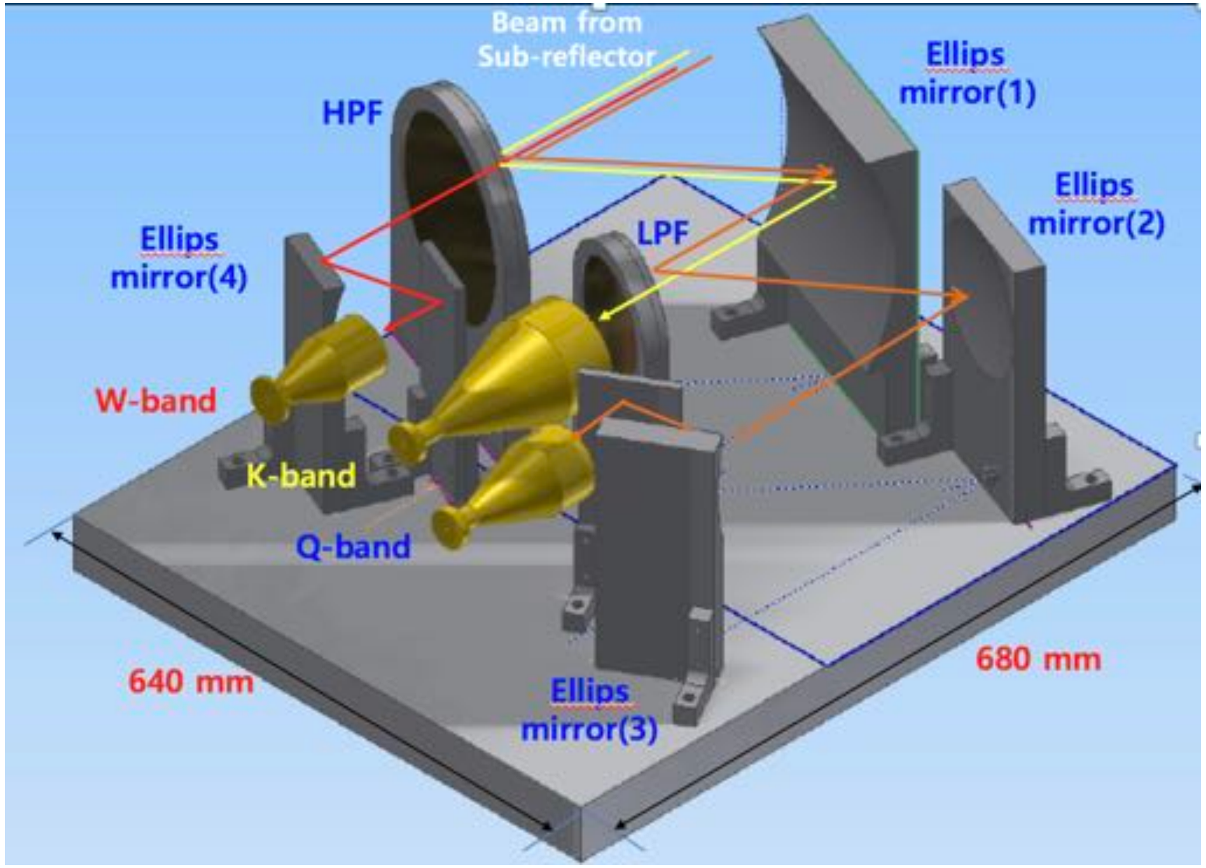
Seog-Tae Han, KVN, compact 3 band system

Yebes similar three band system and OSO/Bonn interested in this idea.

Observe multiple maser line simultaneous.

Position Registration of multifrequency line/continuum maps.

Use 22 and 43 GHz to get atmosphere phase, extend 86 GHz coherence time to look at weaker sources.



5) Getting from here to there….

- BRAND will tell us whether 10:1 (1.5 – 15.5GHz) is feasible, for both broad and narrow angle illumination systems…

- However we already know we can get 3:1/4:1 feeds with <10% efficiency loss for both broad (SKA) and narrow illumination… so……

- Just one Possible target for EVN future, even without demonstrating 10:1 frequency range.

- **A)** Replace current L band (1.6GHz) systems with octave 1.2 - 2.3 GHz. (overlap MERLIN L and S Band)

- **B)** Replace current octave C band (5GHz) systems with 4 – 16 GHz systems. i.e 4:1 ratio (linear polarization) system with target 10% -15% loss in aperture efficiency wrt octave) - overlap eMERLIN L, C and X bands.

Several motivations for an **Old station** to accept 10% -15% loss in sensitivity at any given frequency on replacing C-band with a 4:1 system.

- Increase total BW around desired frequencies to more than compensate for continuum sensitivity
- get MFS uv coverage around each desired image frequency.
- Get spectral index information.
- Determine instantaneous broad band spectral properties of transients.
- Observe multiple bands at once (EVN frequency agility)
- Create aligned multi-frequency images for spectral index
- Access to new frequency regions such as 15GHz.
- Compatible with VGOS antennas.
- Lower running costs for fewer receivers – including less time consuming to calibrate.

On **New antennas** cheaper to build one receiver than three (C,X,U)

- **C)** Replace current high frequency receivers with dual/triple frequency Receivers for 22/43/86GHz