Radio Telescope Receivers

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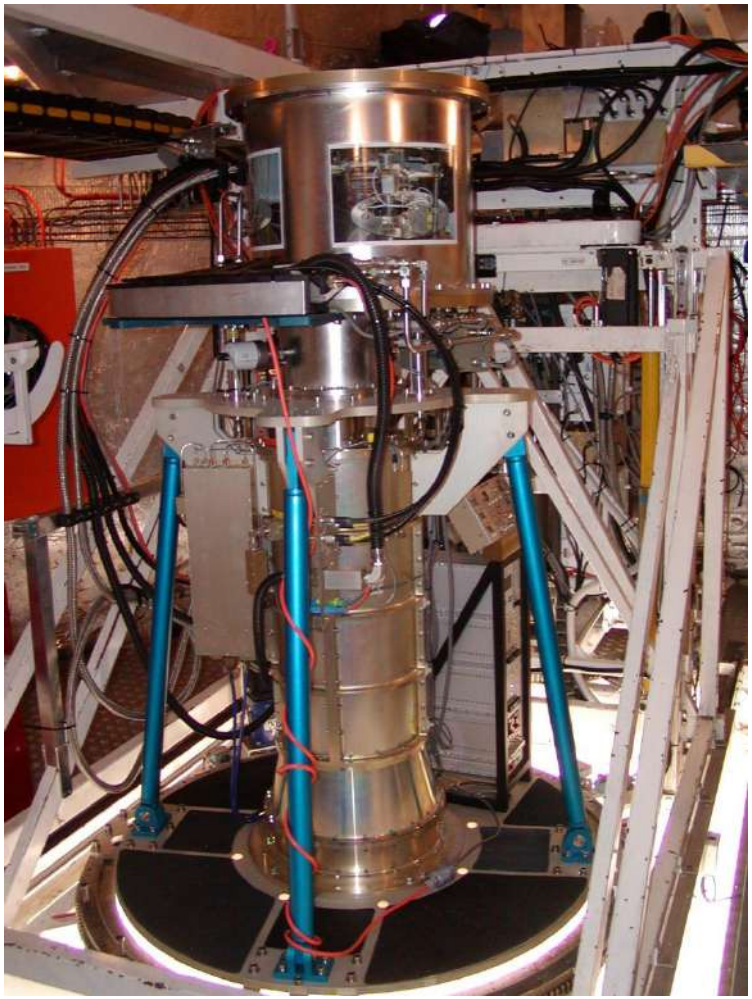
CSIRO ASTRONOMY AND SPACE SCIENCE
www.csiro.au

"A radio receiver is an electronic device that receives radio waves and converts the information carried by them to a usable form"

Wikipedia

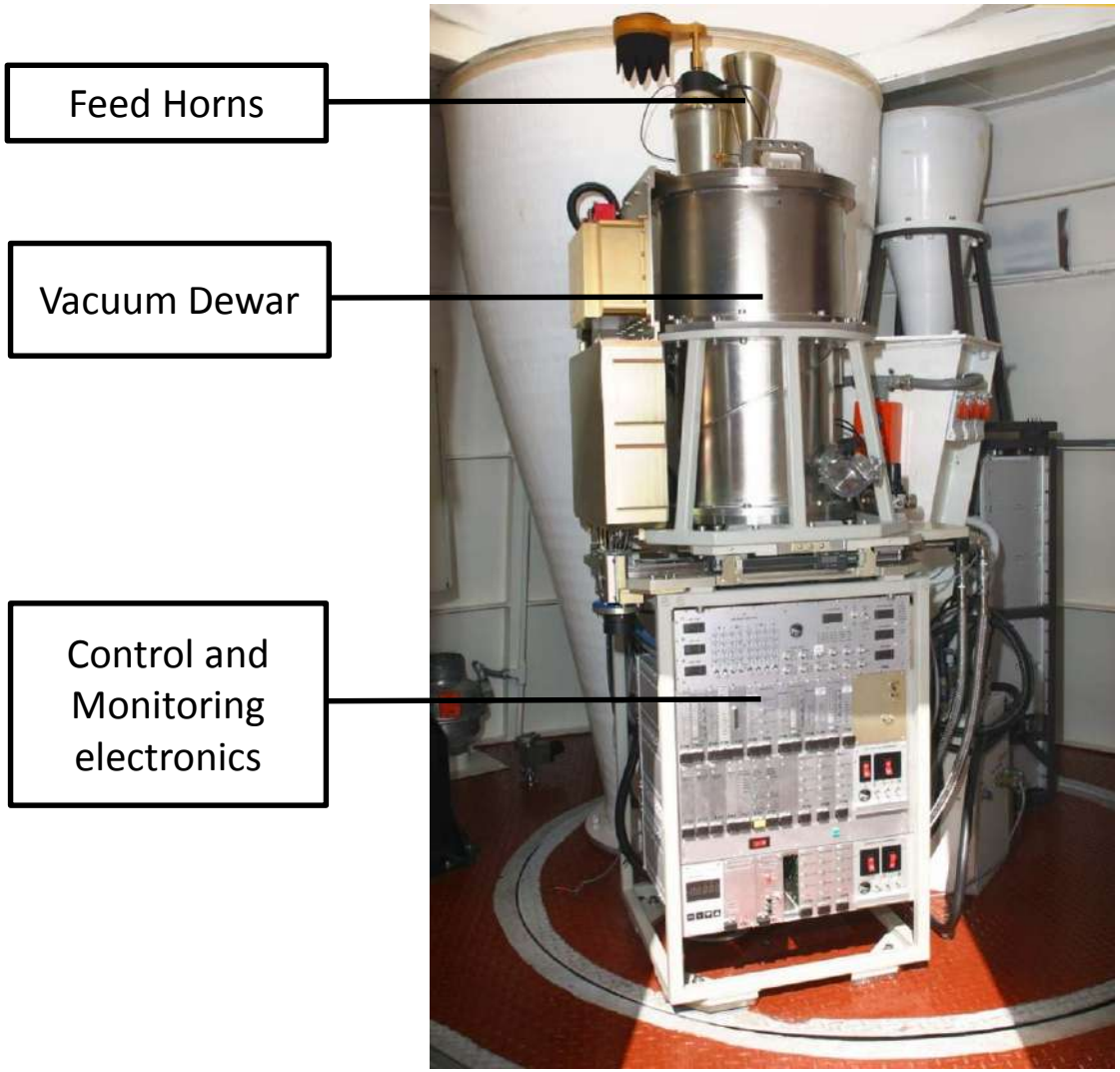
Ours look more like this

- Captures the signal reflected from the antenna
- Determines the beam shape
- Amplifies the signal
- Conditions the signal for digitisation

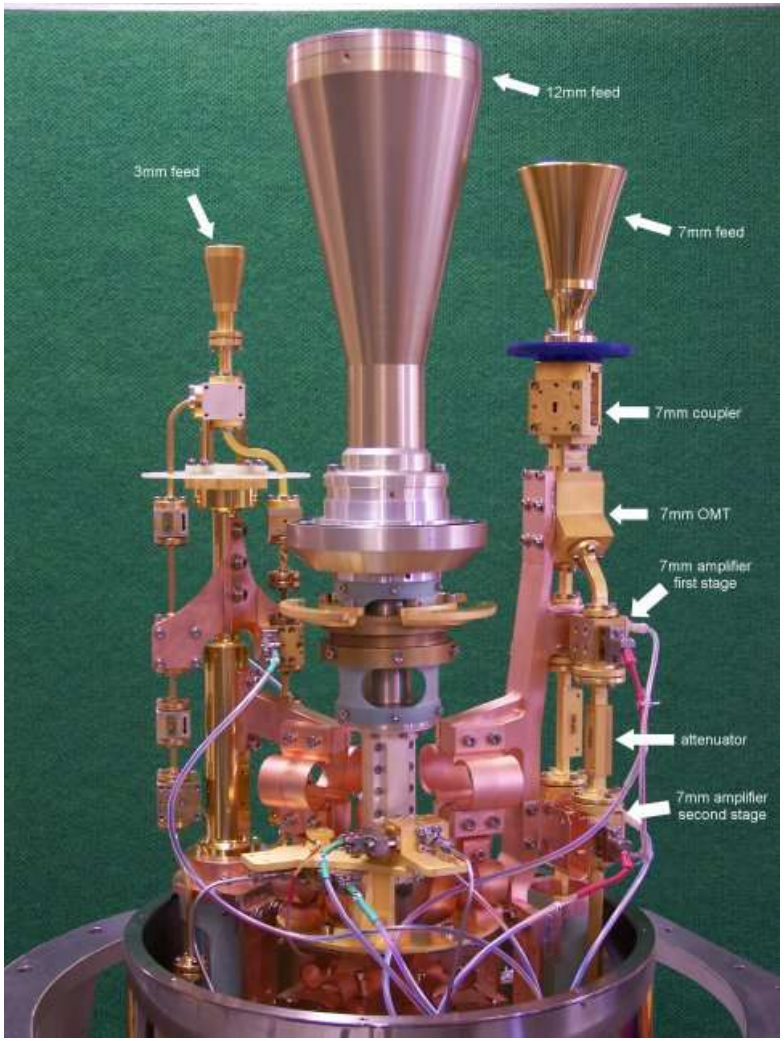


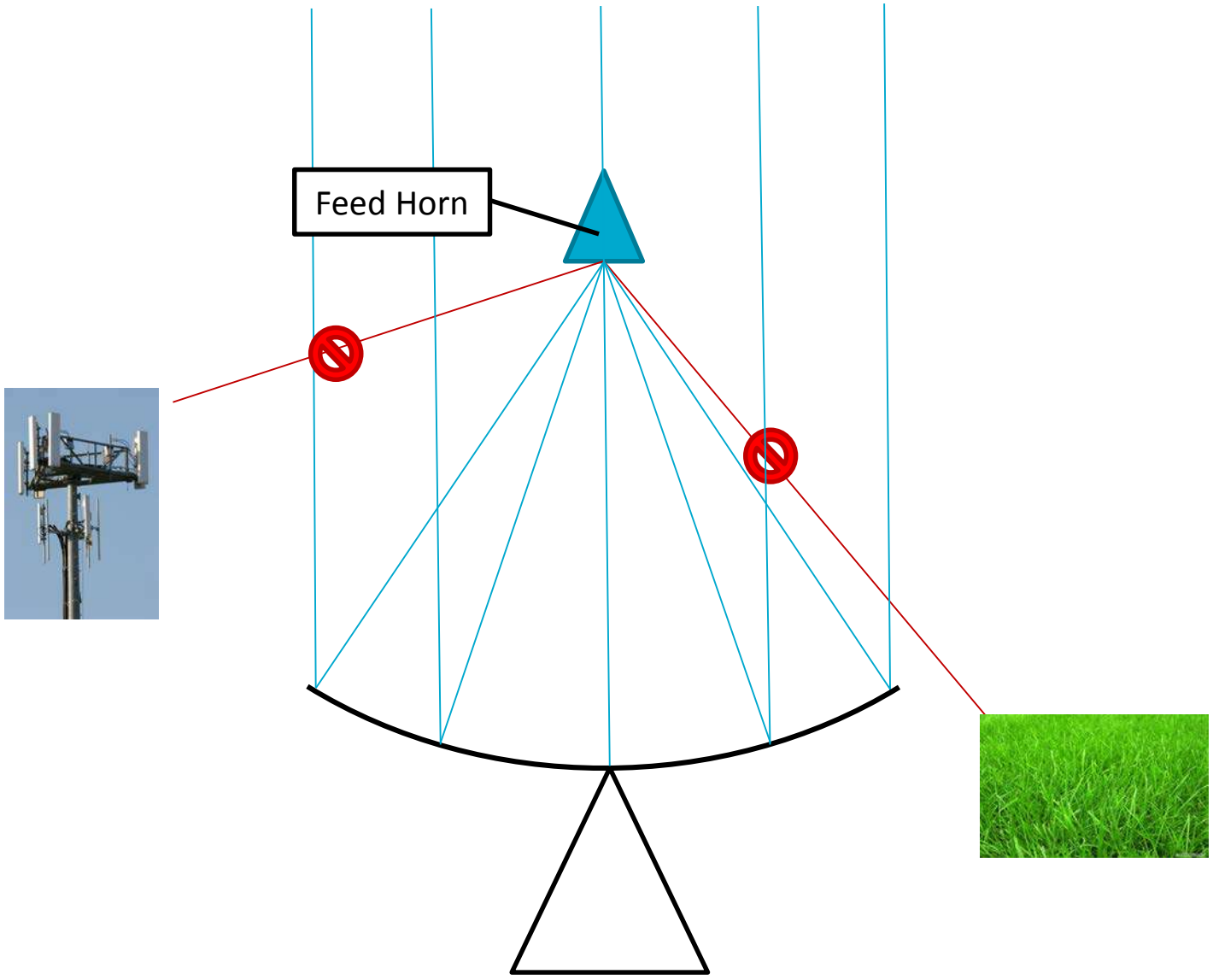
Parkes 10/40cm Receiver

On the outside…

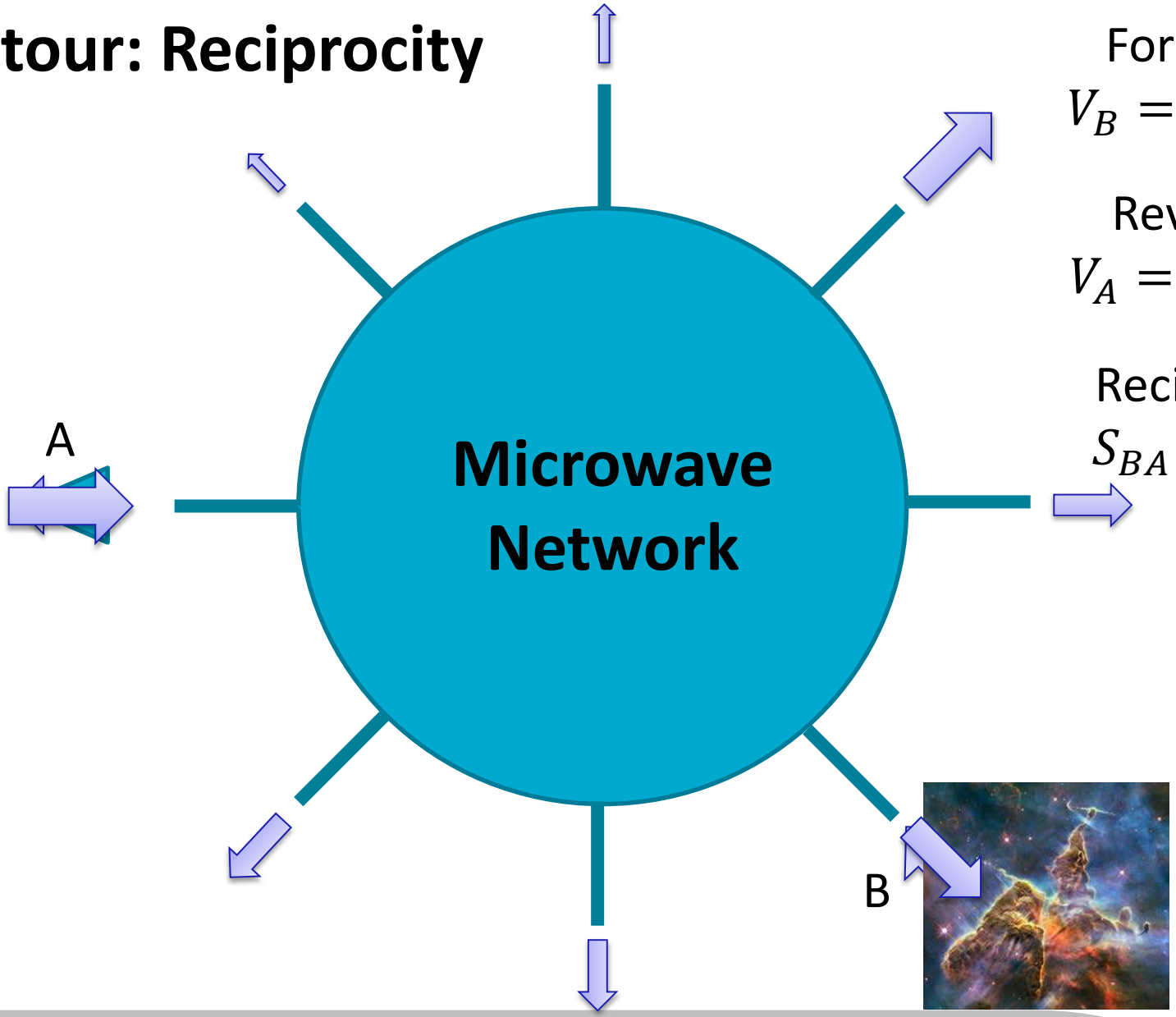


On the inside…




Feed Horn

Detour: Reciprocity



Forward

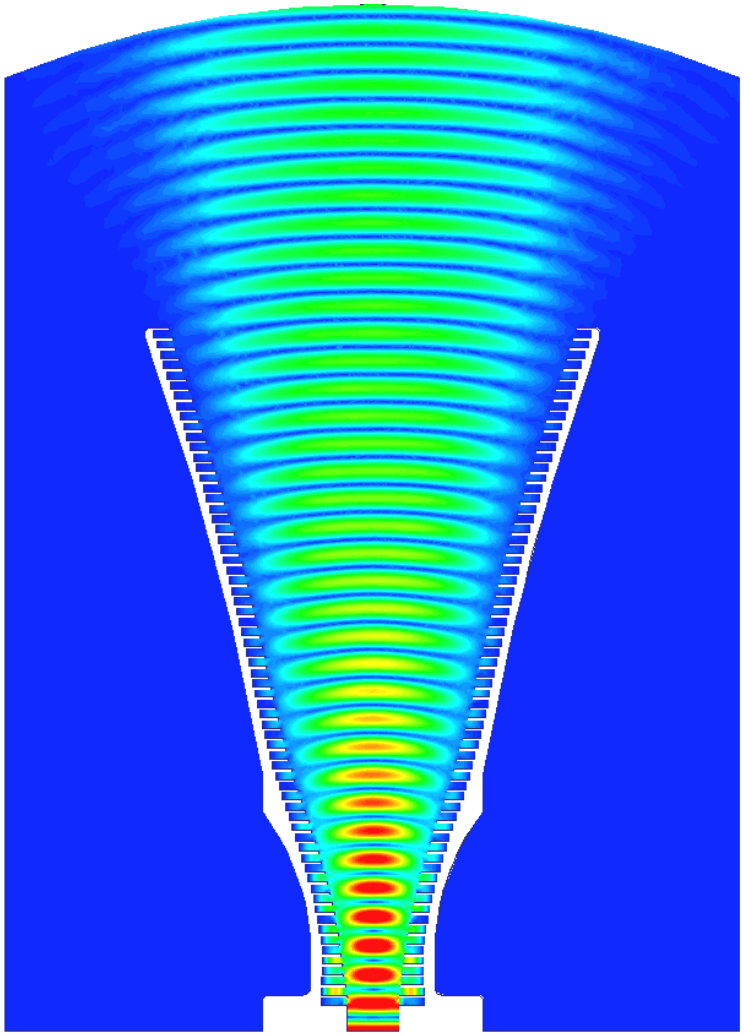
$$V_B = S_{BA} V_A$$

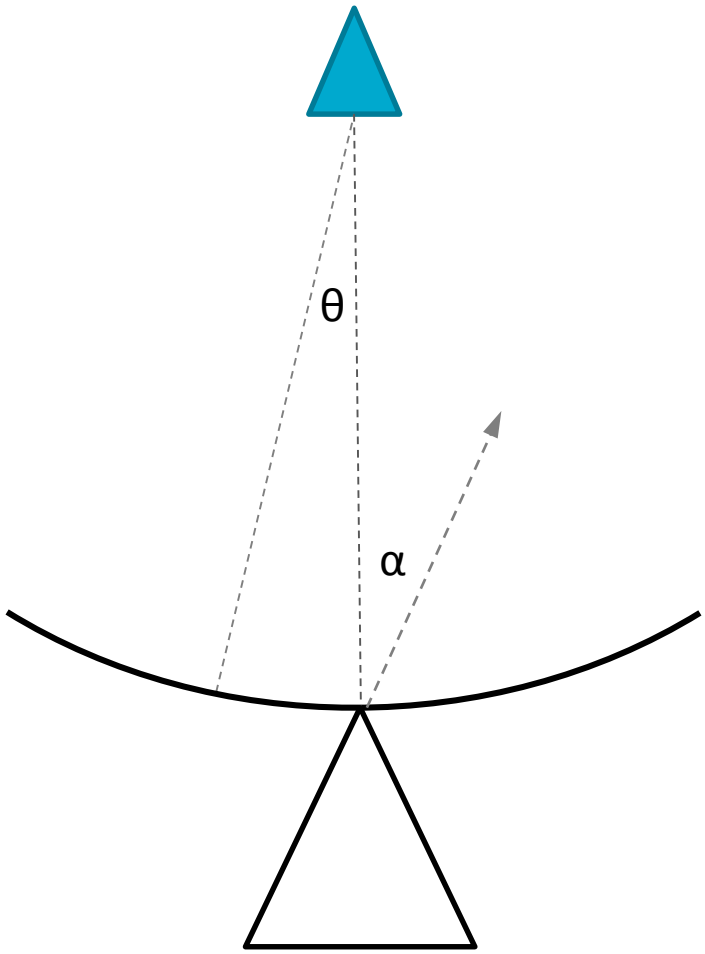
Reverse

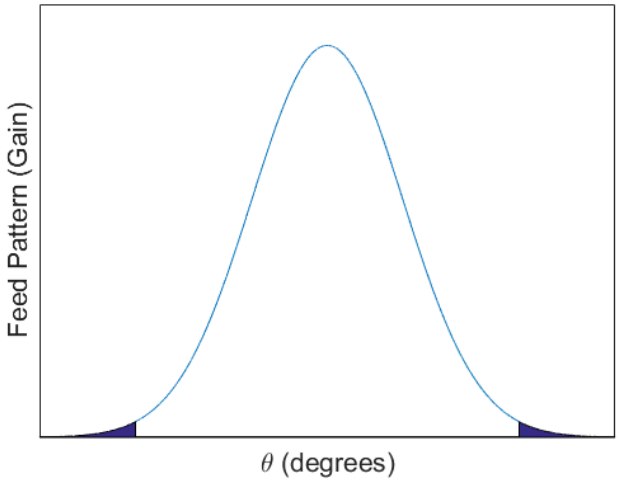
$$V_A = S_{AB} V_B$$

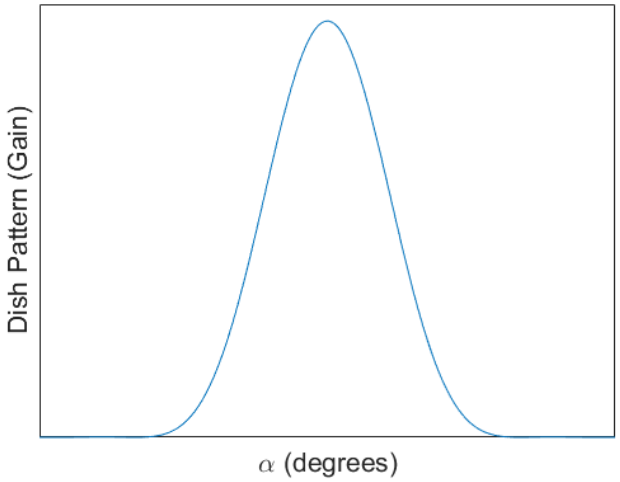
Reciprocal

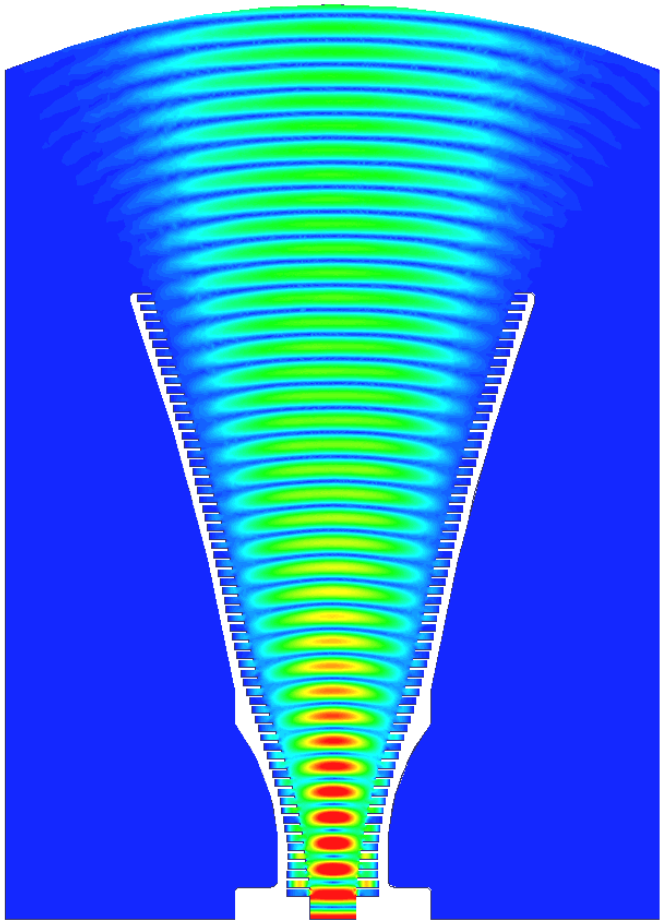
$$S_{BA} = S_{AB}$$

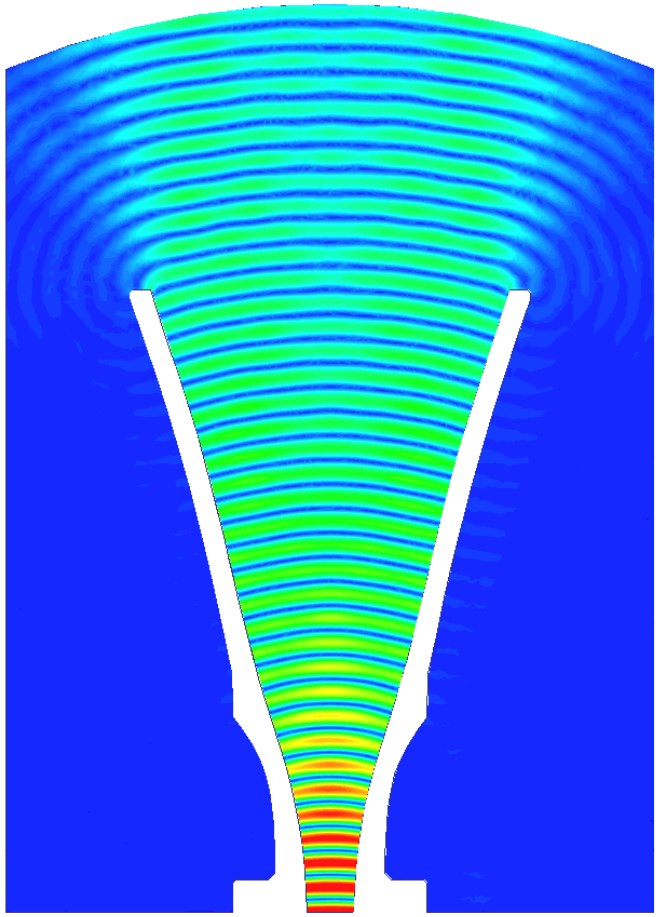



θ
α


Feed Pattern (Gain)
θ (degrees)


Dish Pattern (Gain)
α (degrees)

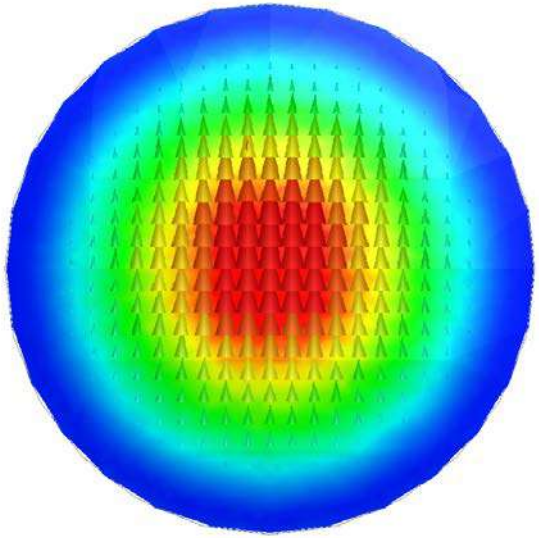


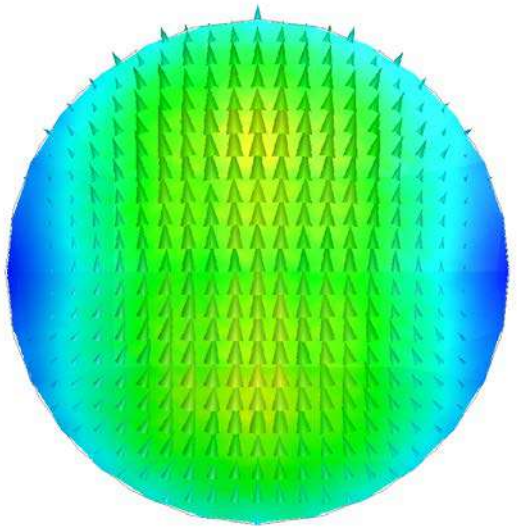


Corrugated

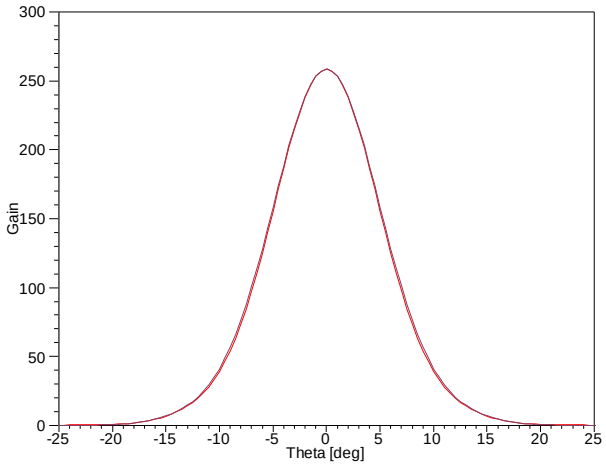
Smooth Walled

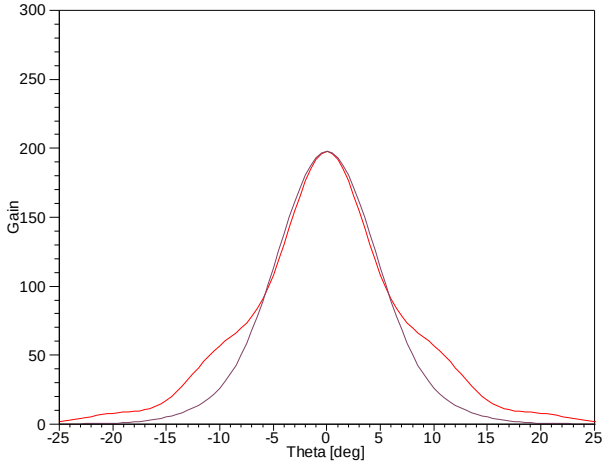
E-Field At Feed mouth

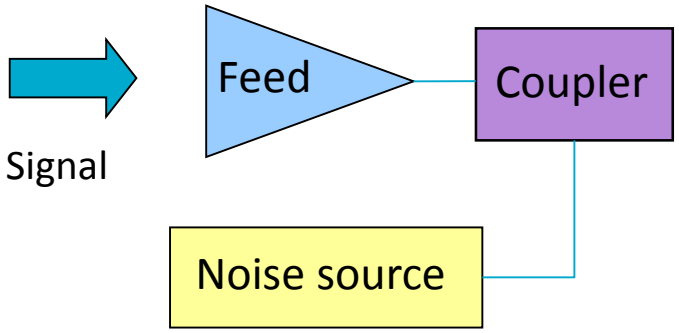


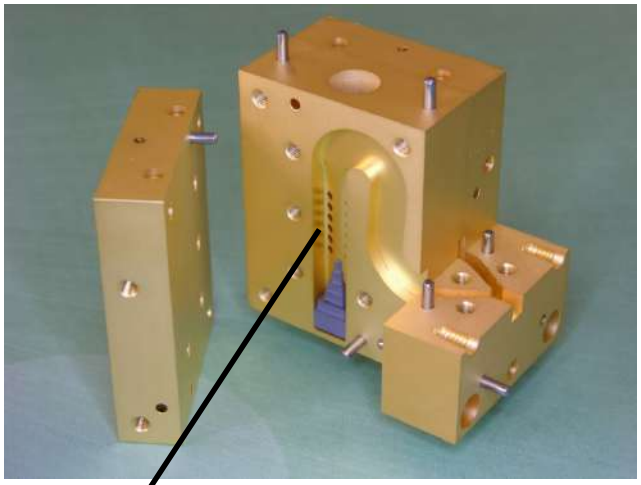


X and Y Feed Patterns



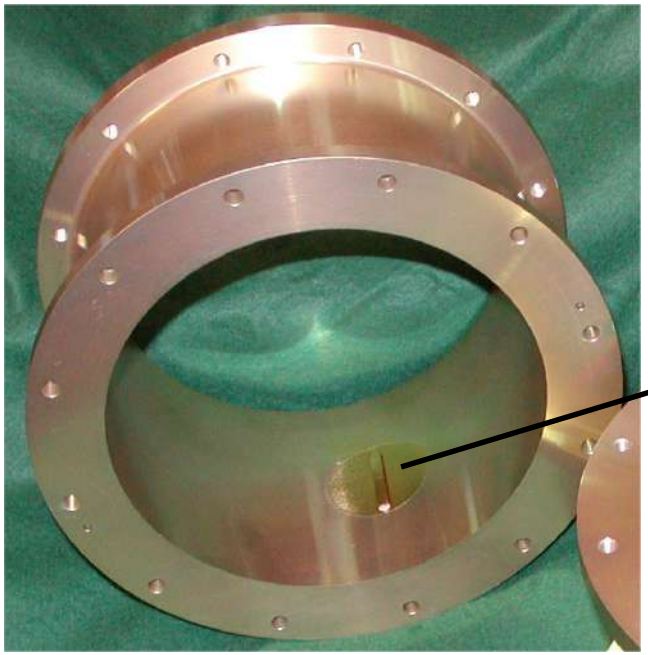






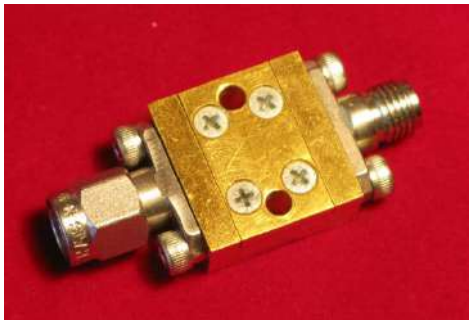
Noise coupled in through small holes

7mm waveguide coupler

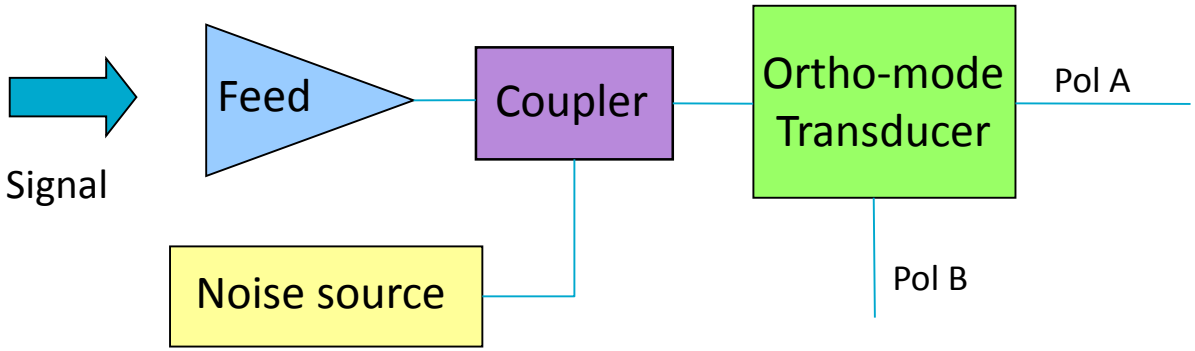


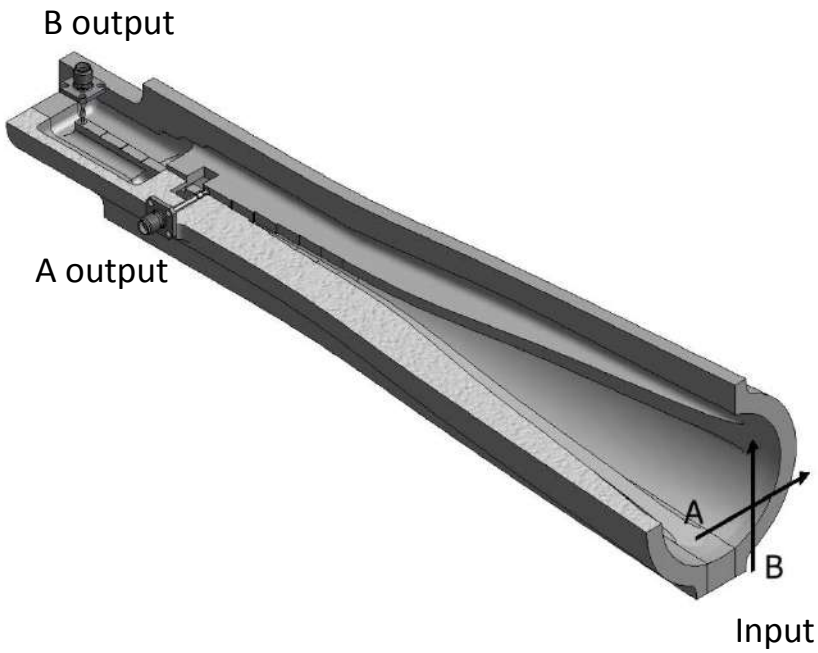
Noise coupled in through vane

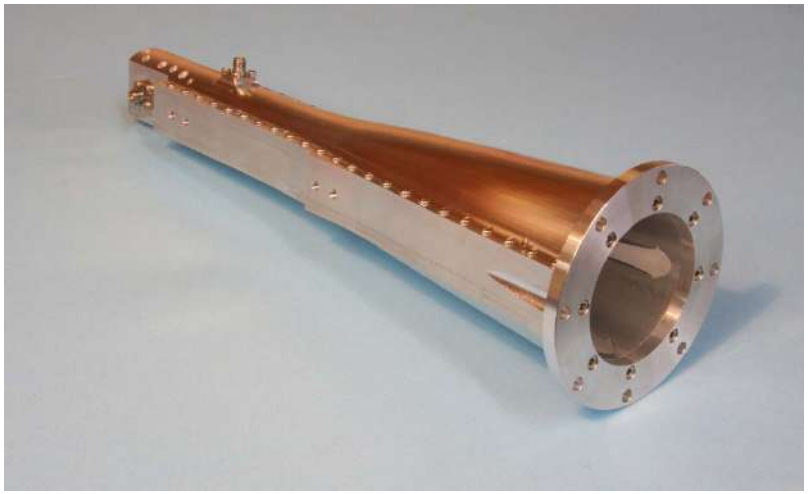
21cm waveguide coupler



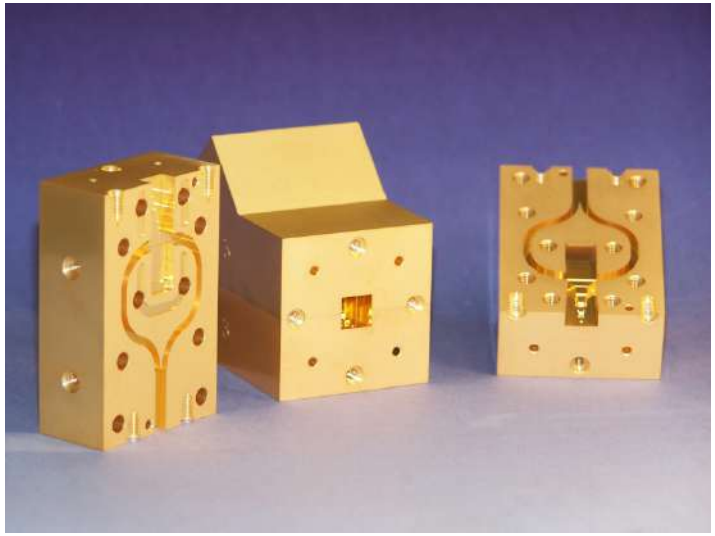
12mm noise source

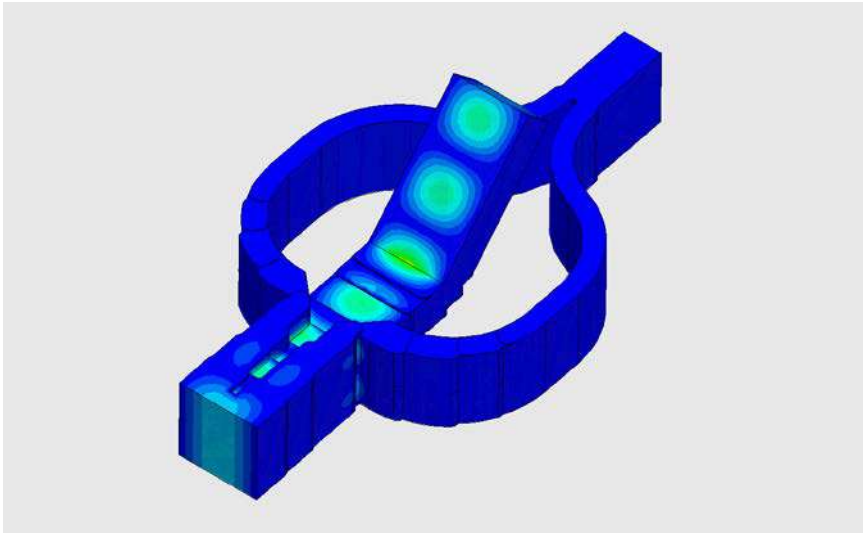

Signal
Feed
Coupler
Ortho-mode Transducer
Pol A
Noise source
Pol B

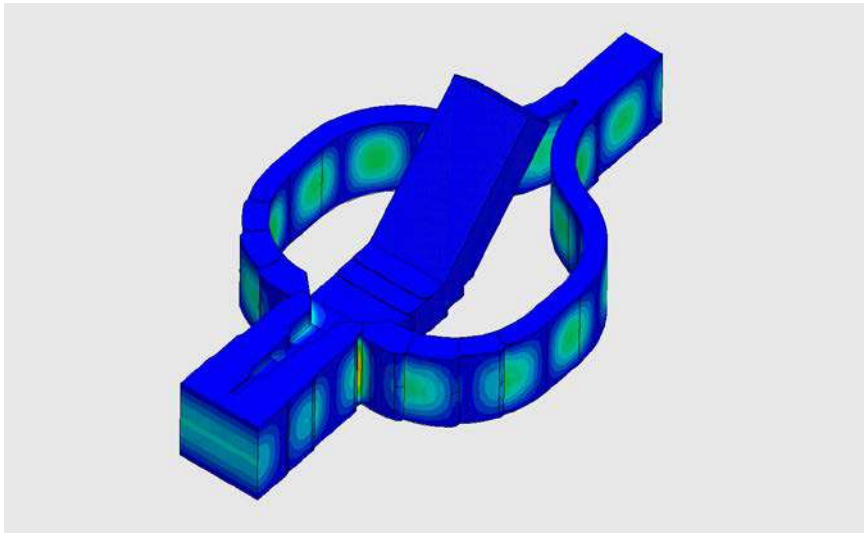

B output
A output
A
B
Input

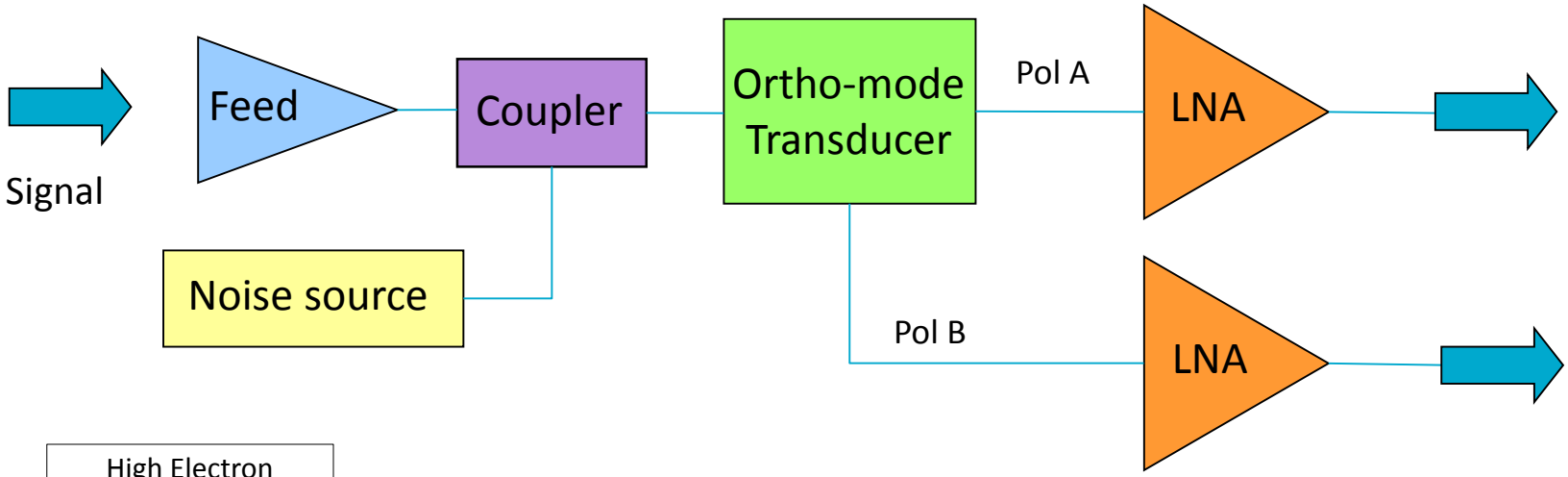


Separating the Polarisations: The OMT



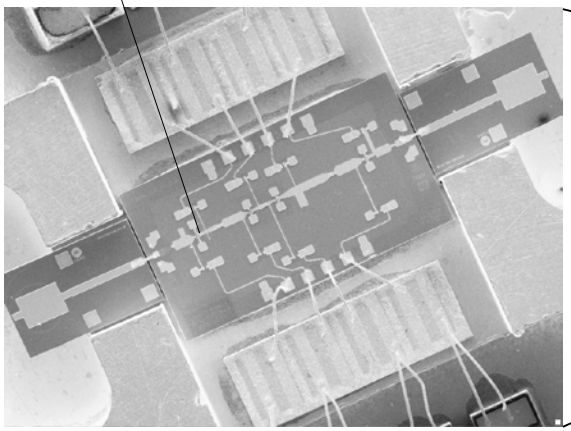


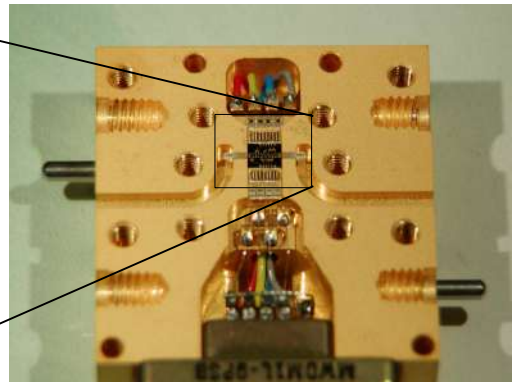


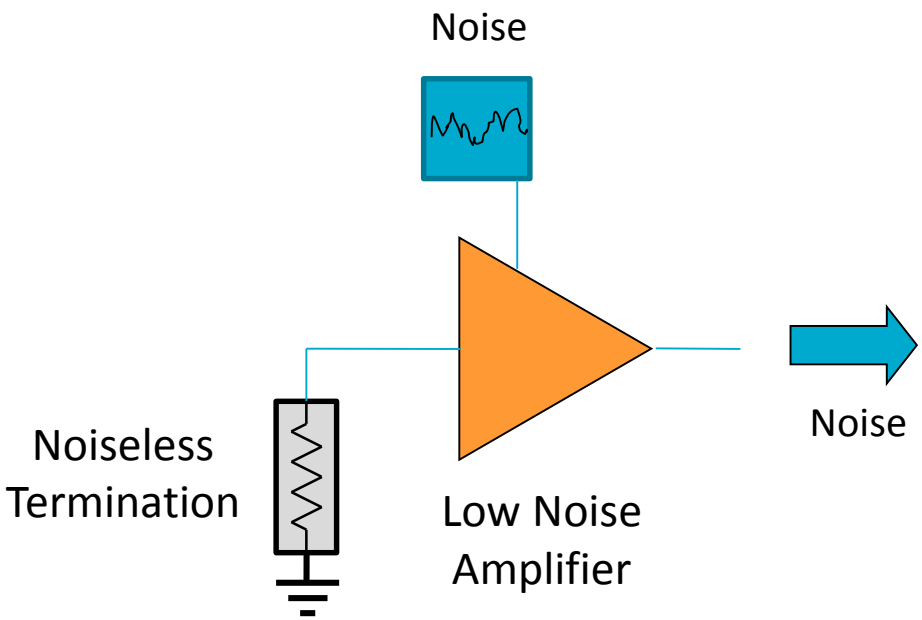


High Electron Mobility Transistor (HEMT)

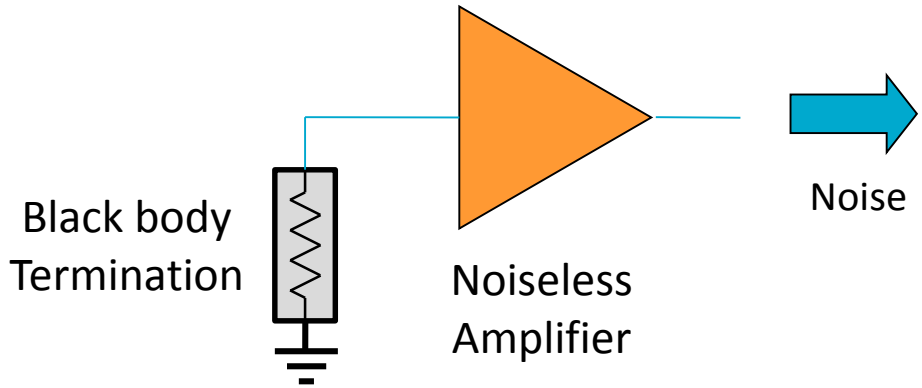
Low Noise Amplifier







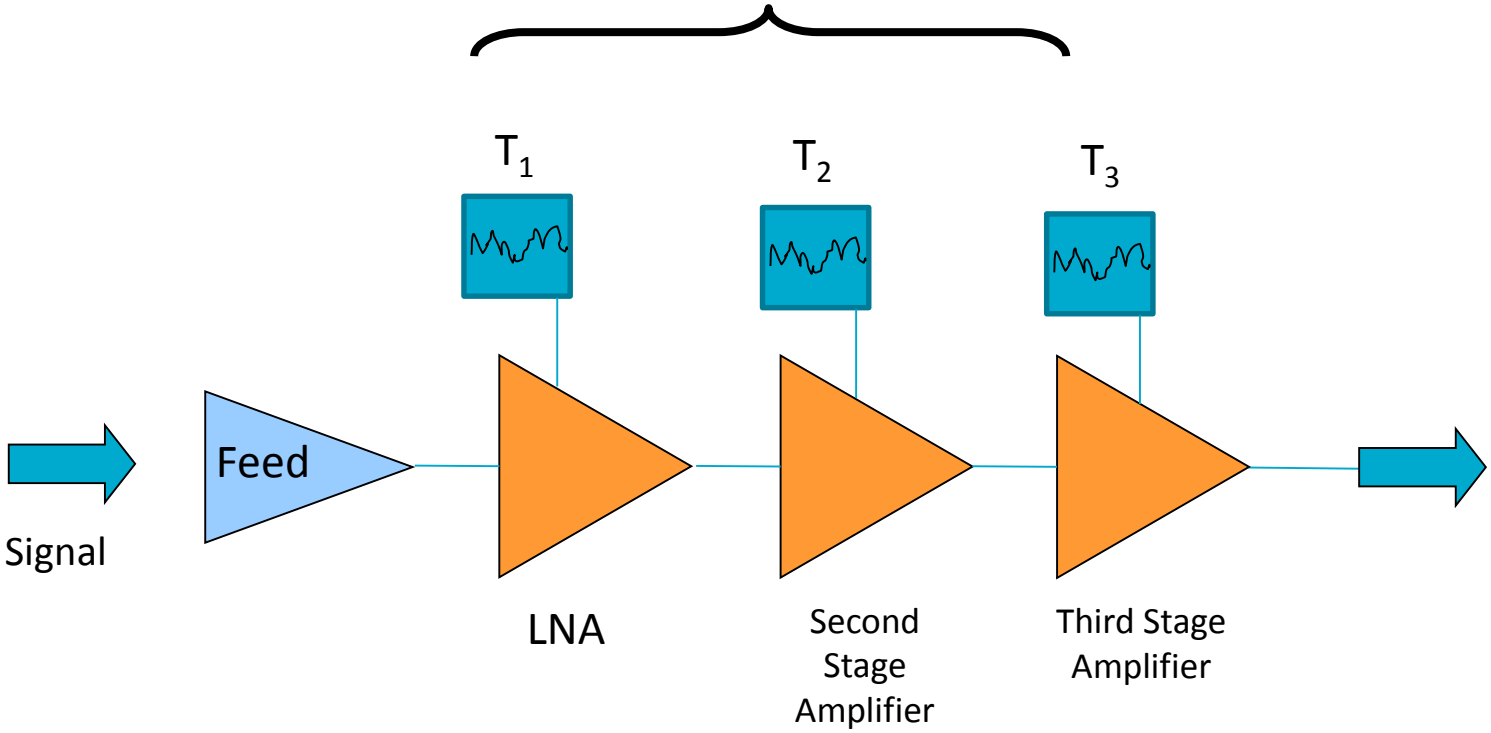
$$P_{output} \propto Gain\ \Delta f$$

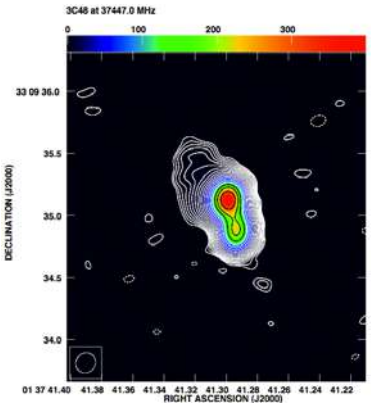


$$P_{output} = Gain\ \Delta f\ k_B\ T_{resistor}$$

$$T_{equivalent} = \frac{P_{output}}{Gain\ \Delta f\ k_B}$$

$$T_{system} = T_1 + \frac{T_2}{Gain_{LNA}} + \frac{T_3}{Gain_{LNA} \times G_2} + \frac{T_4}{Gain_{LNA} \times G_2 \times G_3} \quad \ldots\ldots$$





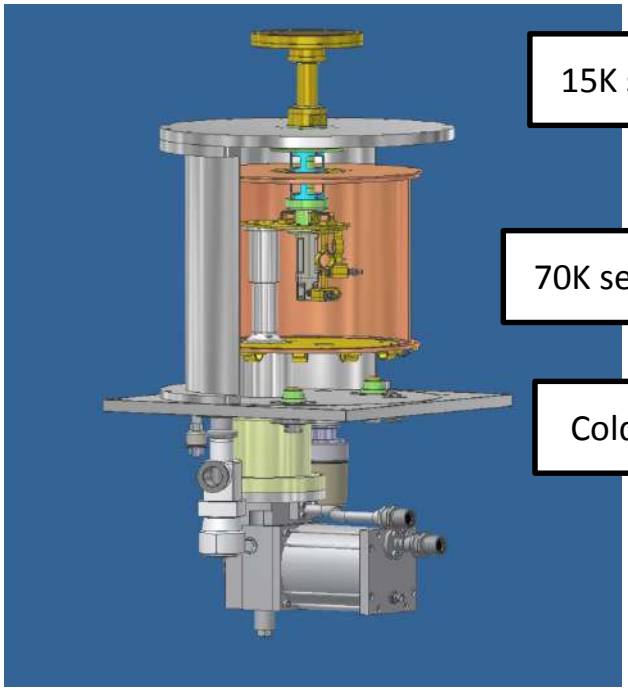
10Jy radio source → ~1K additional noise

Your hand → ~300K additional noise

Mobile Phone at 1 km→ ~1×10^{11} K !!
(in primary beam)

Noise contributions of a typical receiver

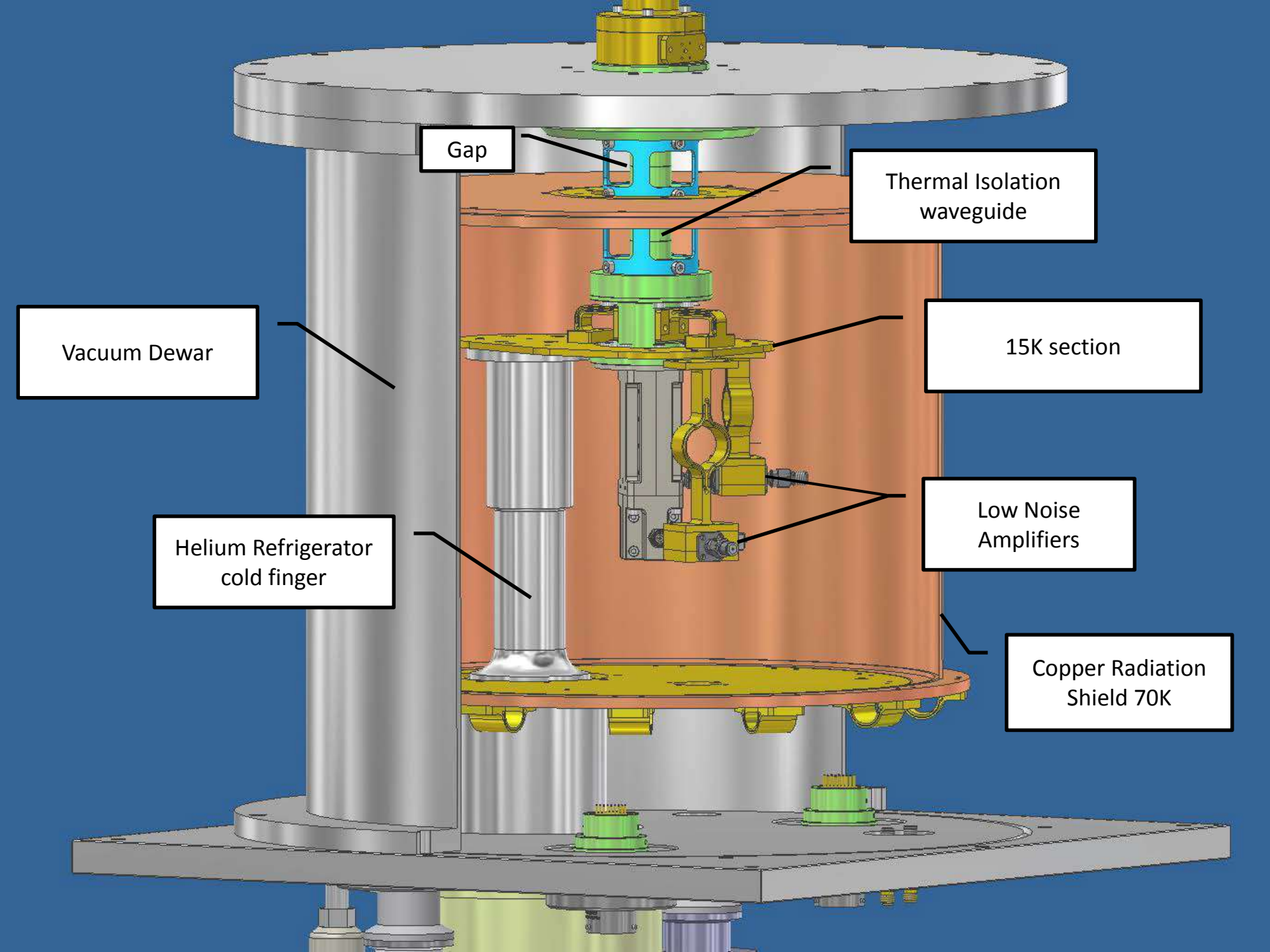
Part	Room Temperature	Cryogenic	Ratio
Sky + CMB (T_{sky})	6K	6K	1
Spillover (T_{spill})	3K	3K	1
Feed + OMT	10K	2K	5
LNA (T_{lna})	35K	5K	7
Rest of the System	1K	1K	1
Total (T_{sys})	**55K**	**17K**	**~3**



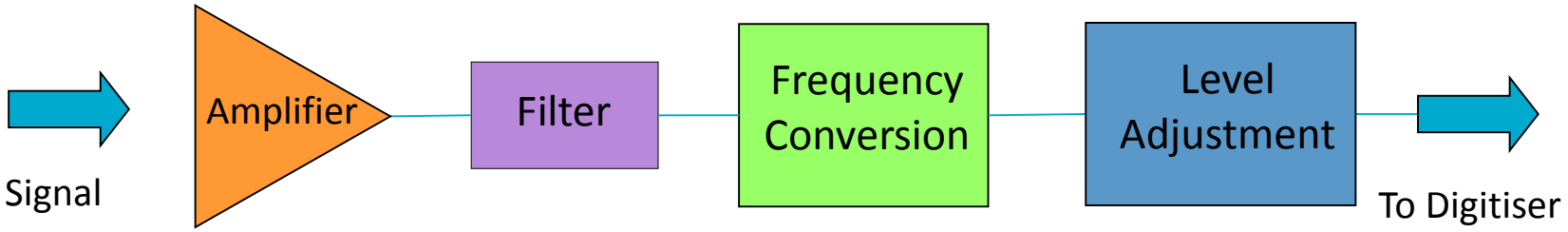
Refrigerator in the Parkes 12mm receiver

Helium Refrigerator

Helium Compressor

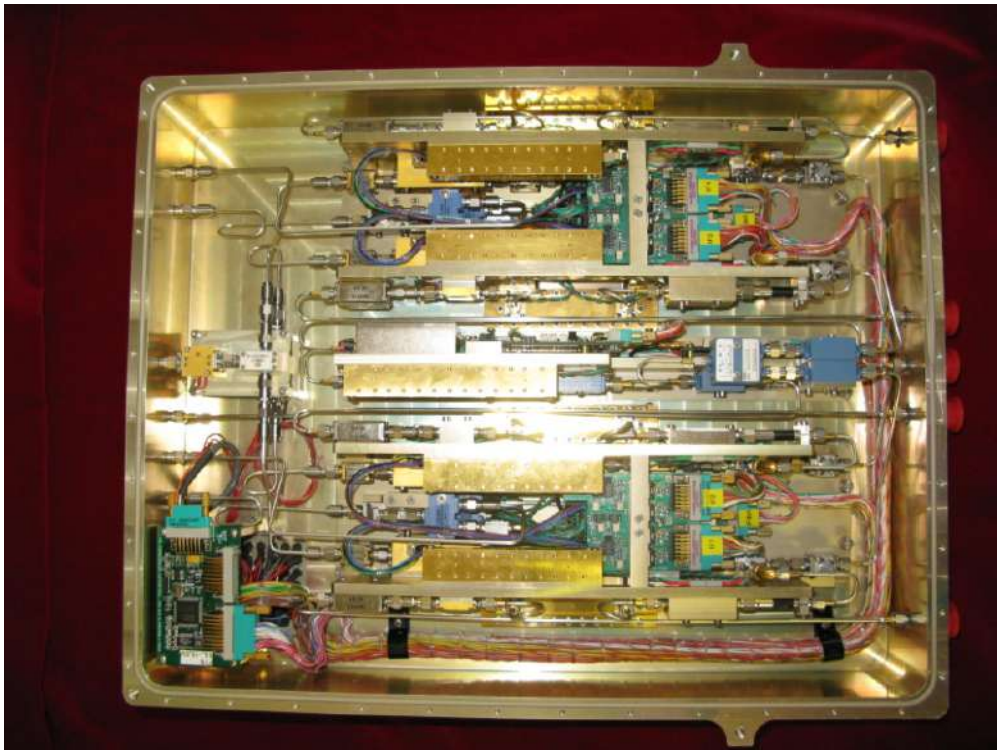

Gap
Thermal Isolation waveguide
Vacuum Dewar
15K section
Low Noise Amplifiers
Helium Refrigerator cold finger
Copper Radiation Shield 70K

The RF System

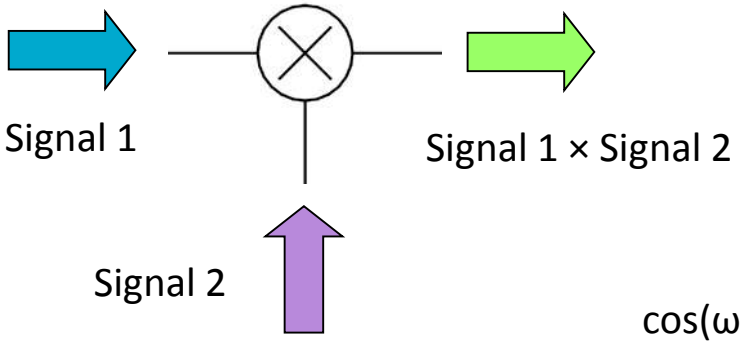


Contains:

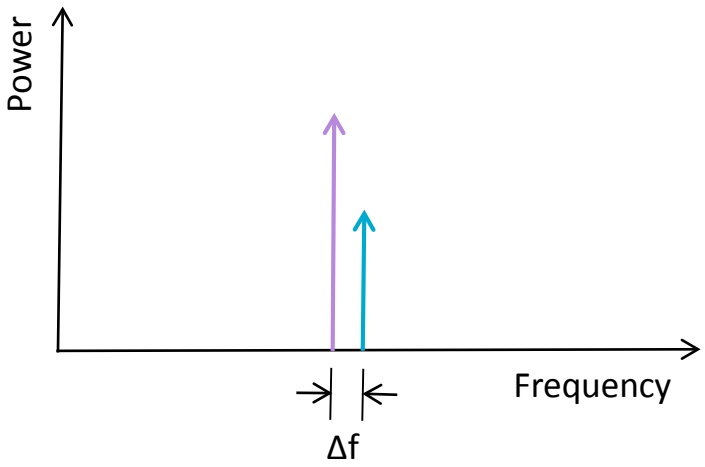
- More amplification
- Band defining filters
- Frequency conversion
- Level adjustment
- Signal detection
- Band shaping



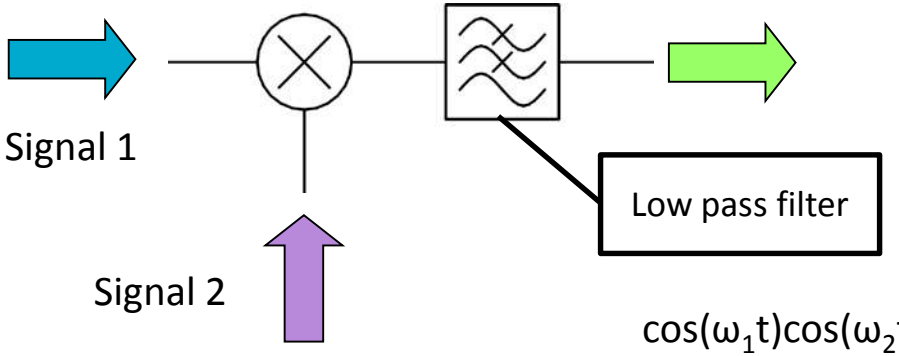
Mixer (Multiplier)



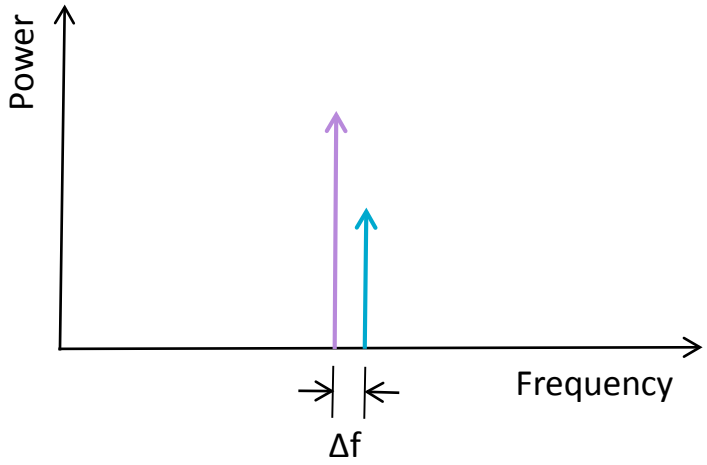
$$\cos(\omega_1 t)\cos(\omega_2 t)=\tfrac{1}{2}[\cos((\omega_1+\omega_2)t)+\cos((\omega_1-\omega_2)t)]$$



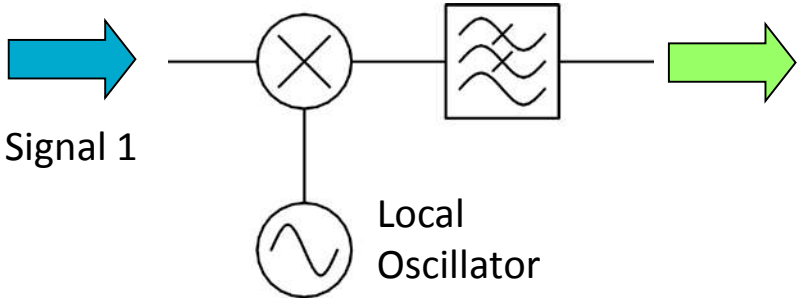
Mixer (Multiplier)



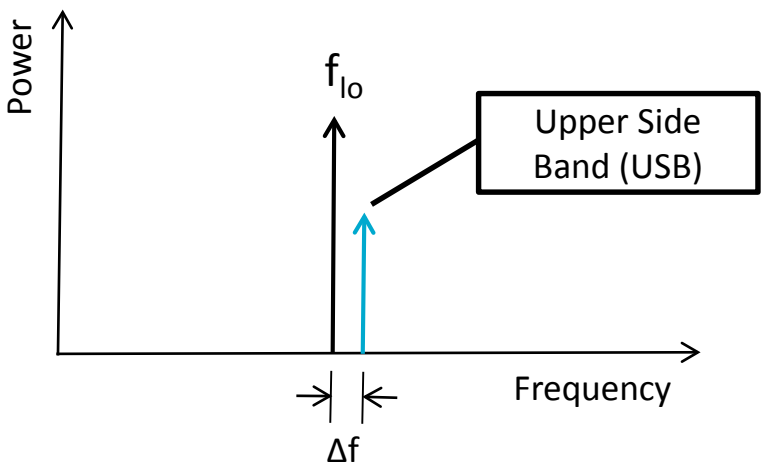
$$\cos(\omega_1 t)\cos(\omega_2 t)=\tfrac{1}{2}[\cos((\omega_1+\omega_2)t)+\cos((\omega_1-\omega_2)t)]$$



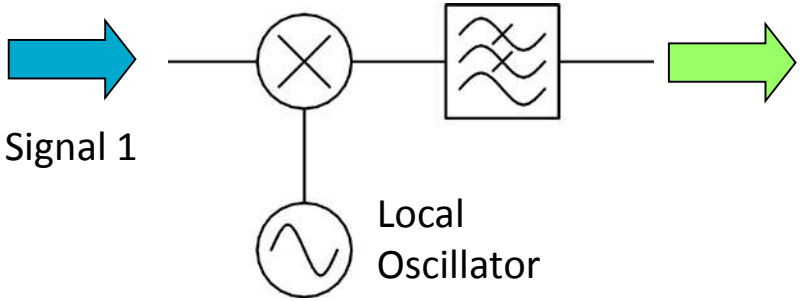
Mixer (Multiplier)



$\cos(\omega_1 t)\cos(\omega_{LO} t) \rightarrow \frac{1}{2}\cos[(\omega_1 - \omega_{LO})t]$

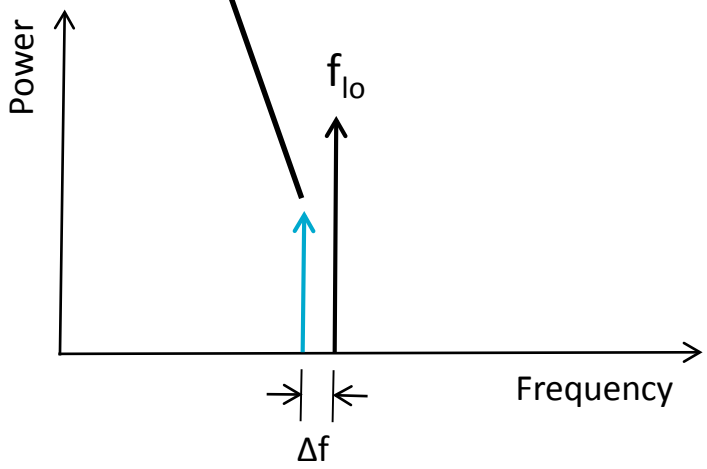


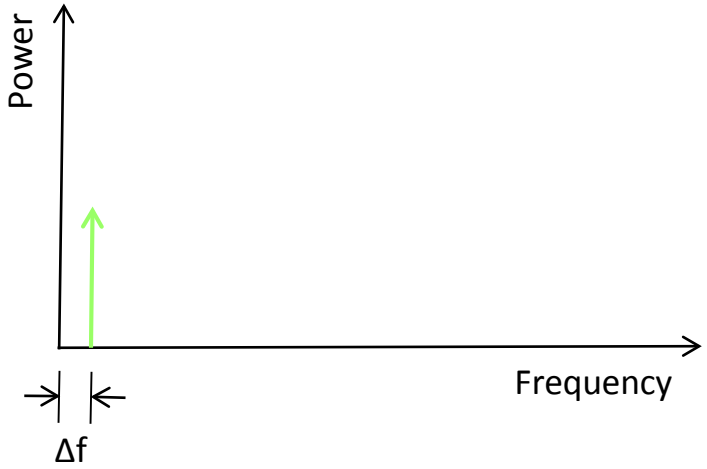
Mixer (Multiplier)

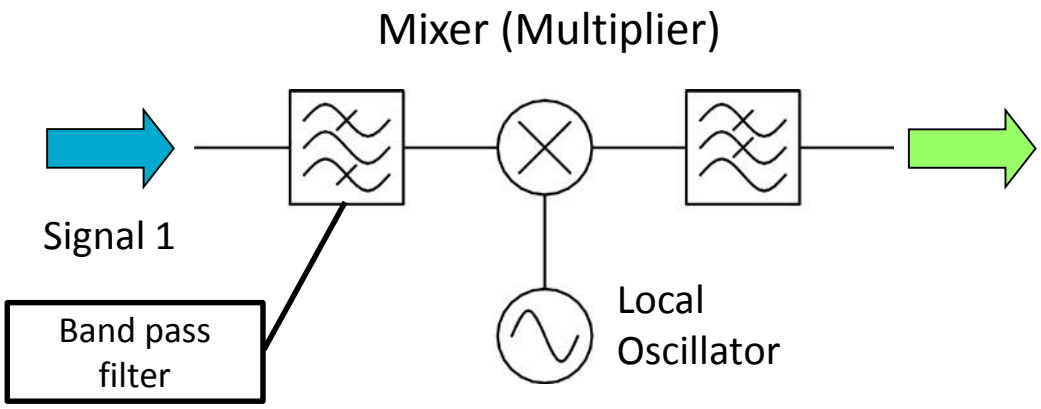


$\cos(\omega_1 t)\cos(\omega_{LO} t) \rightarrow \frac{1}{2}\cos[(\omega_{LO}-\omega_1)t]$

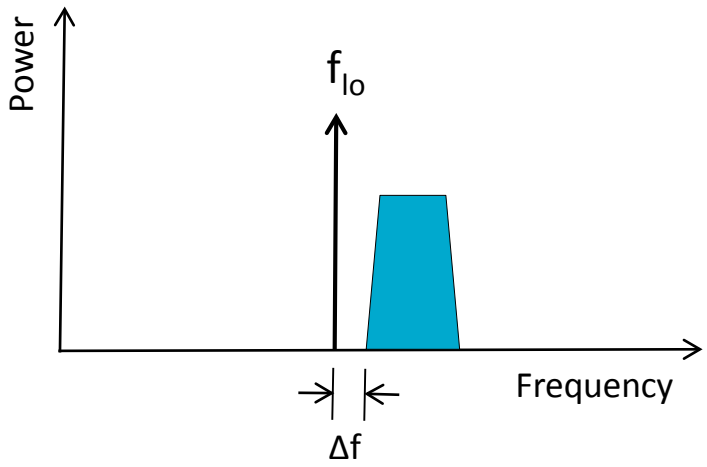
Lower Side Band
(LSB)

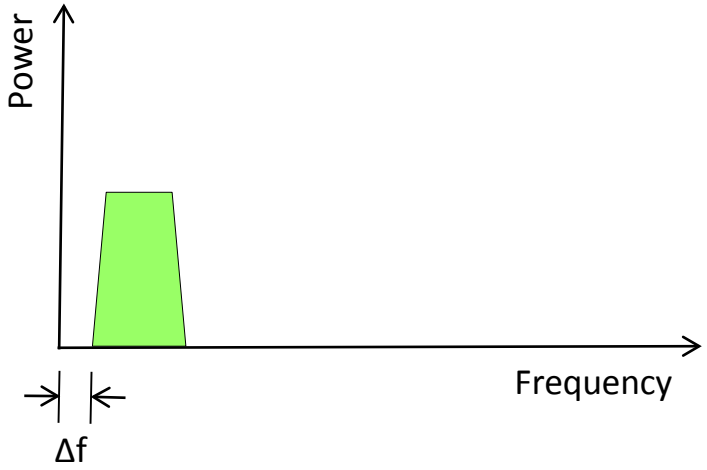


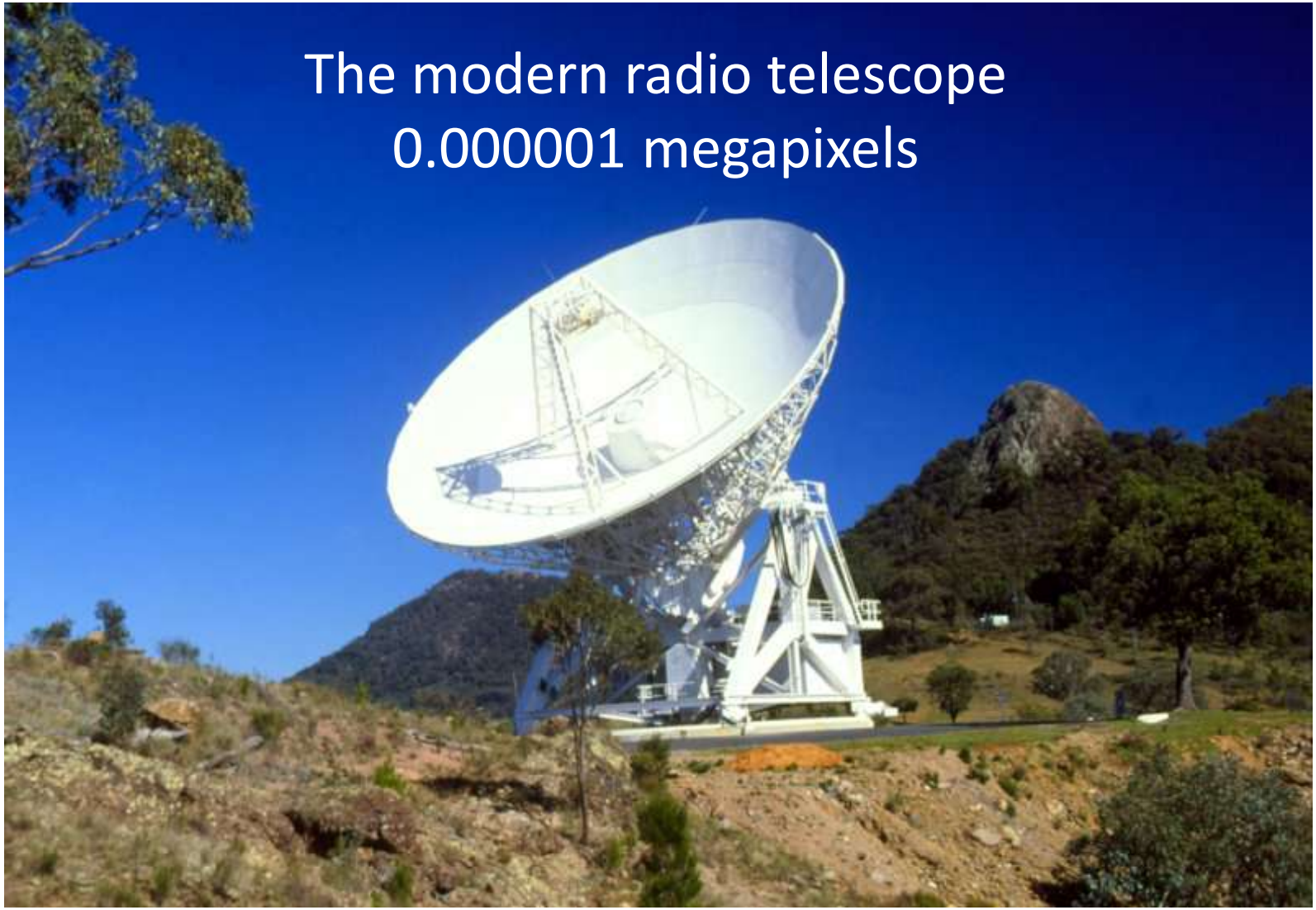



Mixer (Multiplier)
Signal 1
Band pass filter
Local Oscillator


M20226LA


Power
f_{lo}
Frequency
Δf


Power
Frequency
Δf


The modern radio telescope
0.000001 megapixels

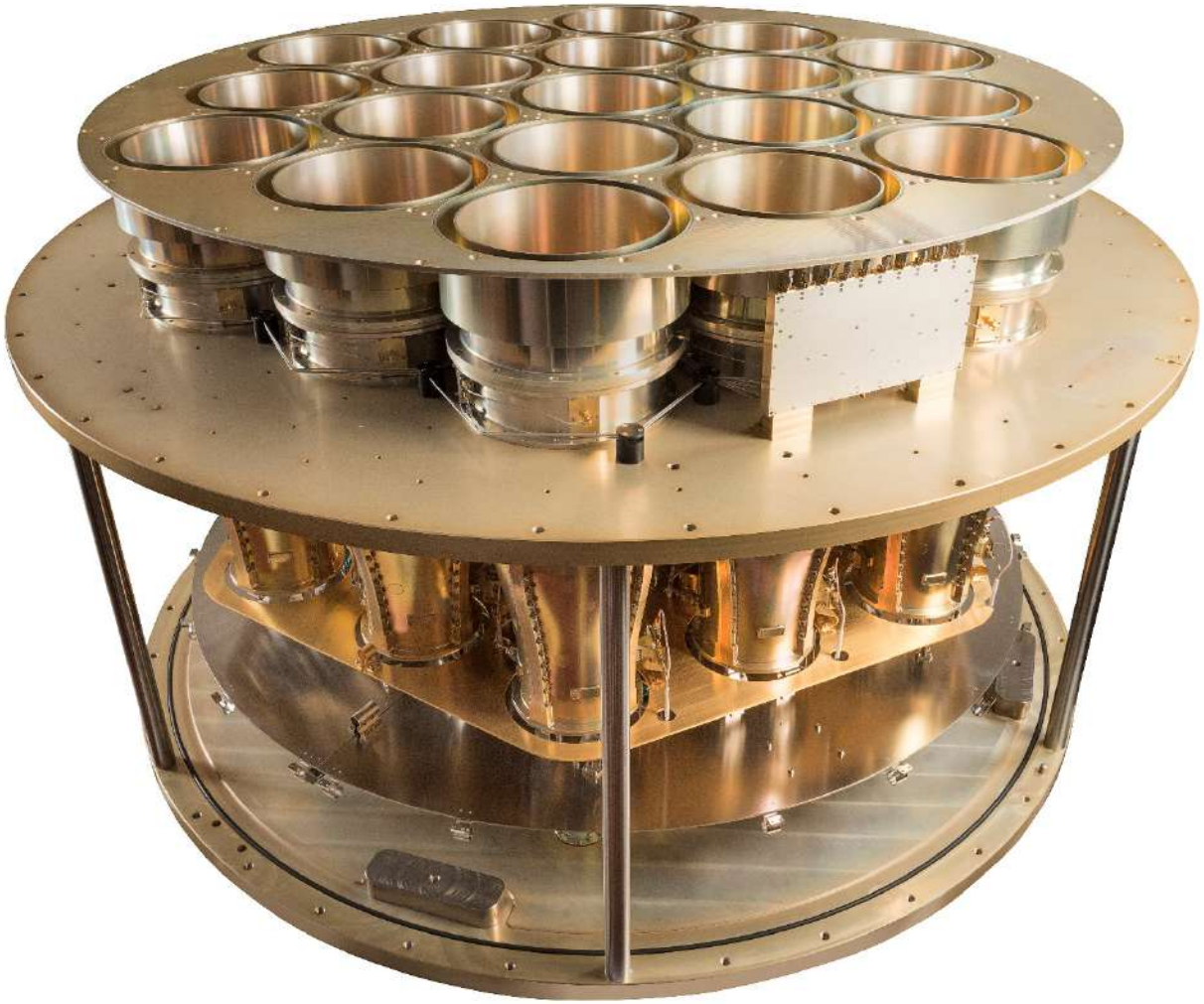
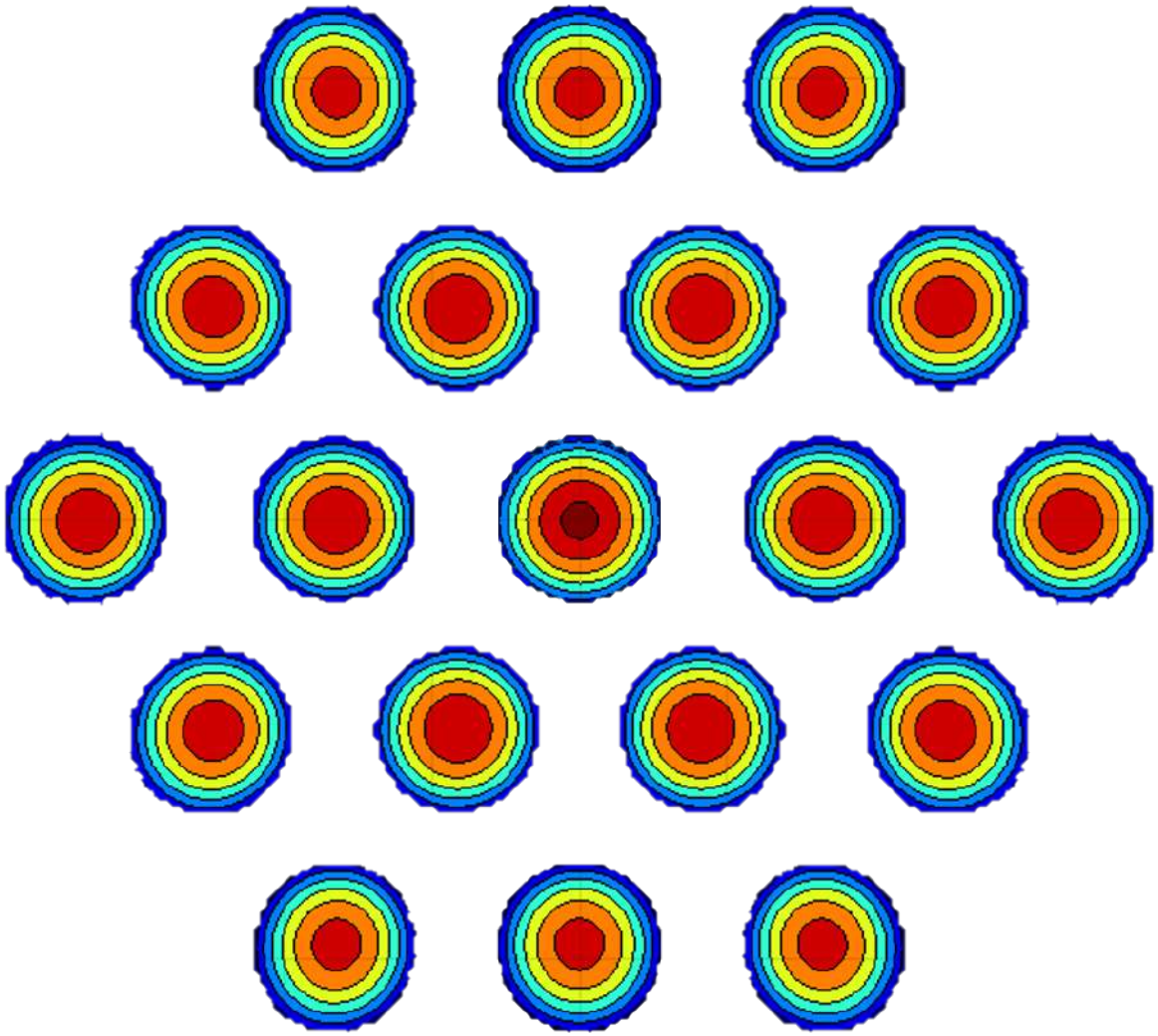
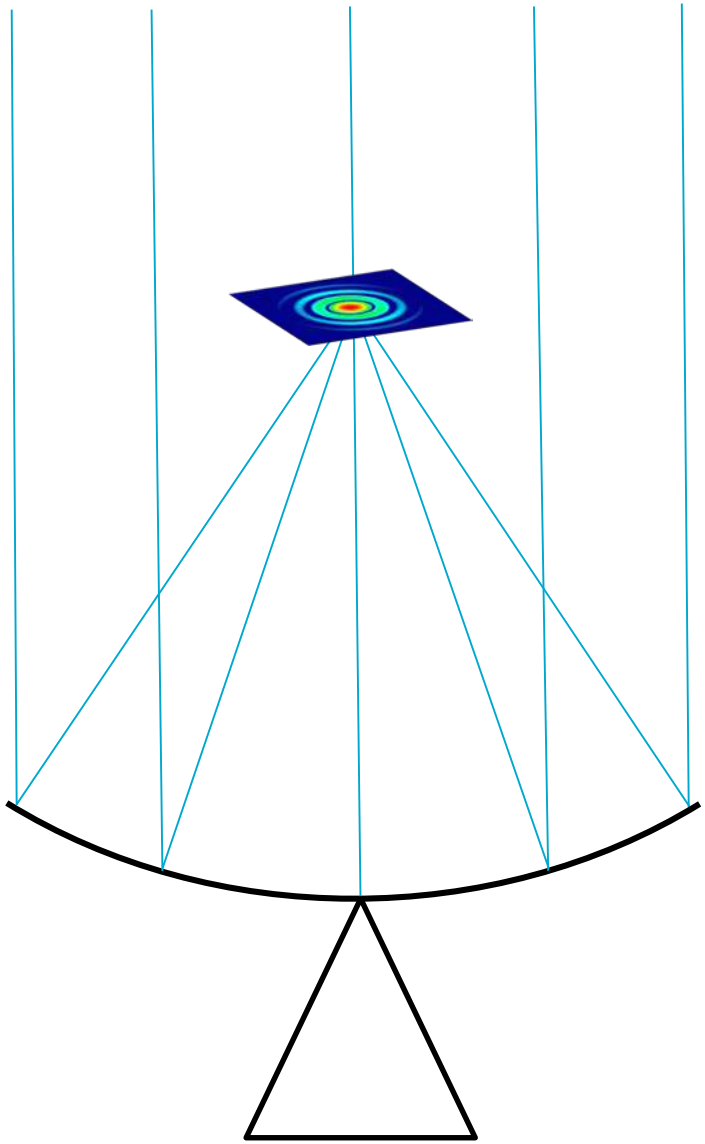
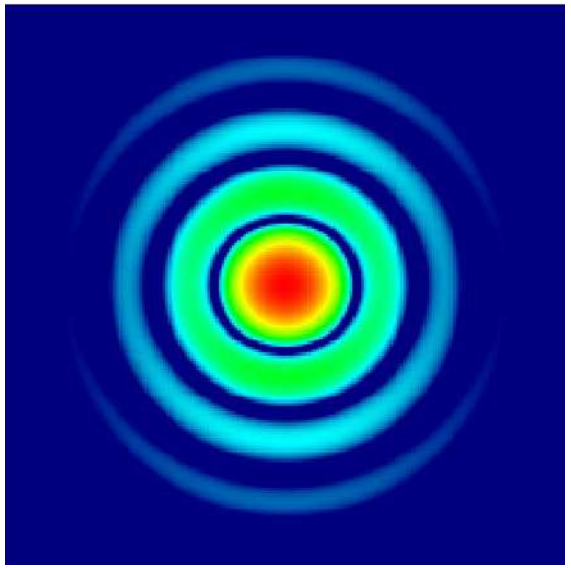
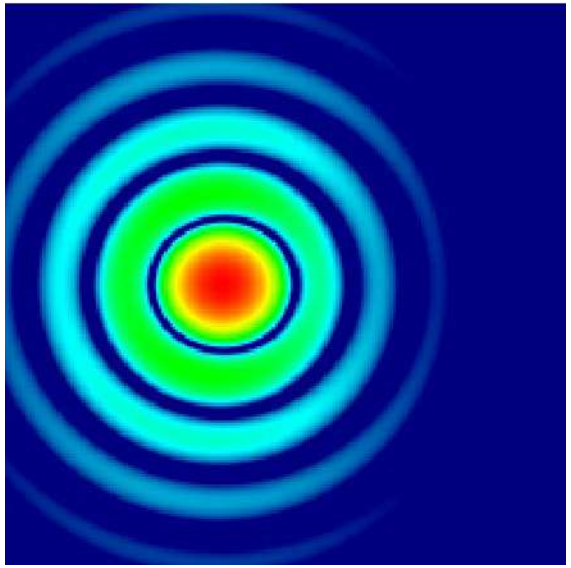


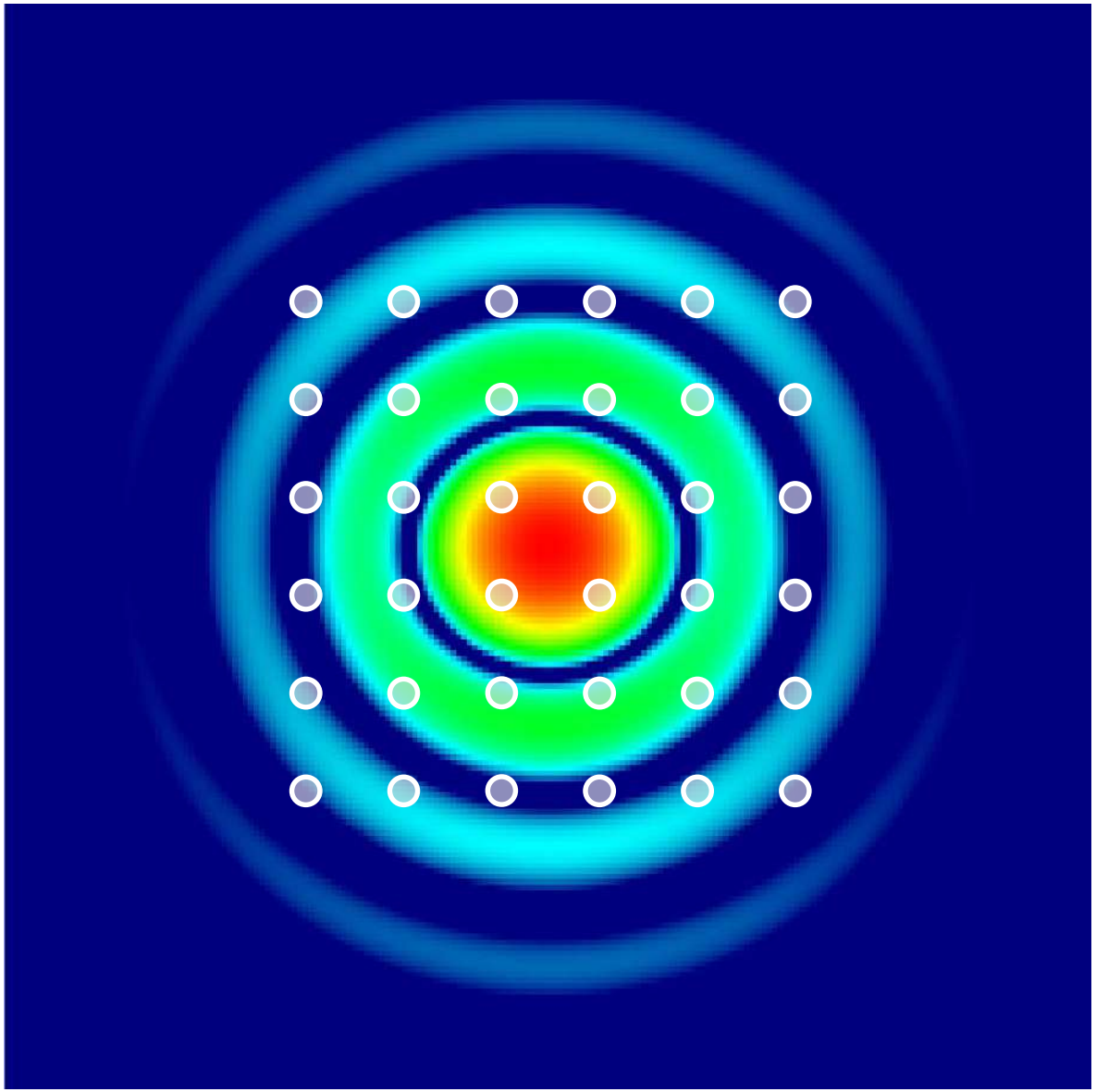
Photo credit: Wheeler Studios

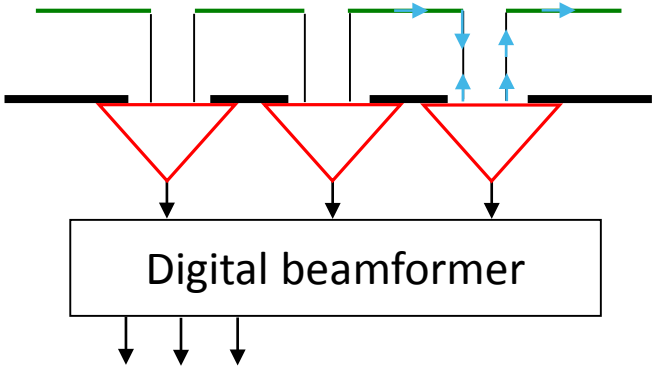




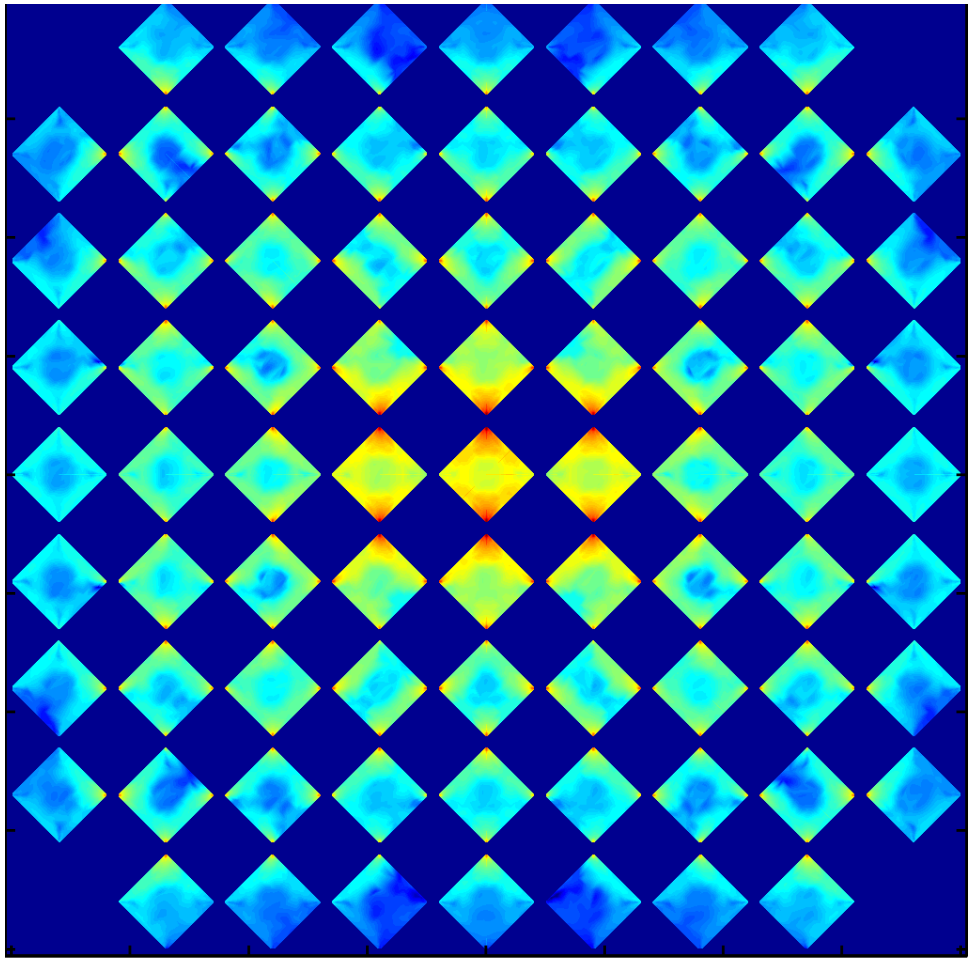








Weighted (complex)
sum of inputs



Thank you

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