

Radio Telescope Receivers

Alex Dunning

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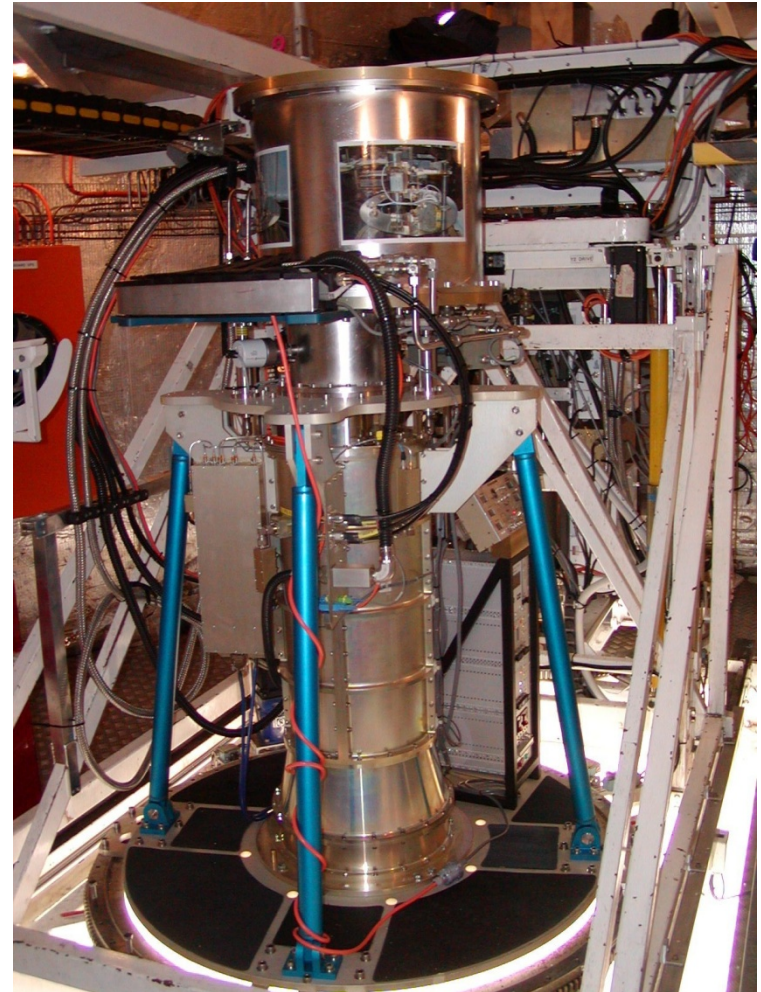
“A radio receiver is an electronic device that receives radio waves and converts the information carried by them to a usable form”

Wikipedia



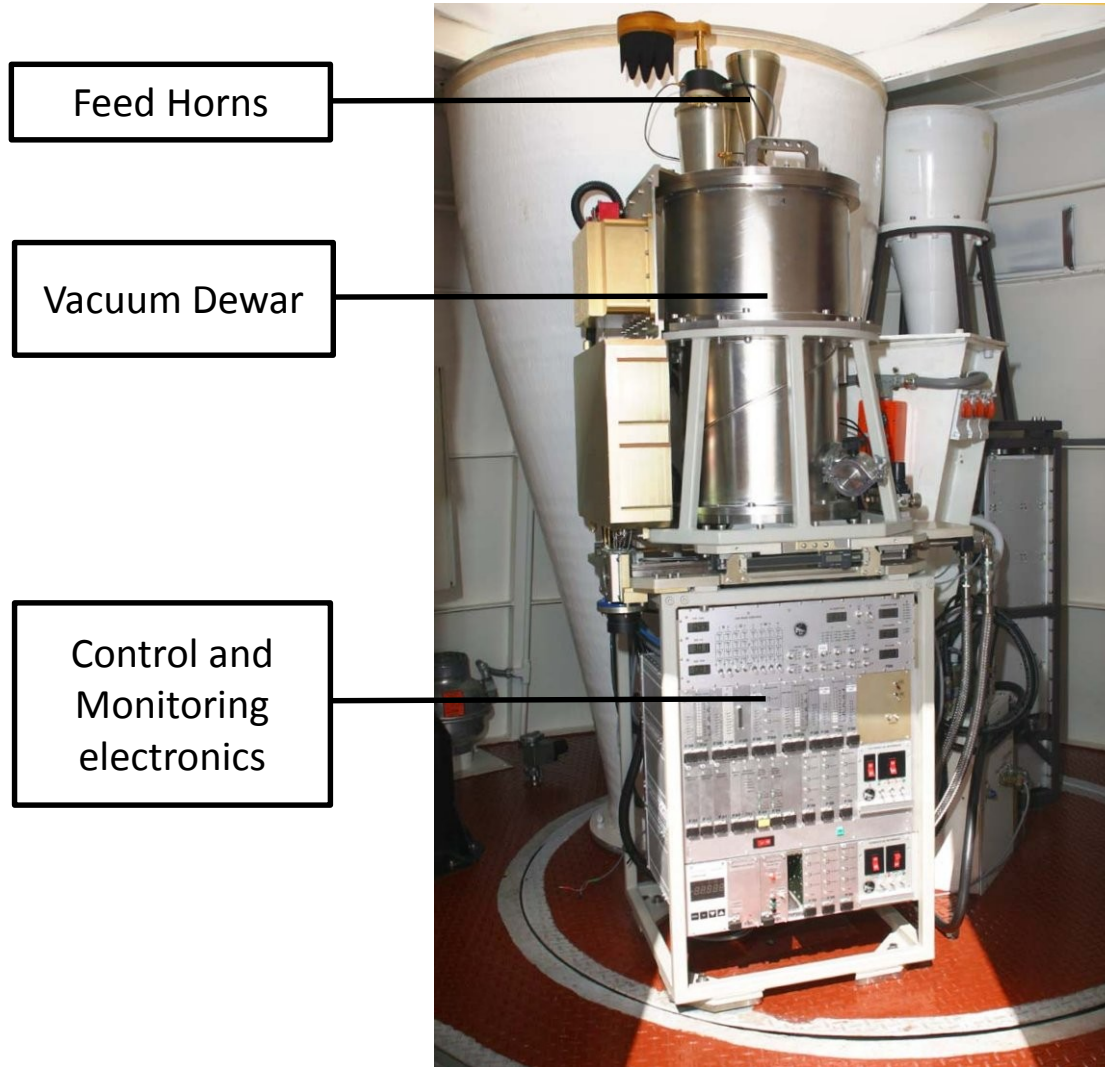
Ours look more like this

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

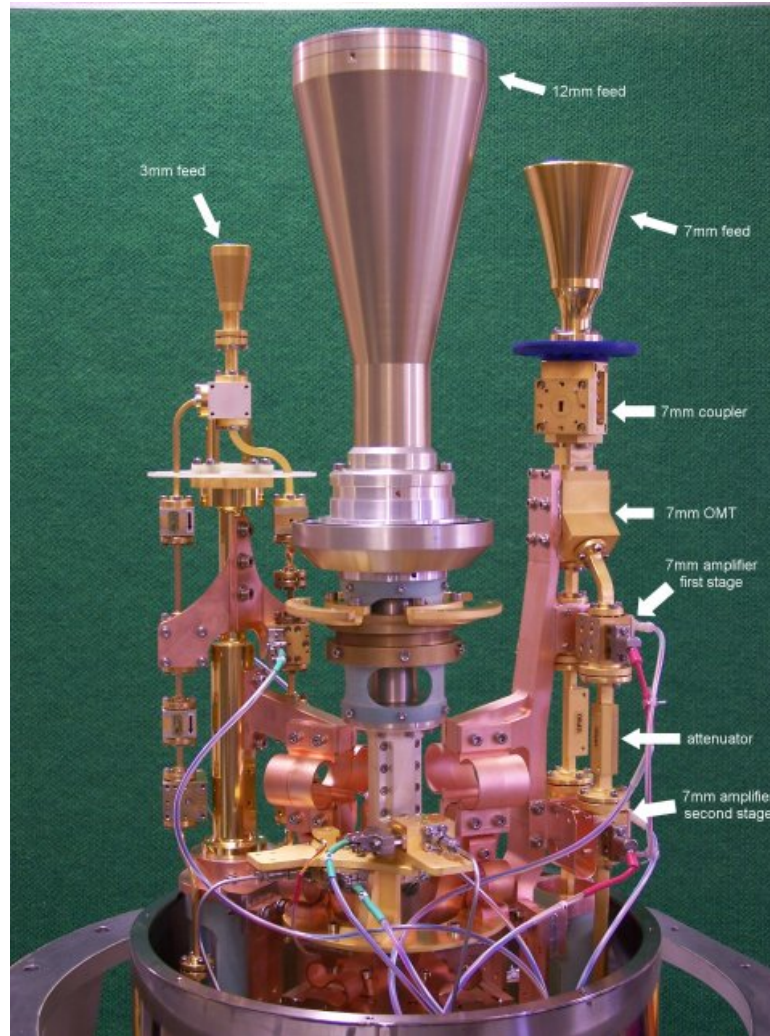


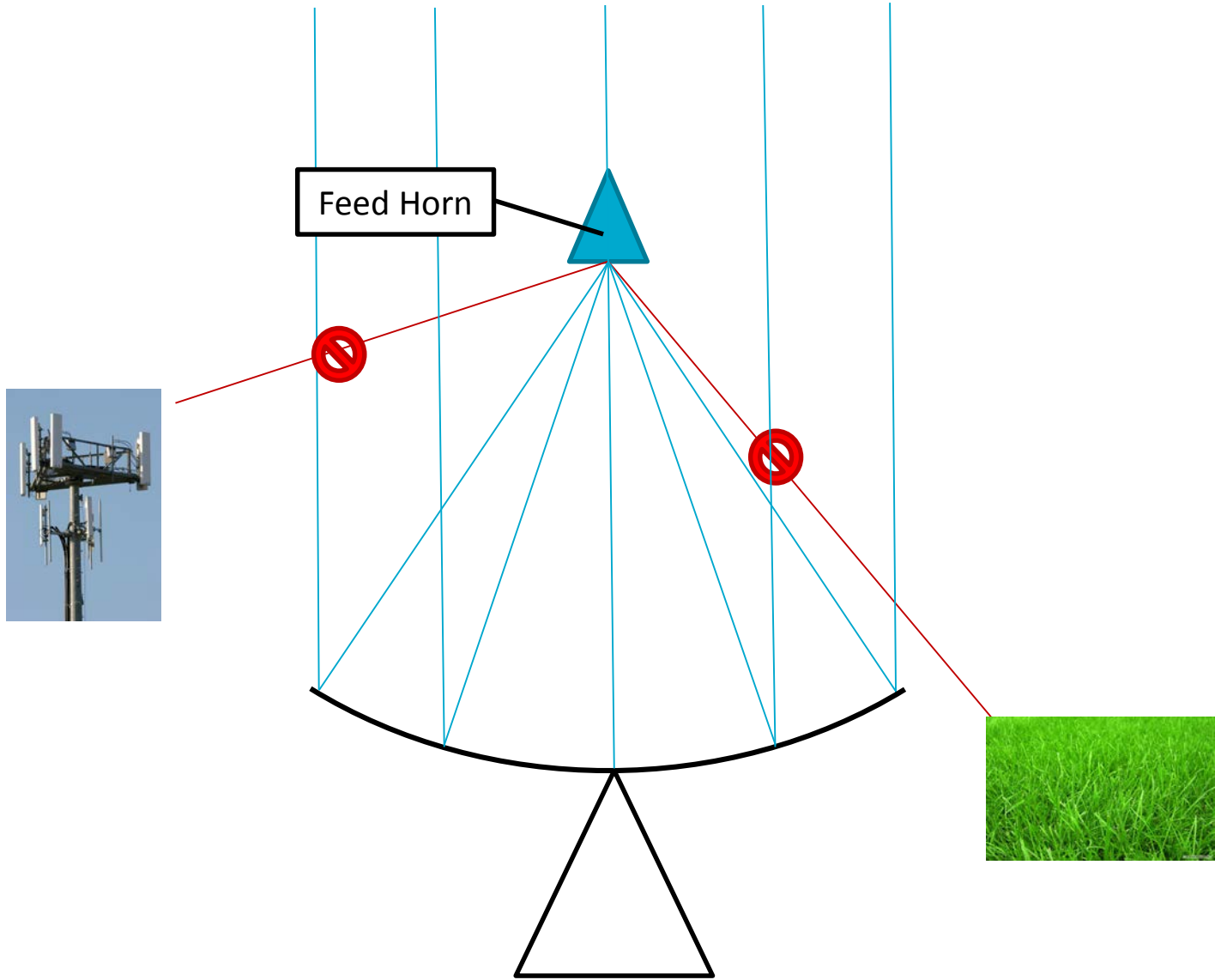
Parkes 10/40cm Receiver

On the outside...

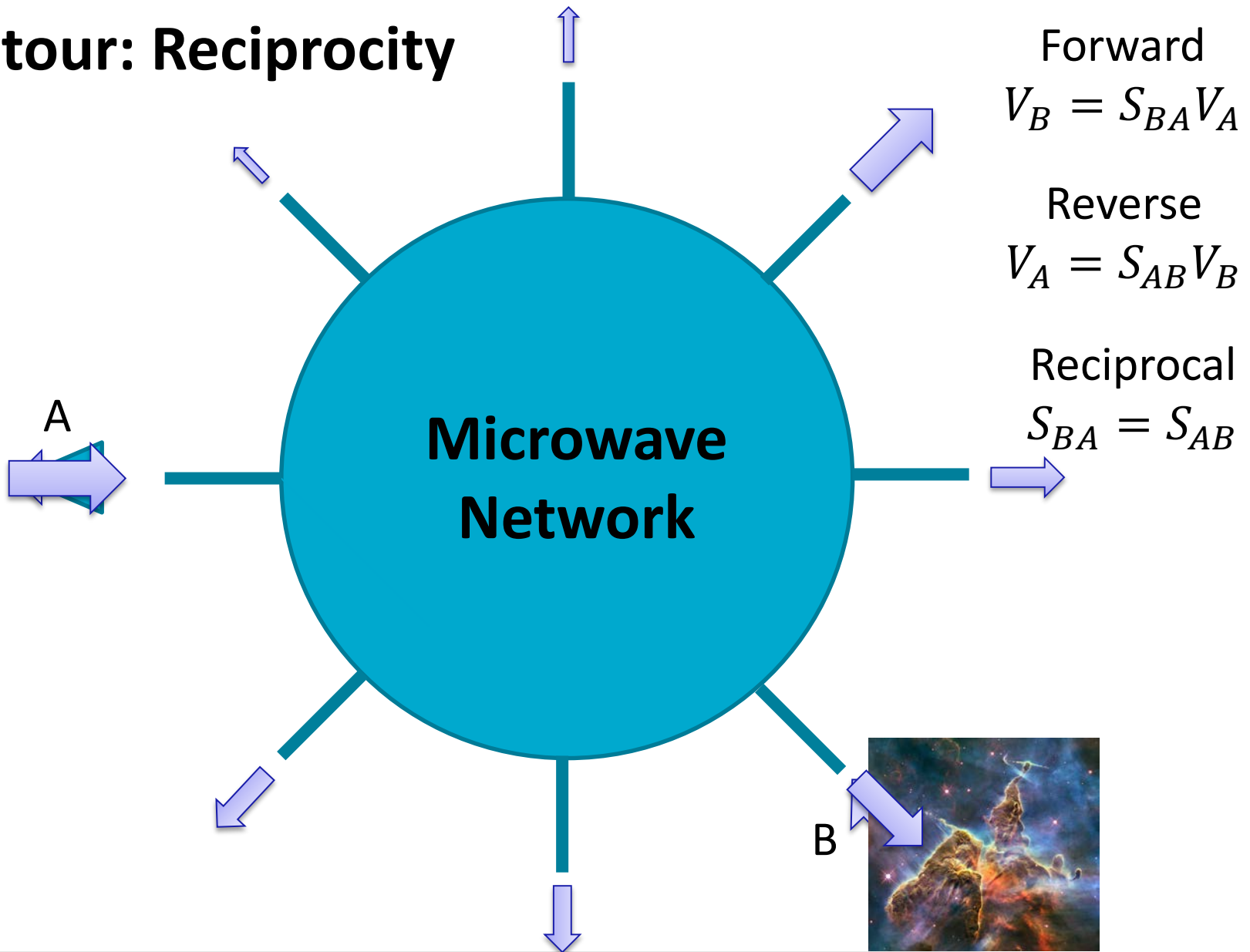


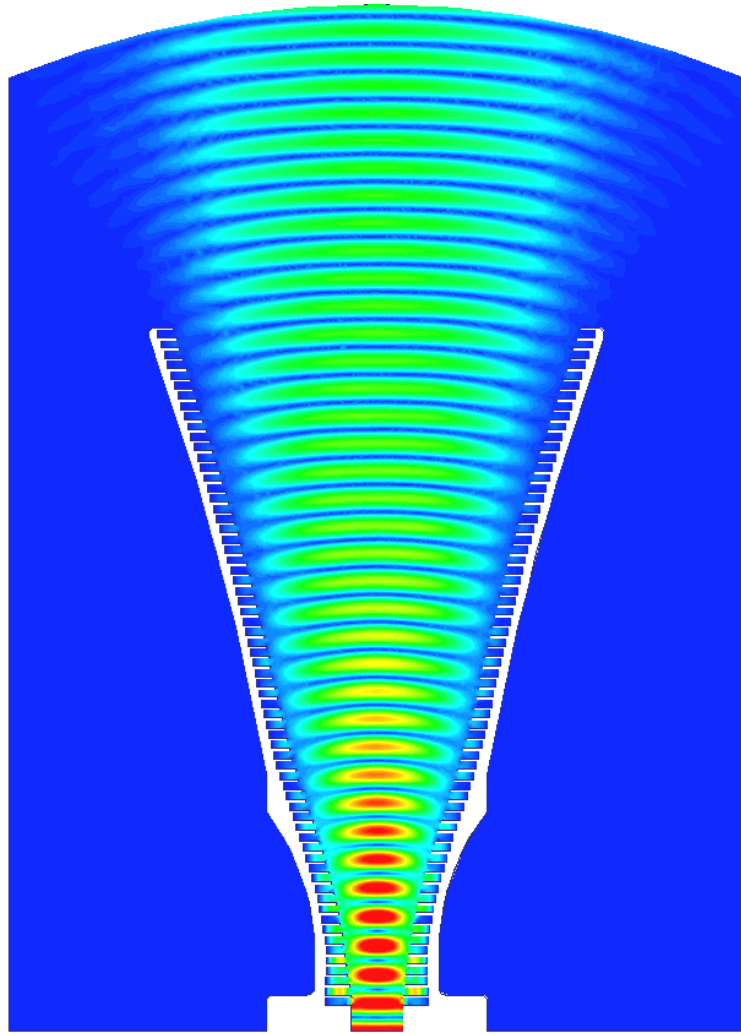
On the inside...

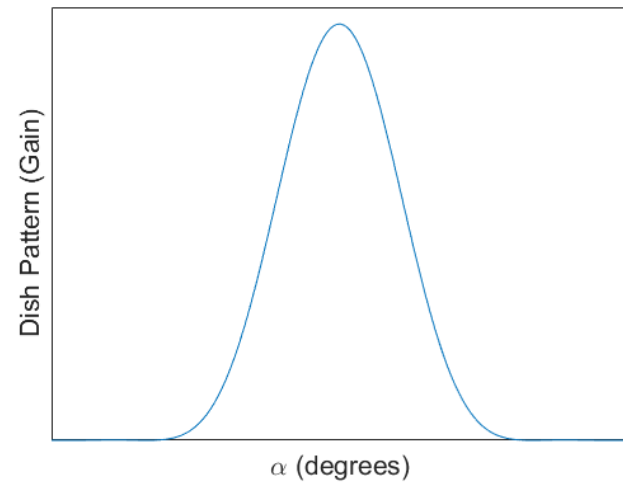
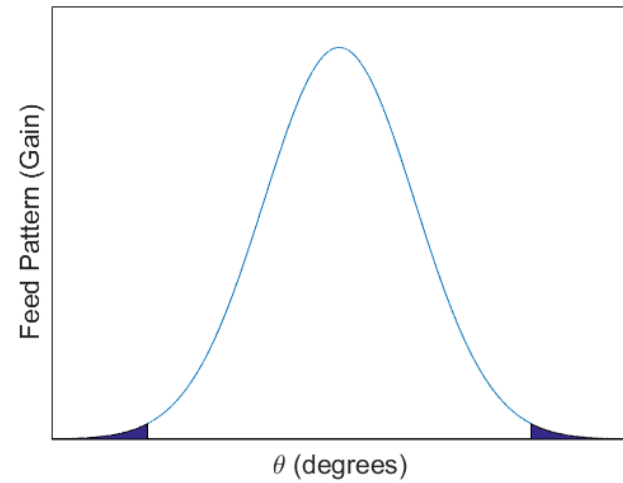
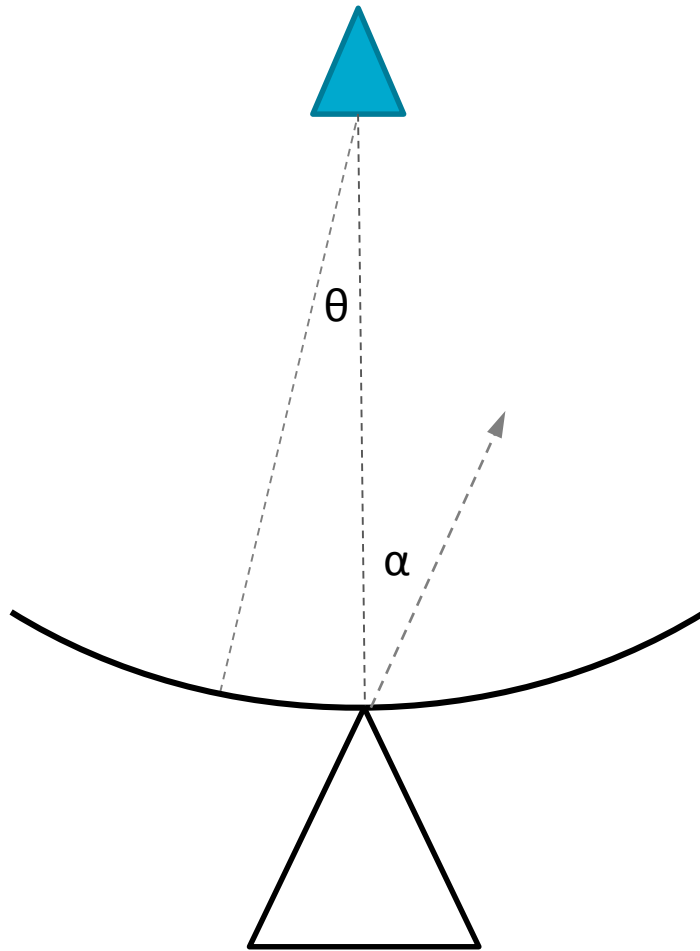


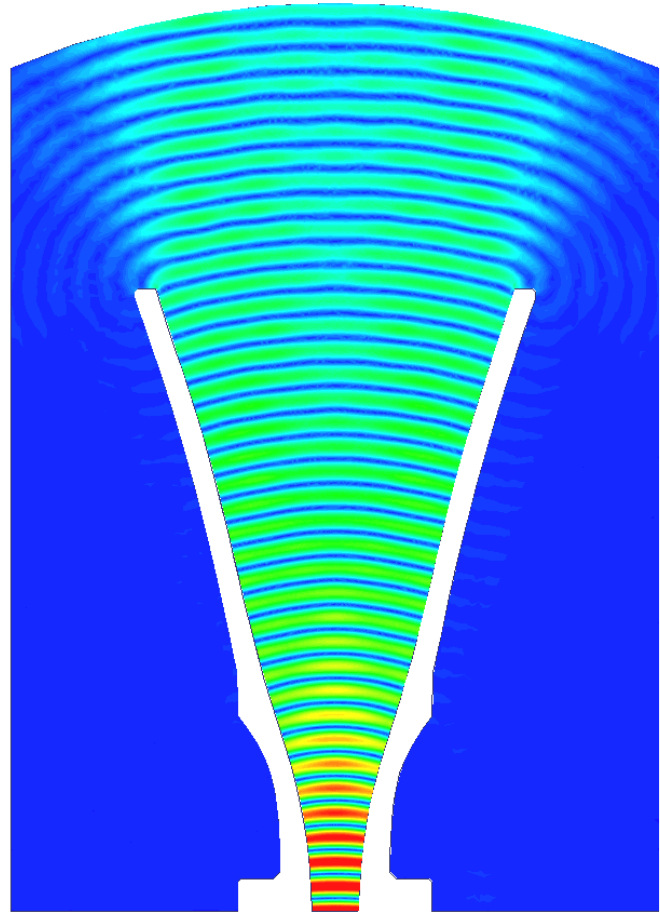
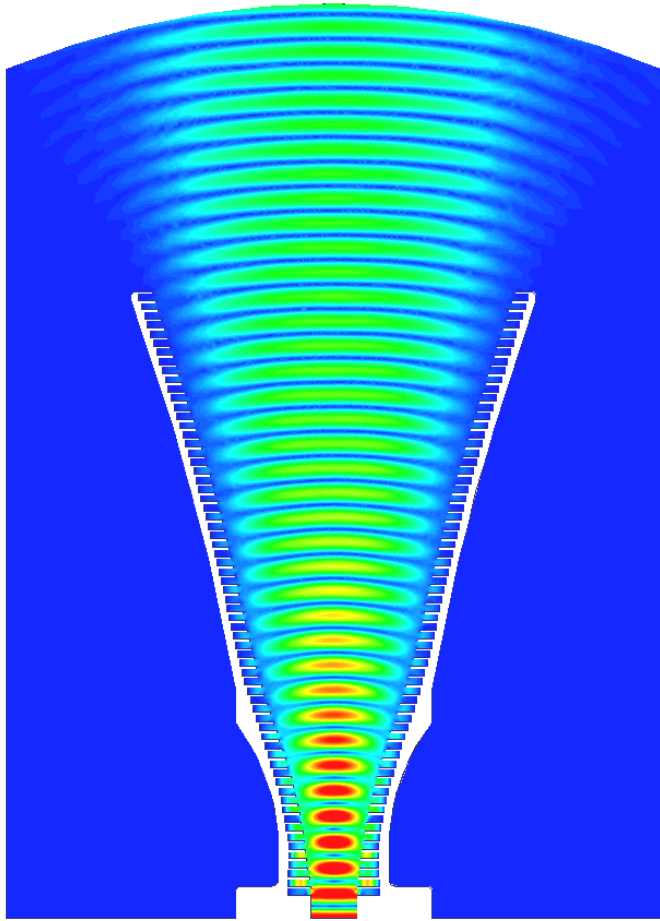


Detour: Reciprocity

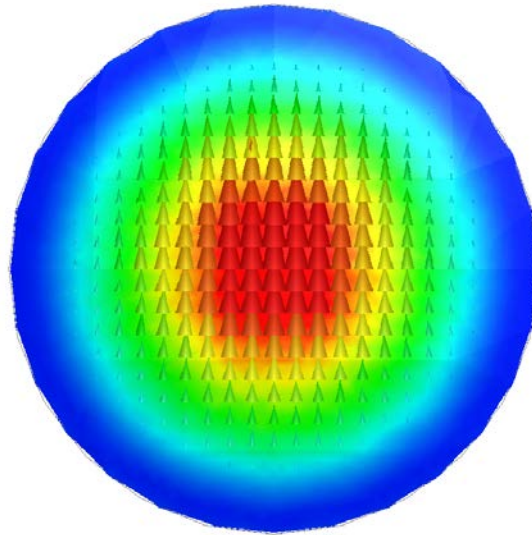






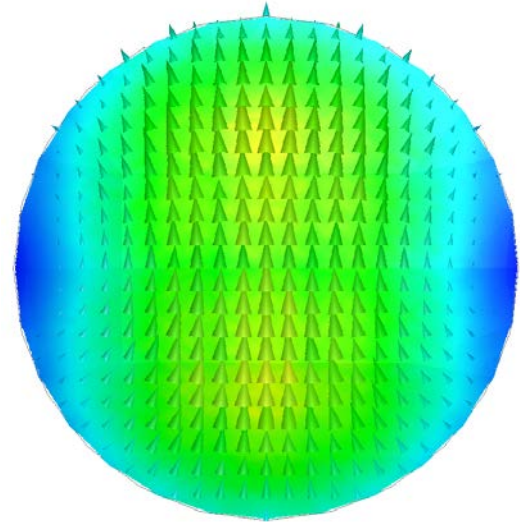


Corrugated

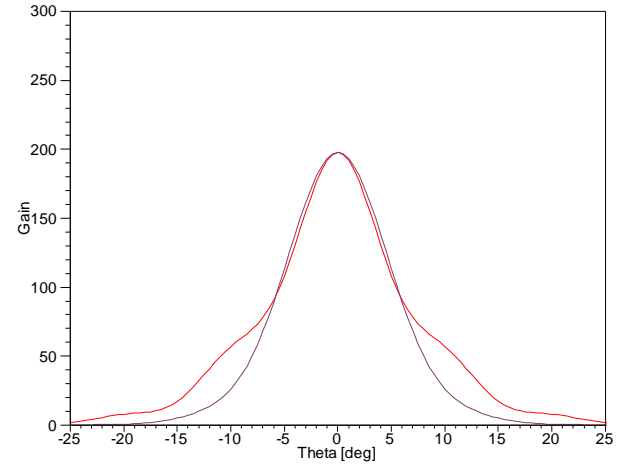
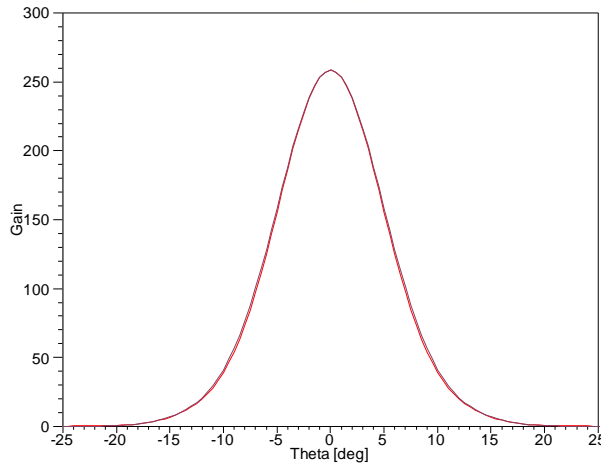


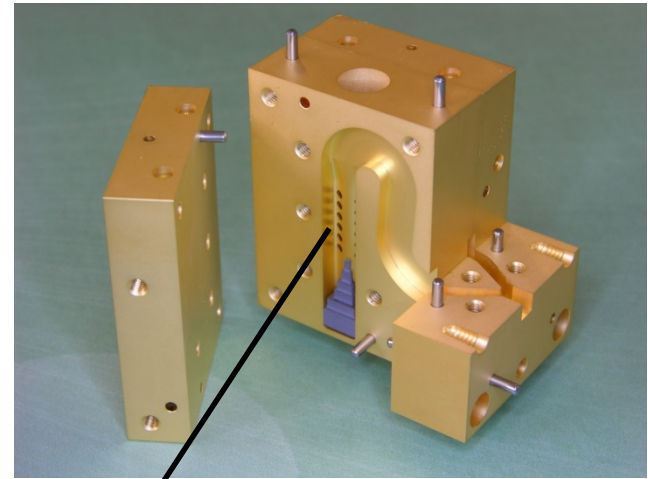
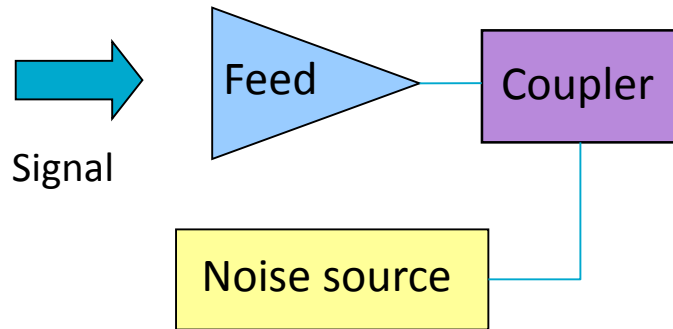
E-Field At
Feed mouth

Smooth Walled



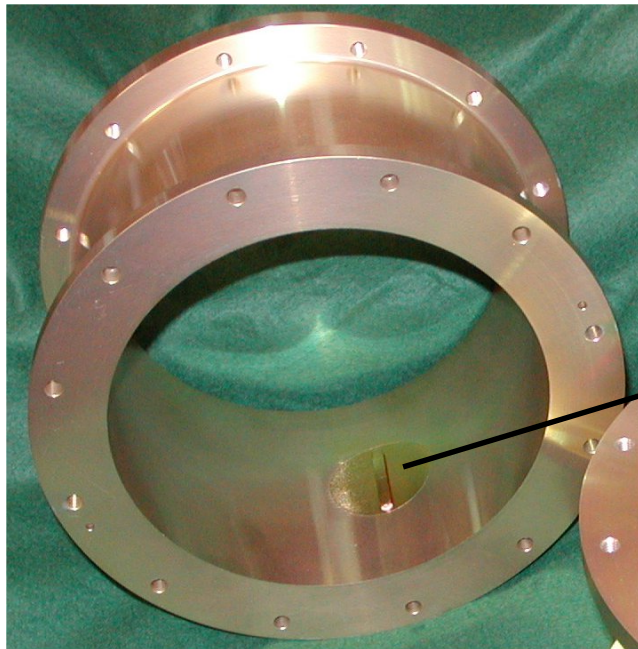
X and Y Feed
Patterns





Noise coupled in through small holes

7mm waveguide coupler

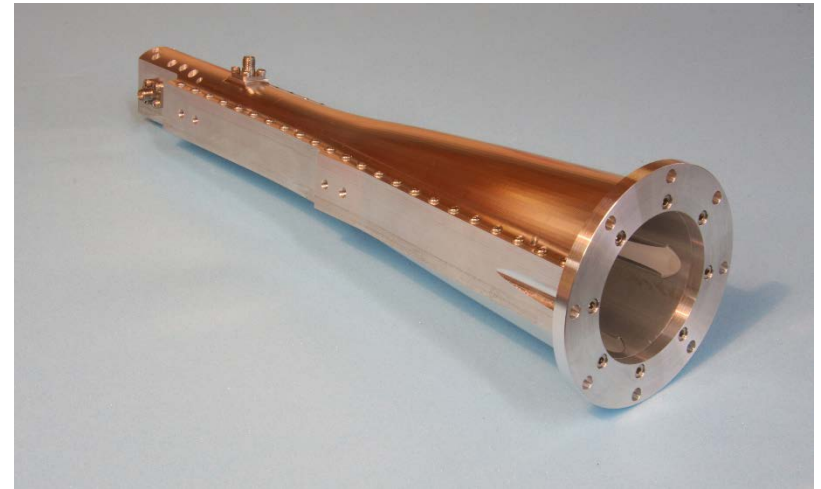
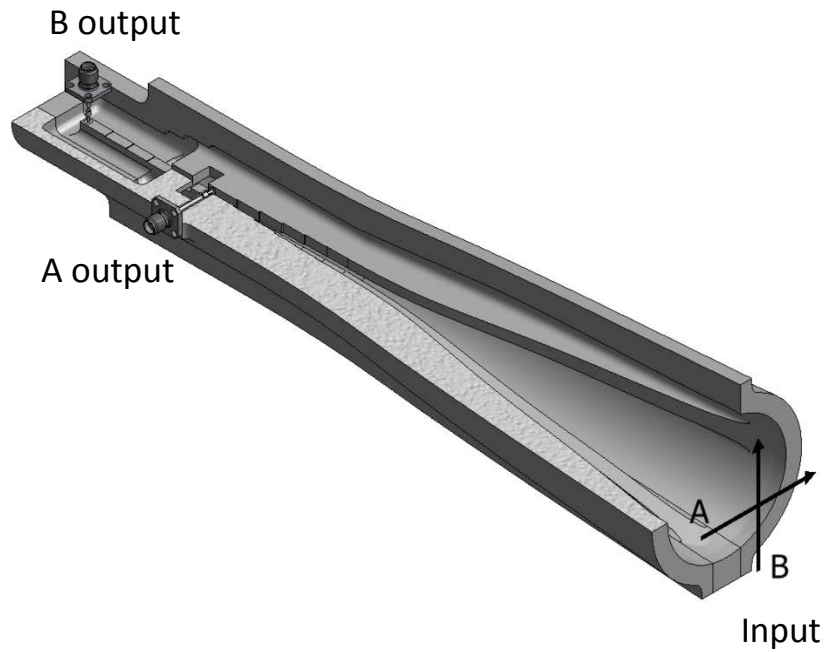
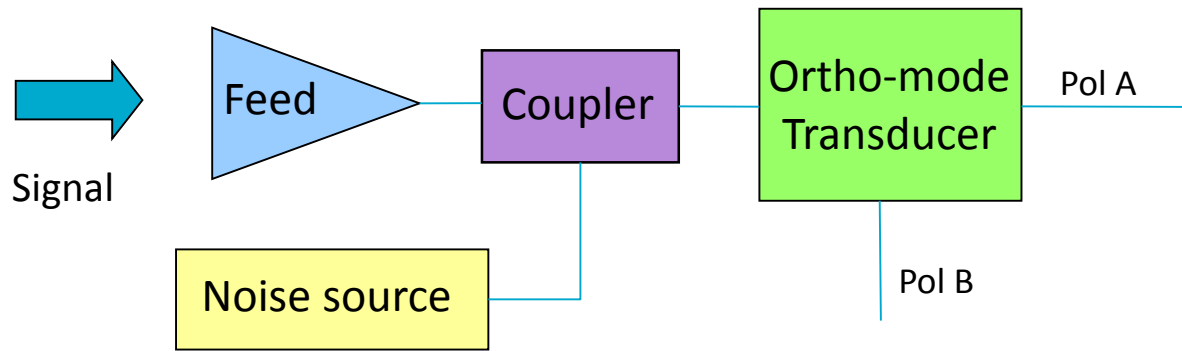


Noise coupled in through vane

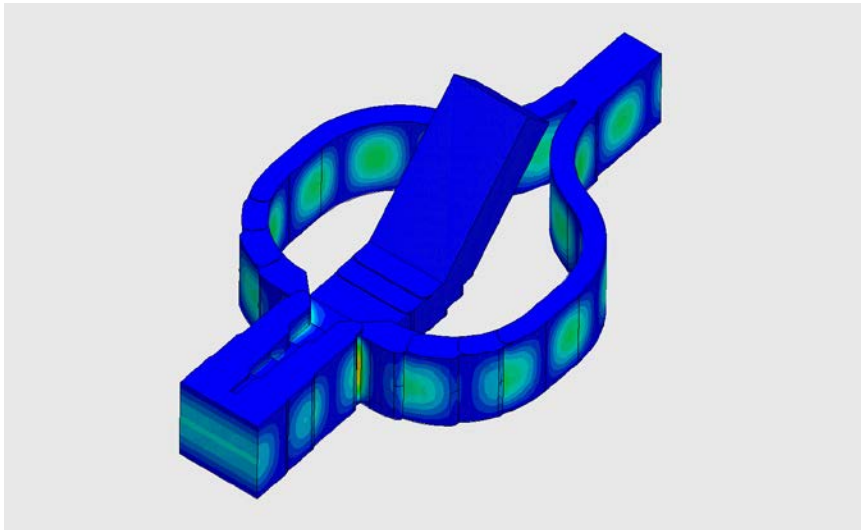
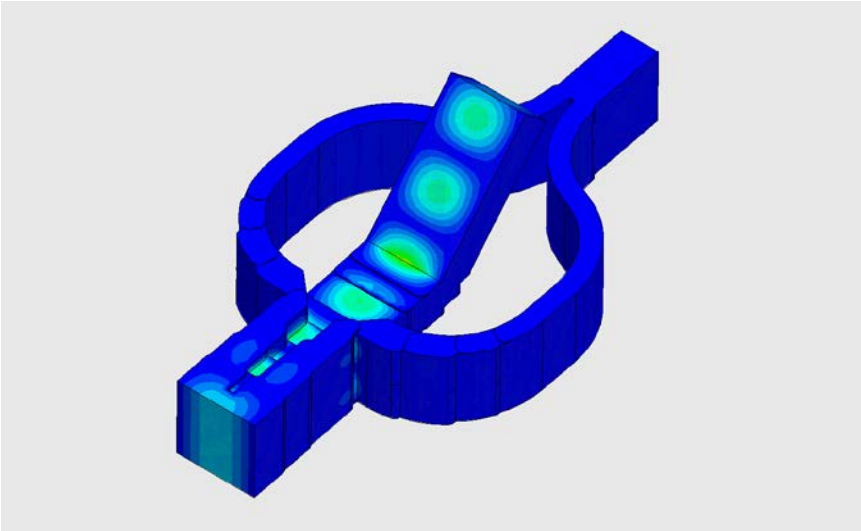
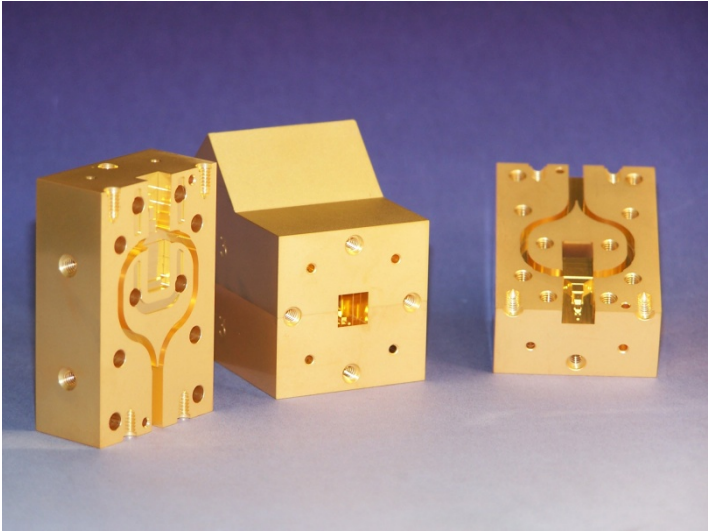
21cm waveguide coupler

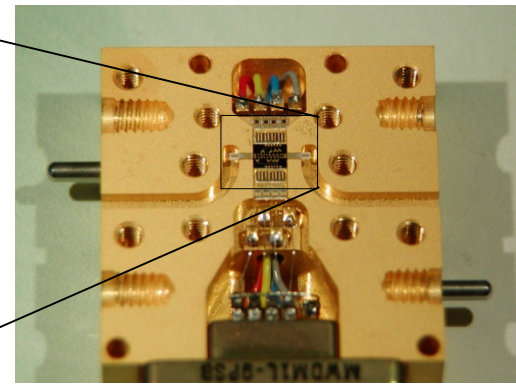
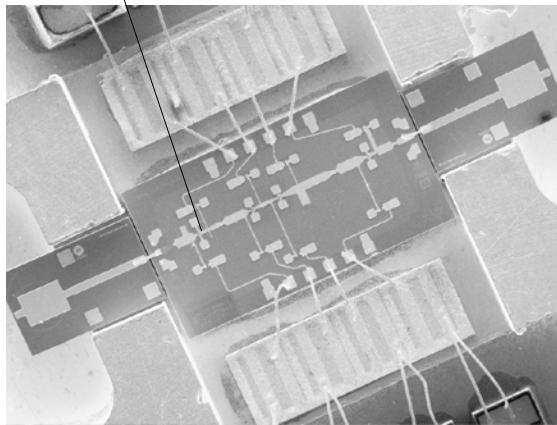
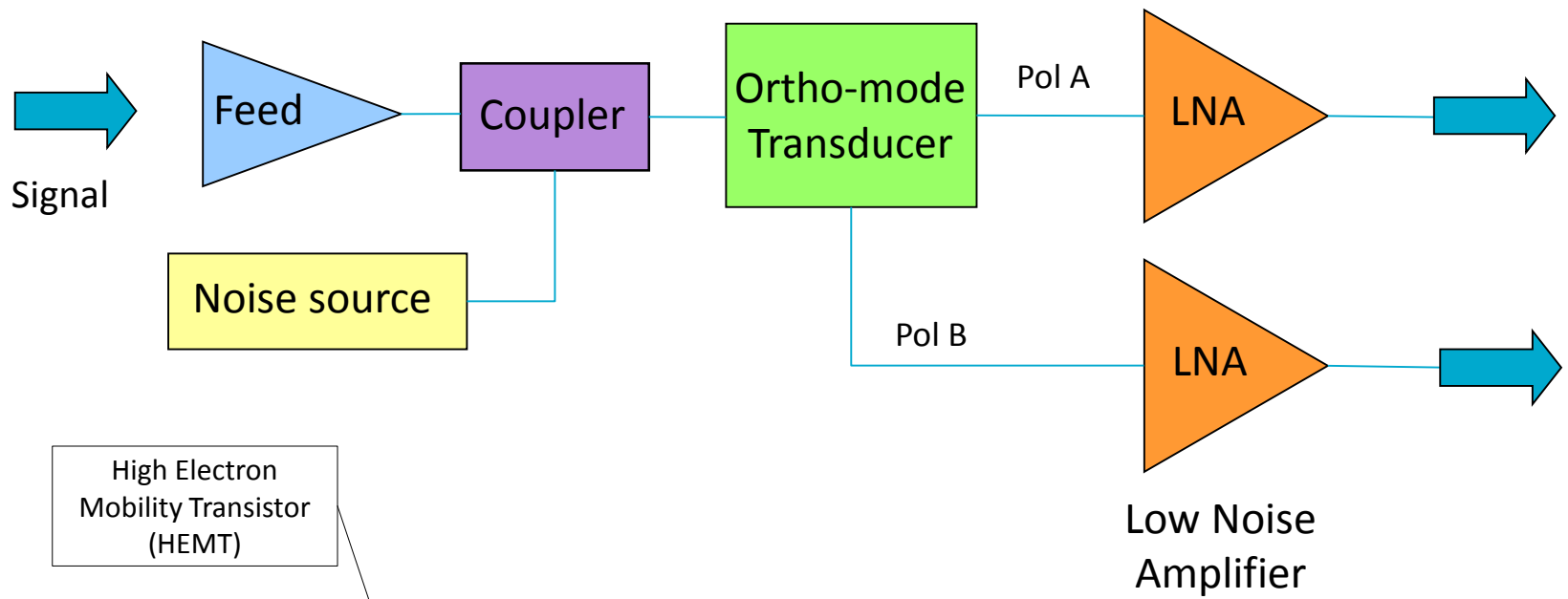


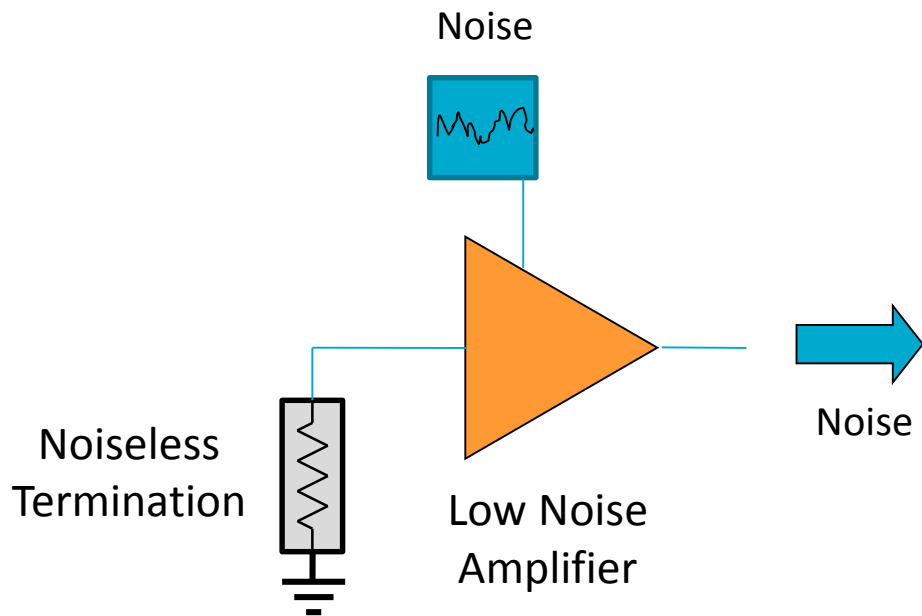
12mm noise source



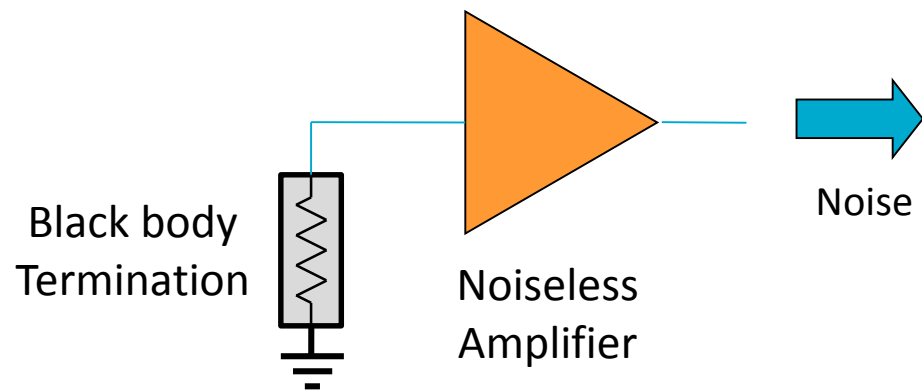
Separating the Polarisations: The OMT







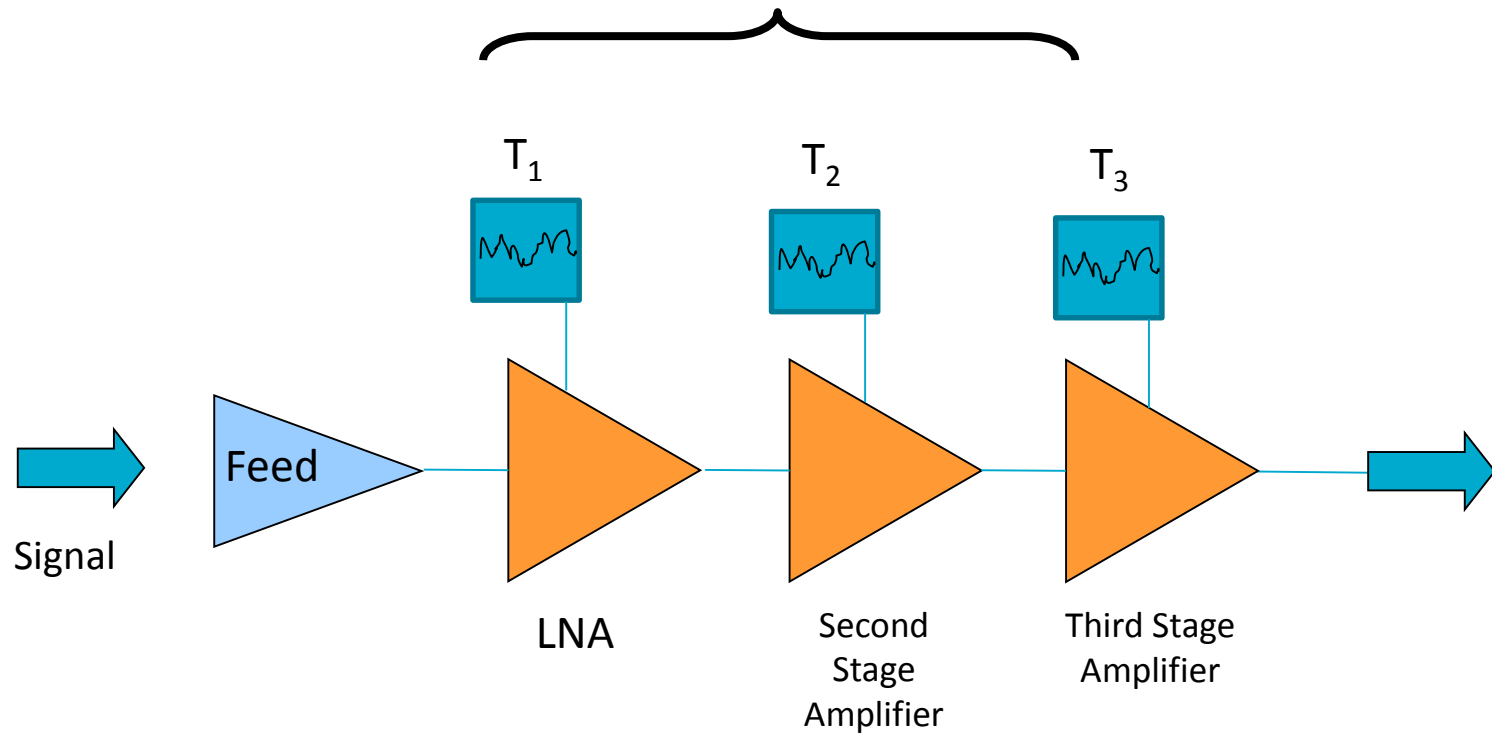
$$P_{output} \propto Gain \Delta f$$

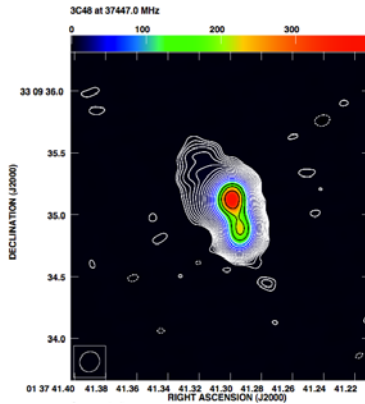


$$P_{output} = Gain \Delta f k_B T_{resistor}$$

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

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





10Jy radio source \rightarrow $\sim 1\text{K}$ additional noise



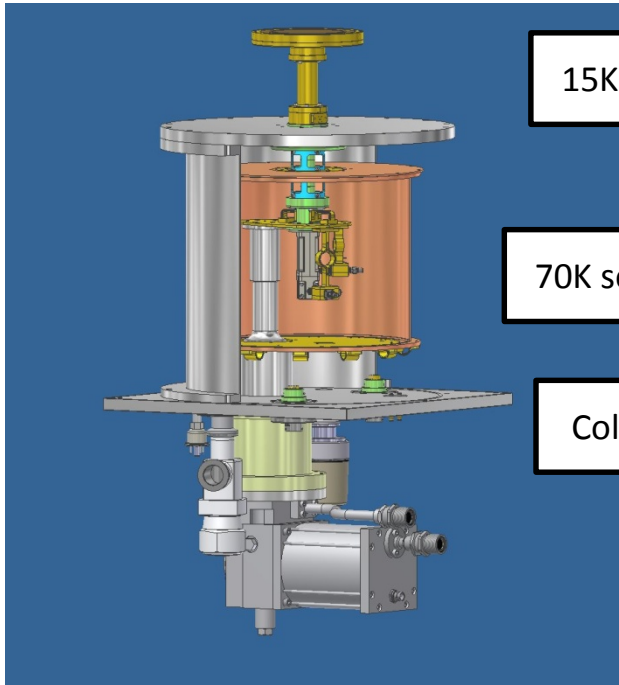
Your hand \rightarrow $\sim 300\text{K}$ additional noise



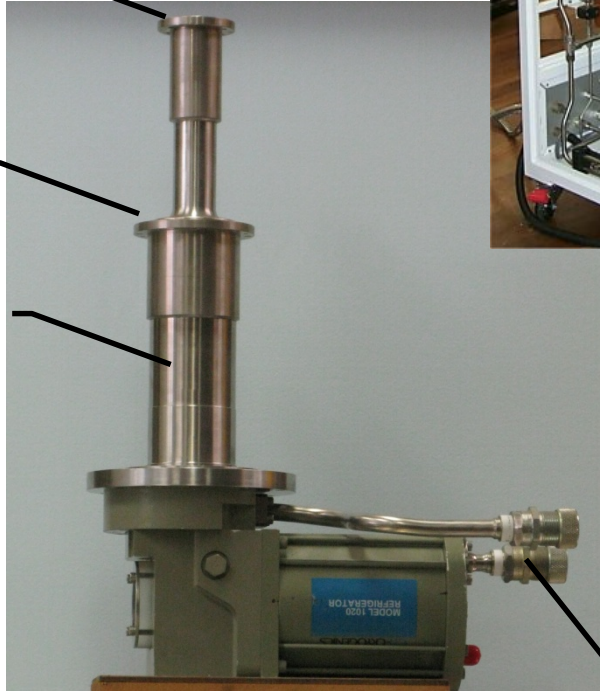
Mobile Phone at 1 km \rightarrow $\sim 1 \times 10^{11}$ K !!
(in primary beam)

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

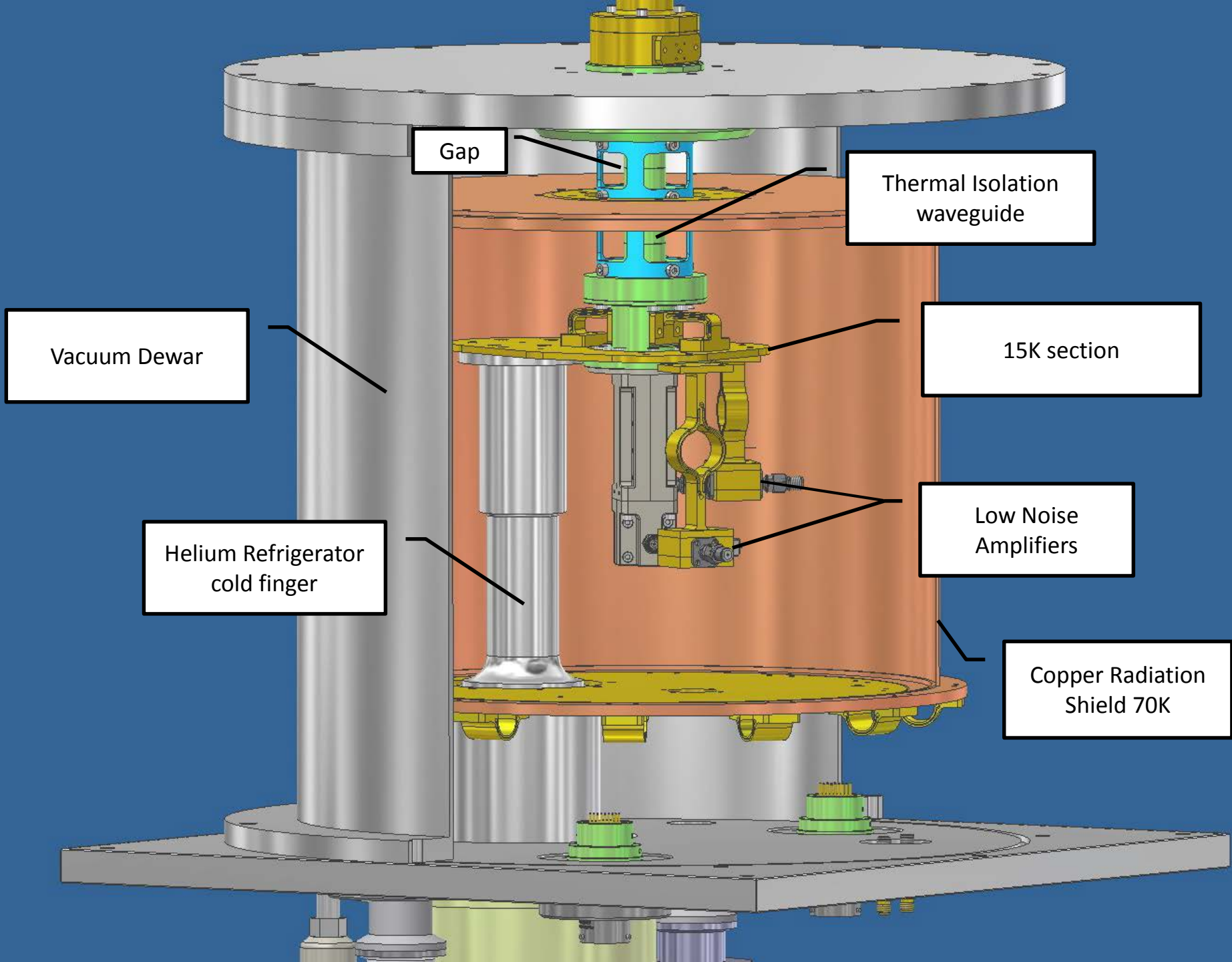


Helium Refrigerator

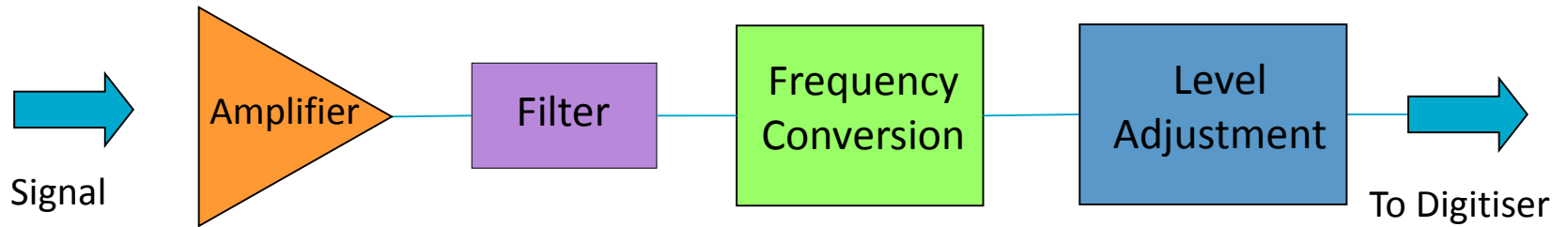


Helium Compressor

Helium Lines

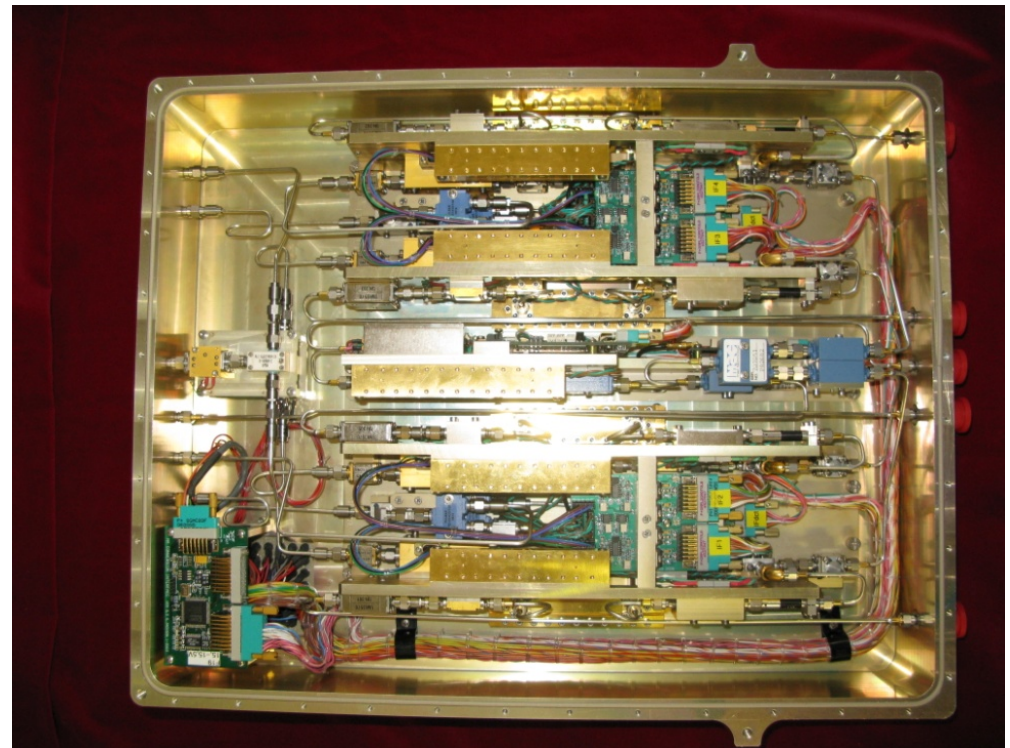


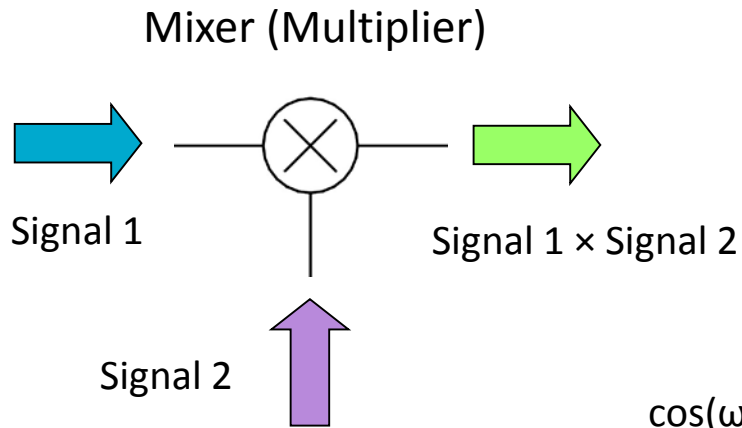
The RF System



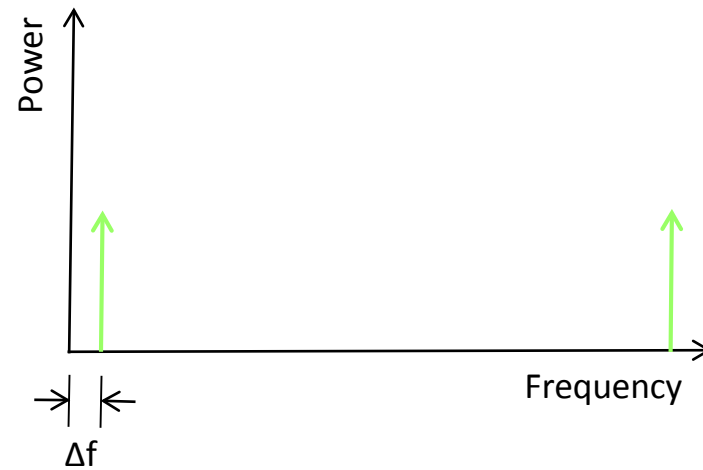
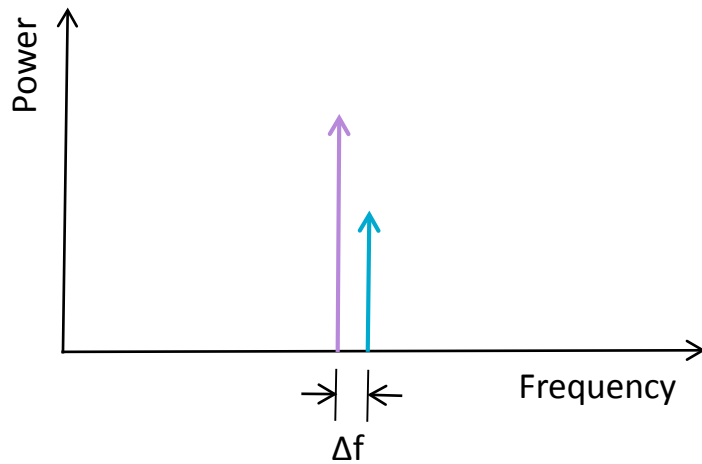
Contains:

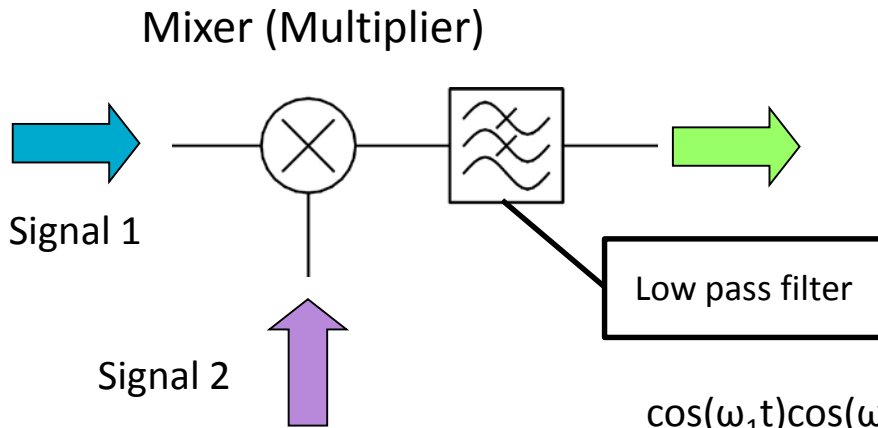
- More amplification
- Band defining filters
- Frequency conversion
- Level adjustment
- Signal detection
- Band shaping



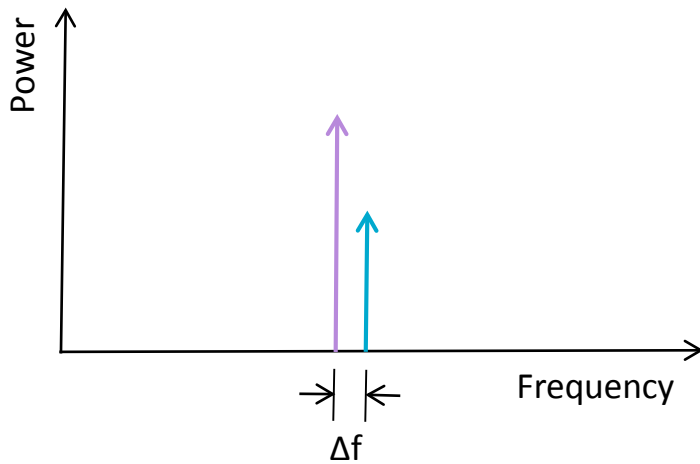
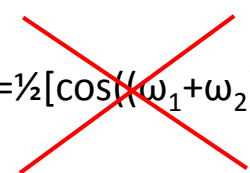


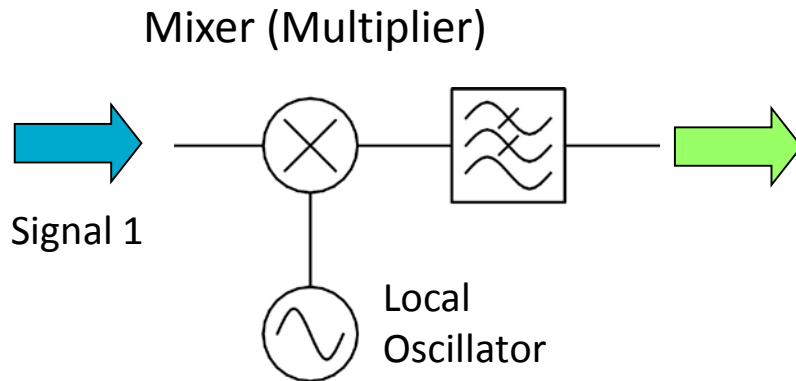
$$\cos(\omega_1 t)\cos(\omega_2 t) = \frac{1}{2}[\cos((\omega_1 + \omega_2)t) + \cos((\omega_1 - \omega_2)t)]$$



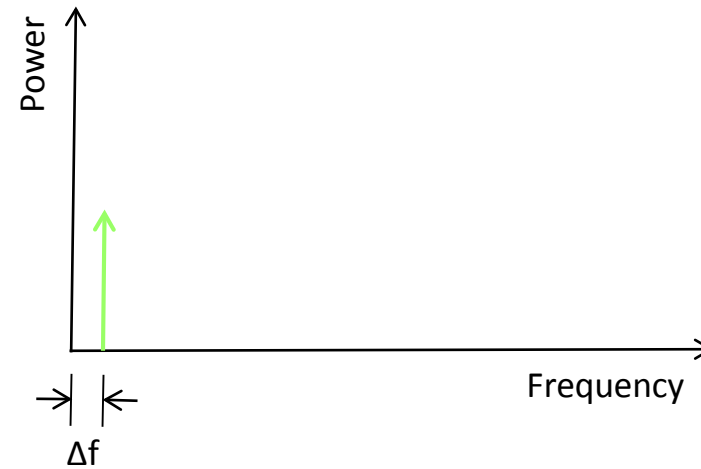
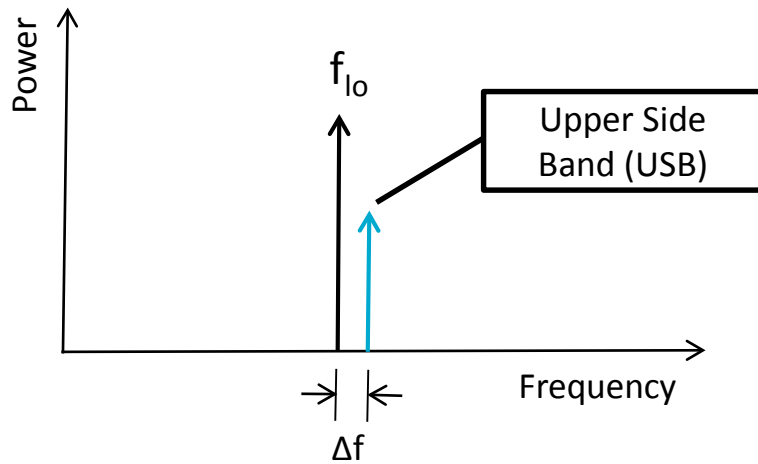


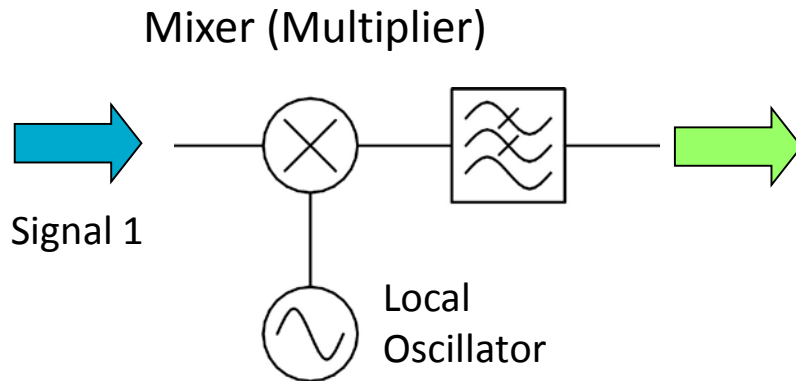
$$\cos(\omega_1 t)\cos(\omega_2 t) = \frac{1}{2}[\cos((\omega_1 + \omega_2)t) + \cos((\omega_1 - \omega_2)t)]$$



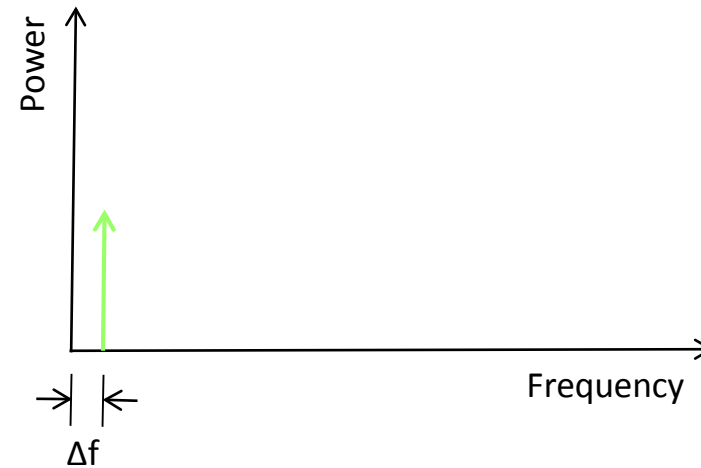
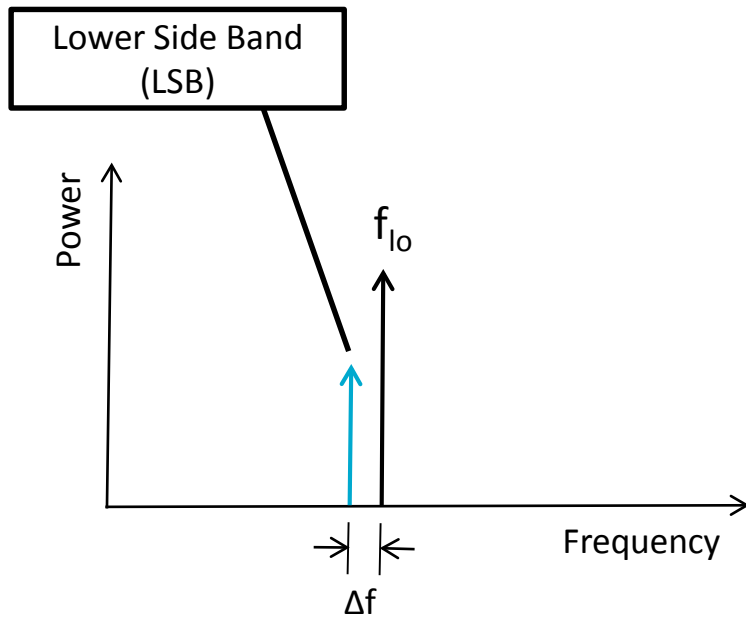


$$\cos(\omega_1 t)\cos(\omega_{LO} t) \rightarrow \frac{1}{2}\cos[(\omega_1 - \omega_{LO})t]$$

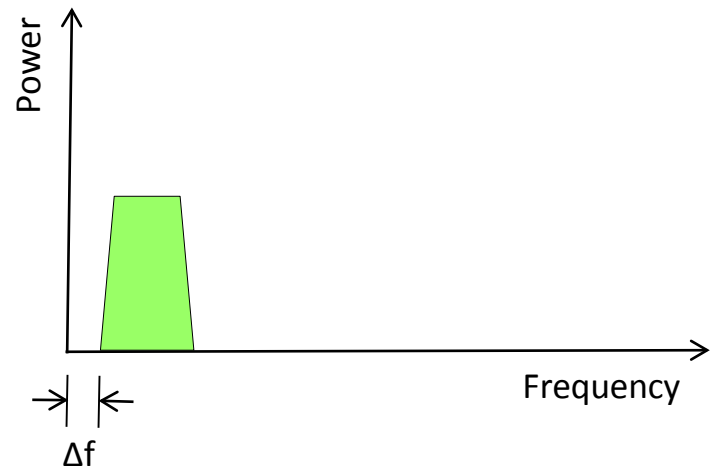
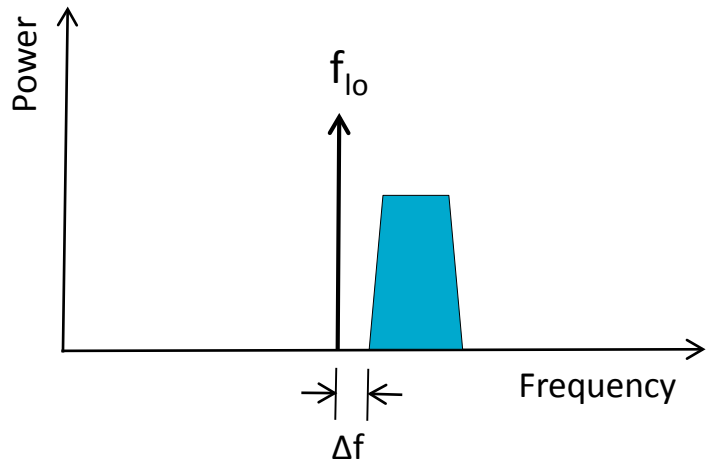
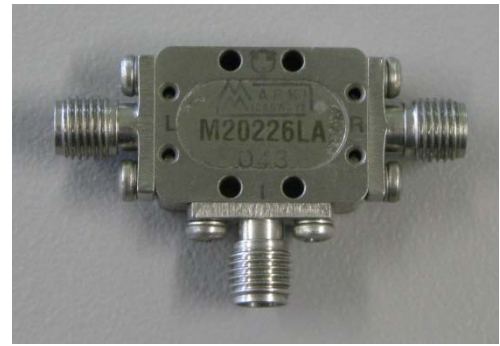
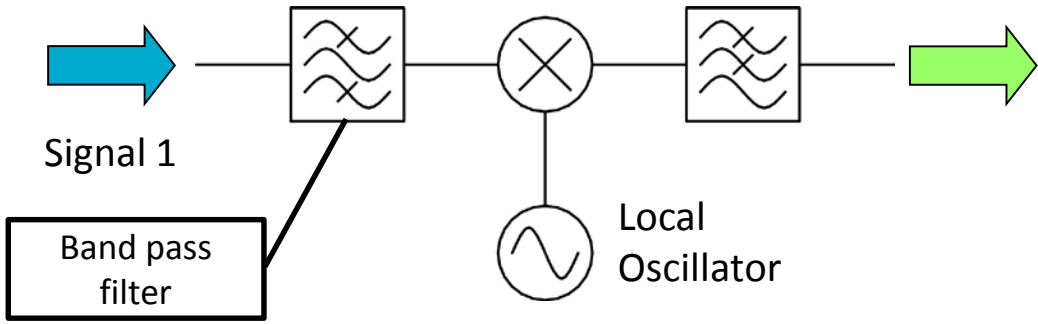




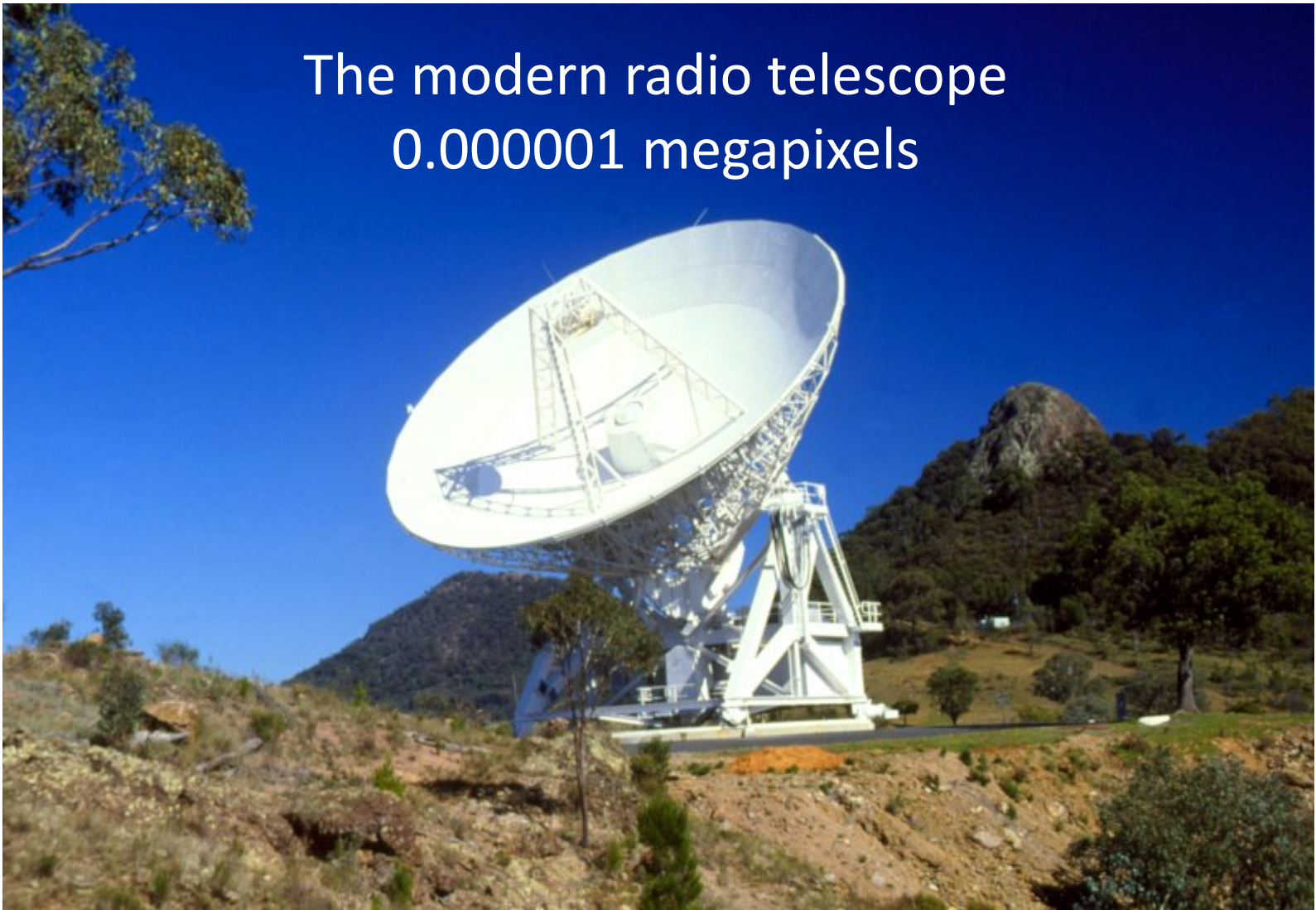
$$\cos(\omega_1 t)\cos(\omega_{LO} t) \rightarrow \frac{1}{2}\cos[(\omega_{LO}-\omega_1)t]$$



Mixer (Multiplier)



The modern radio telescope 0.000001 megapixels



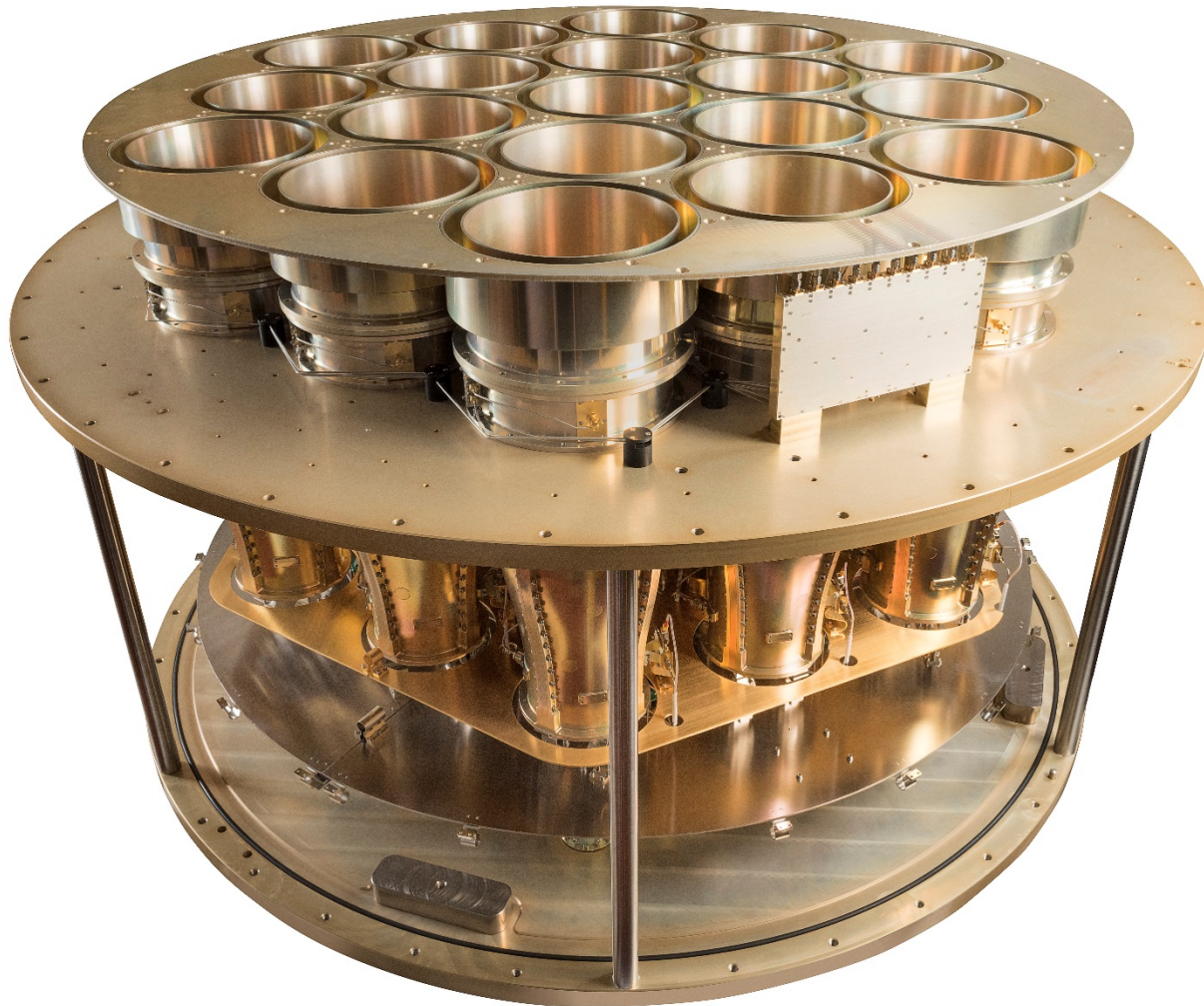
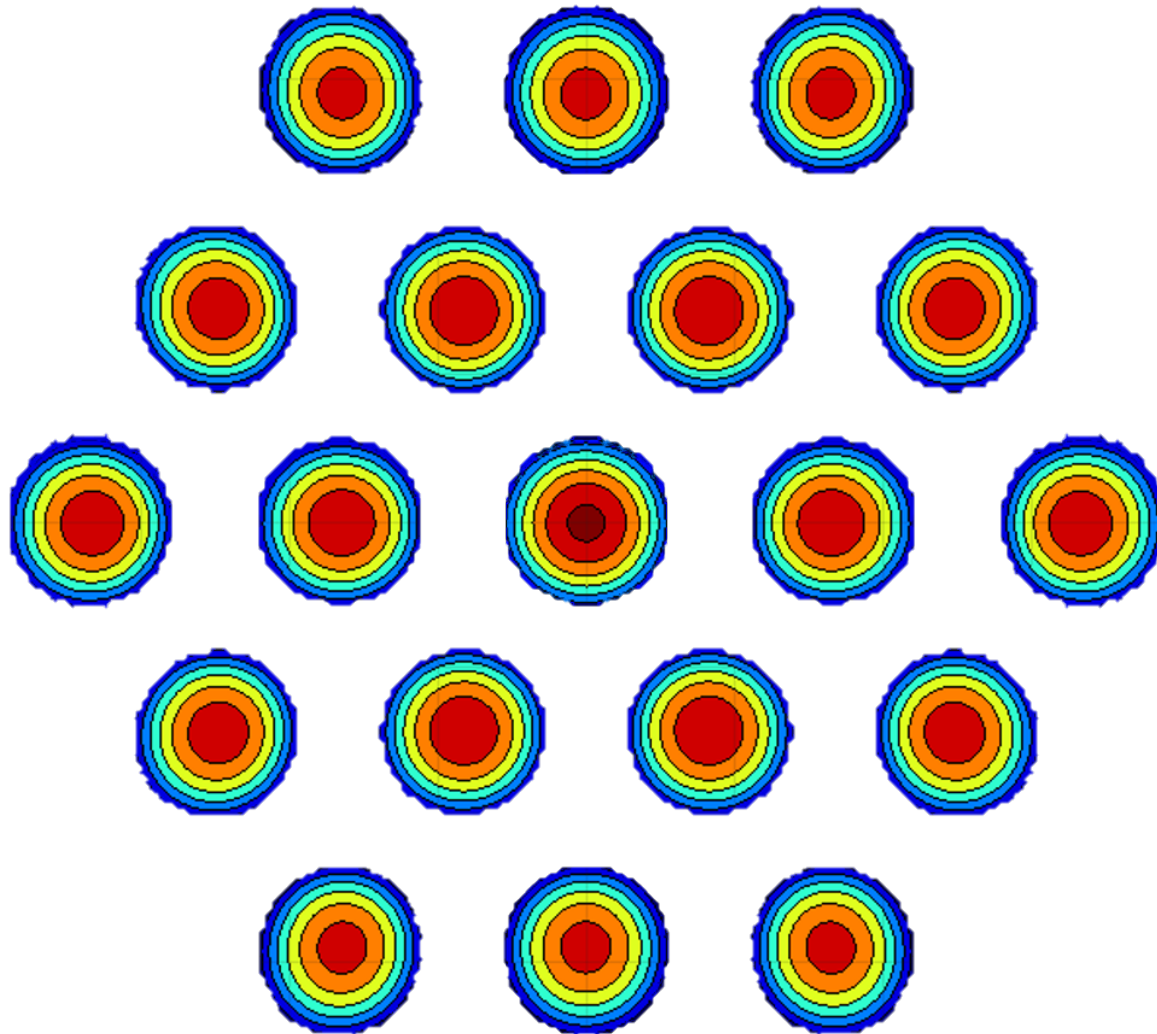
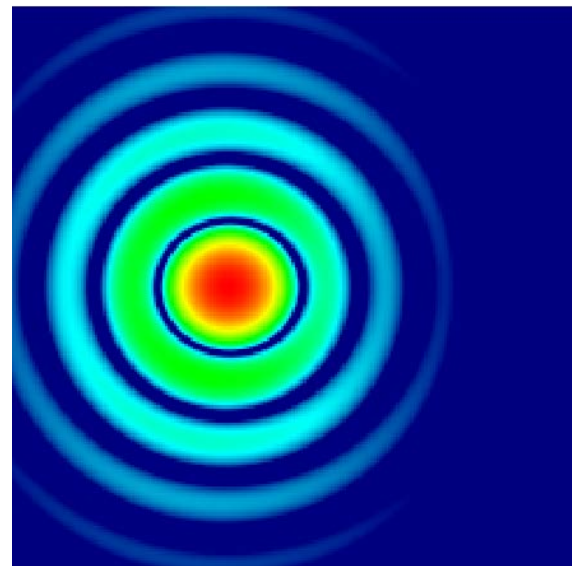
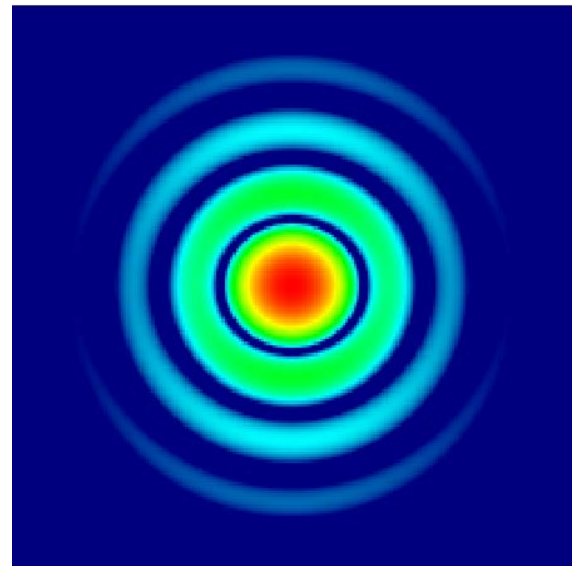
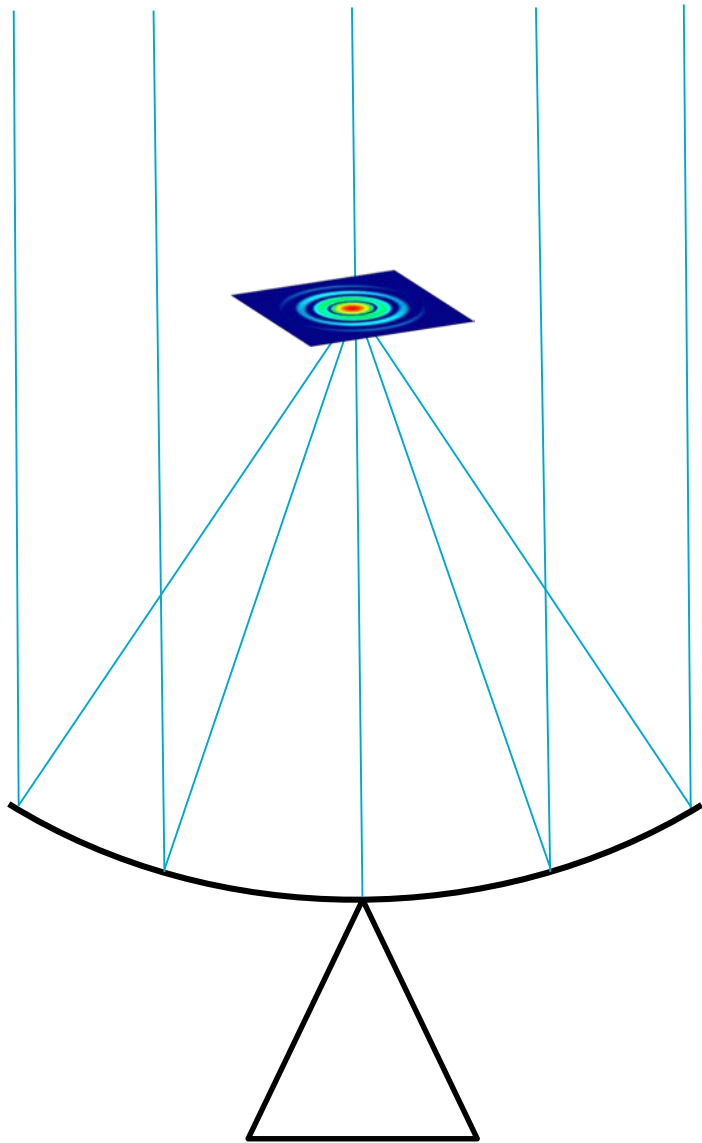
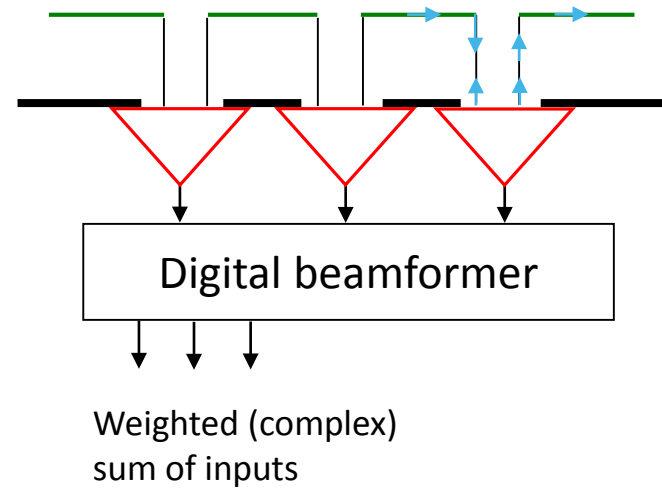
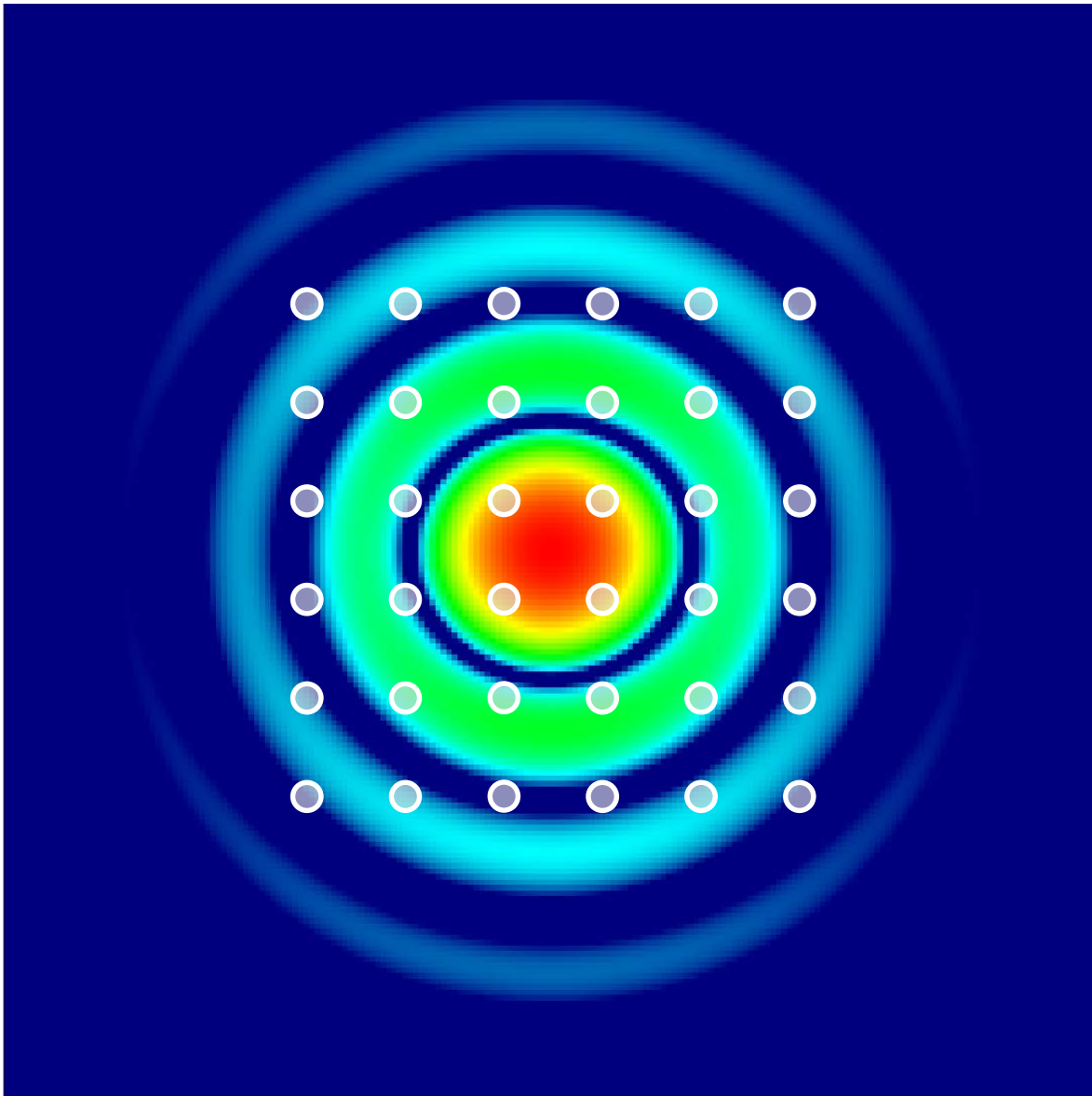
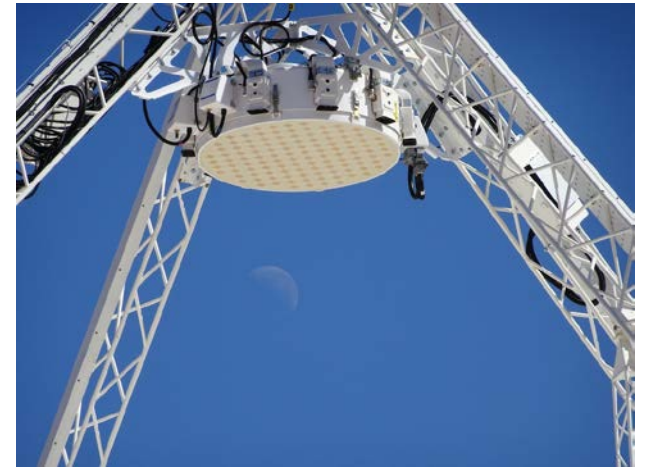
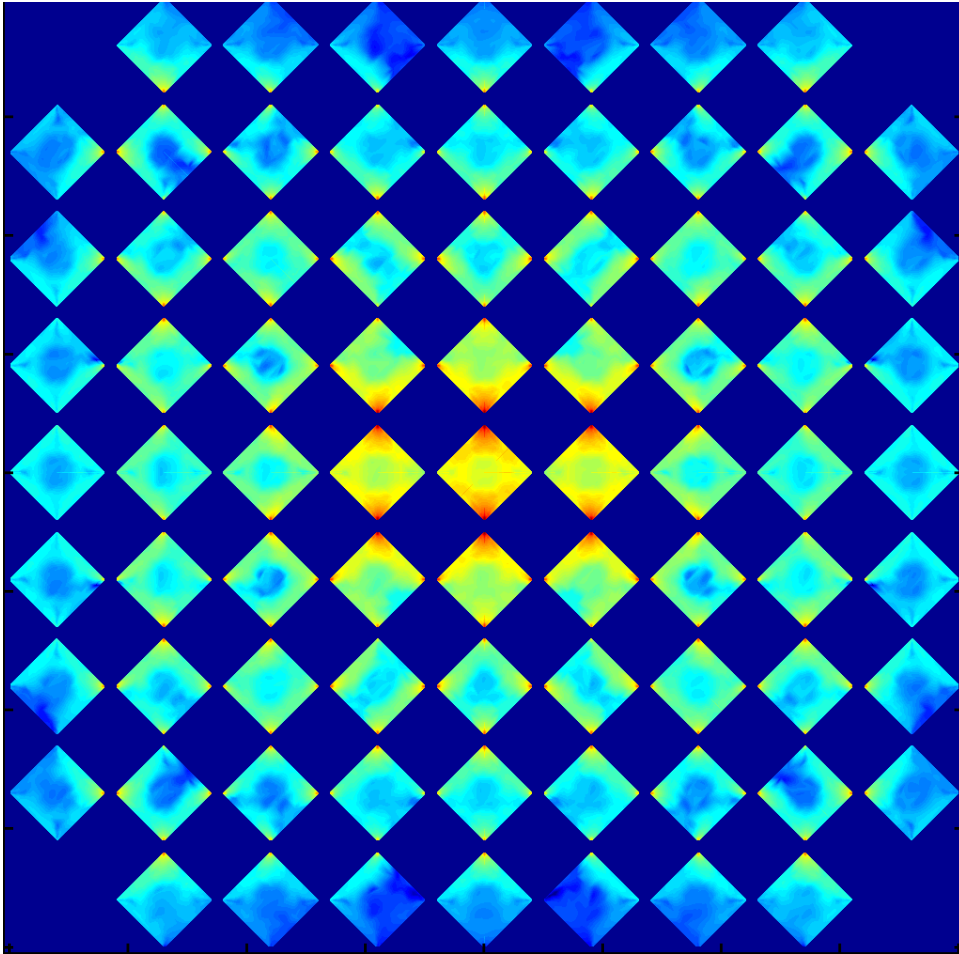


Photo credit: Wheeler Studios











Thank you

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