Receiver Systems

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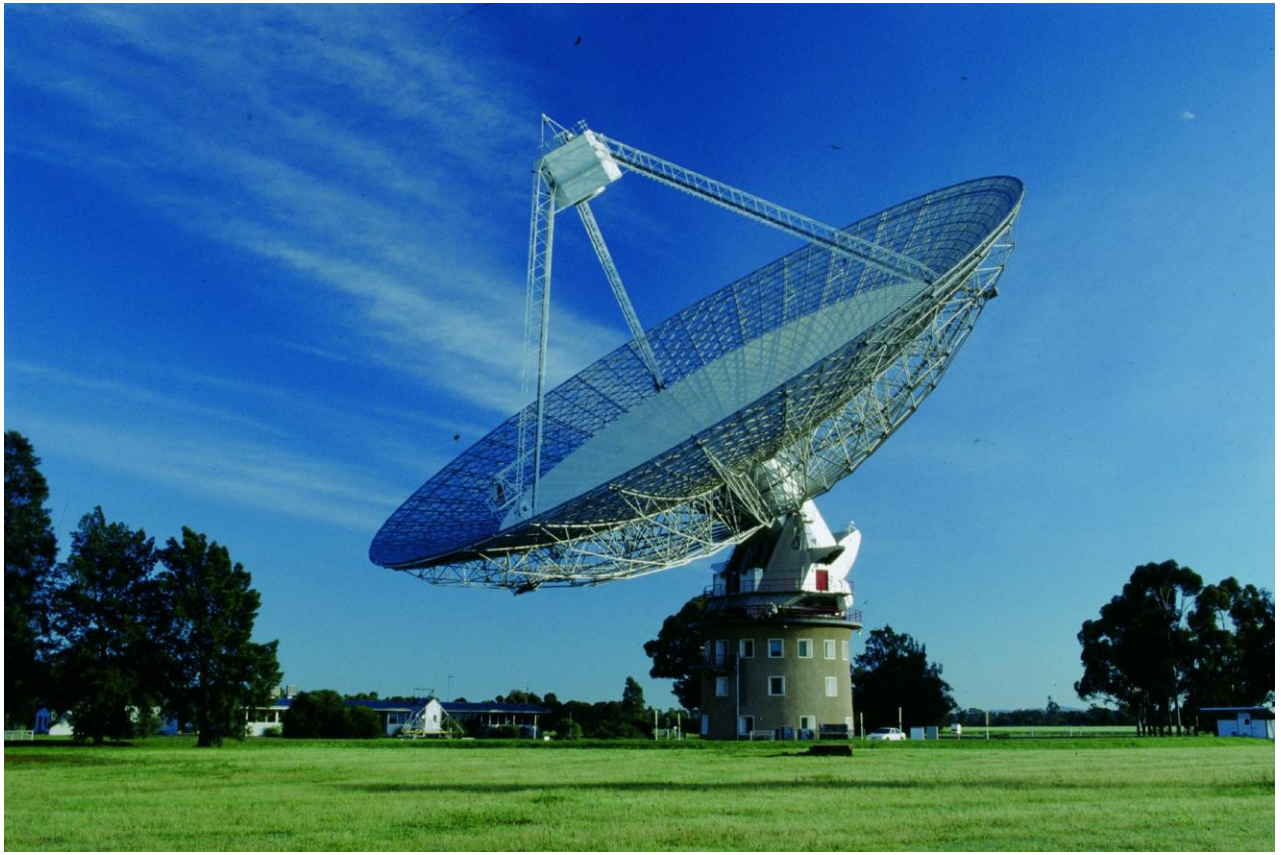
The Basic Structure of a typical Radio Telescope

Receiver	Captures and amplifies the incoming radiation
Conversion	Filters and reduces the frequency of the microwave signal
Digitiser	Converts the analog signal to a digital bit stream
Signal Processing / Correlator	Divides signal into frequency bins and forms correlation products between signals

They are much the same



Radiotelescope Receivers

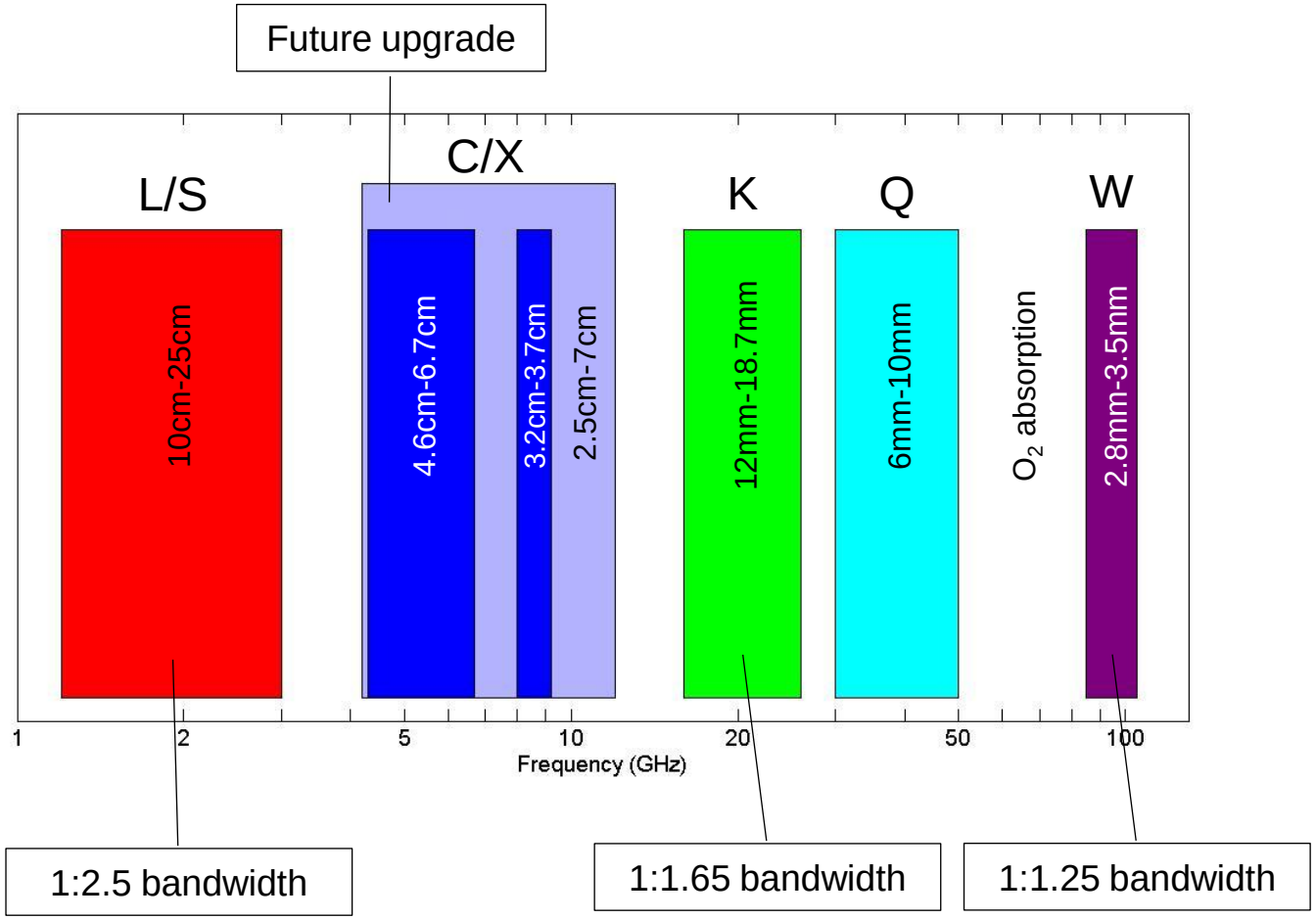
The Receiver

On the outside...

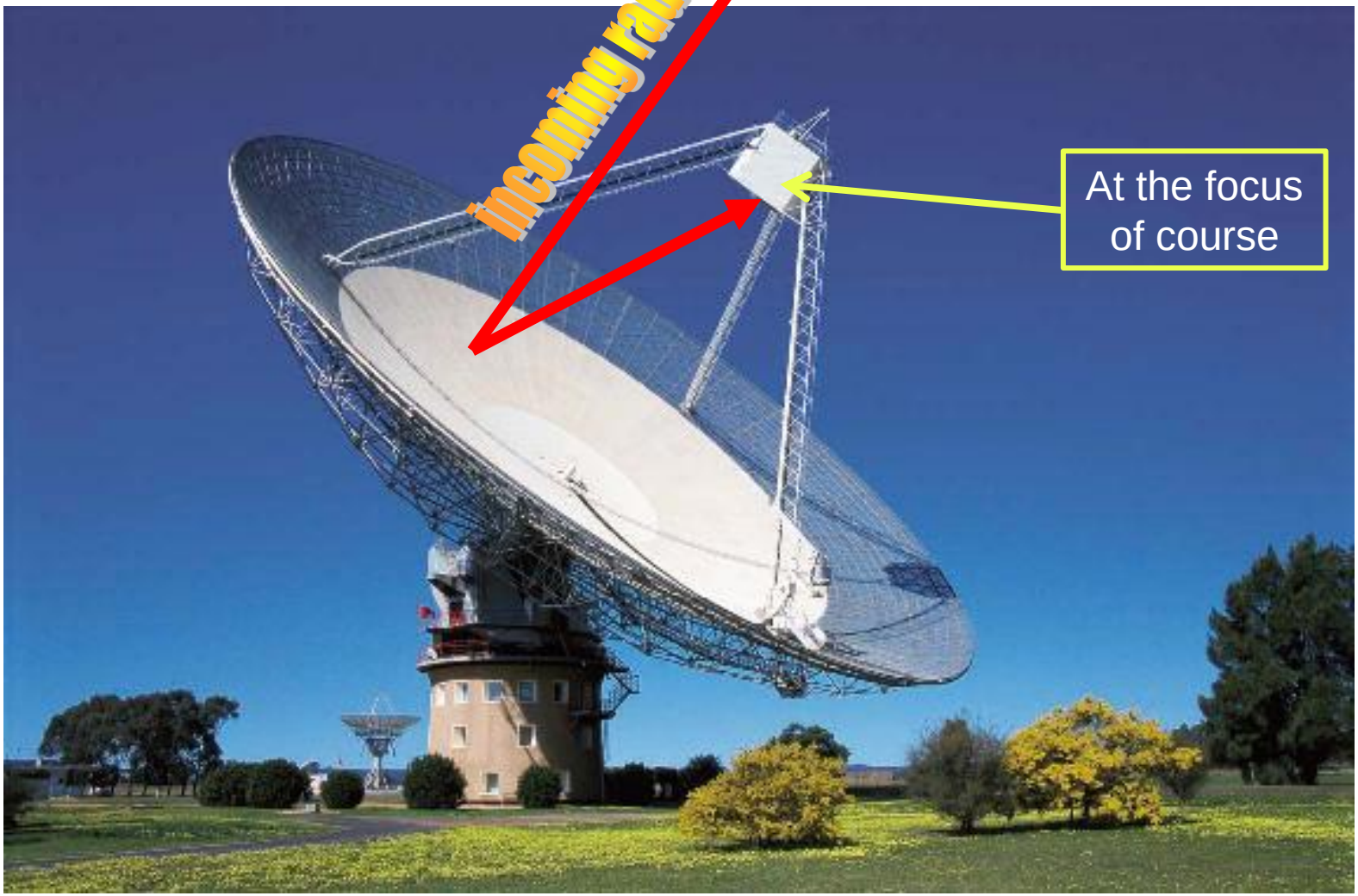
The Receiver

On the inside...

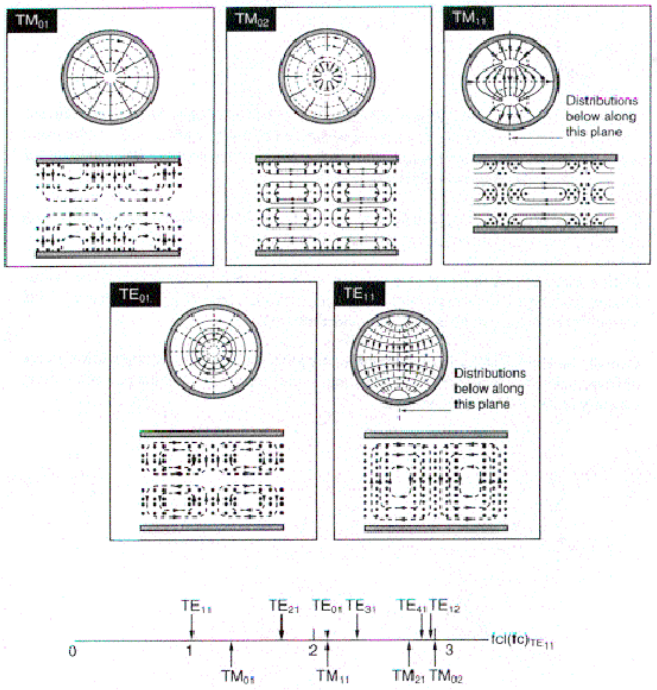
The Australia Telescope Receivers



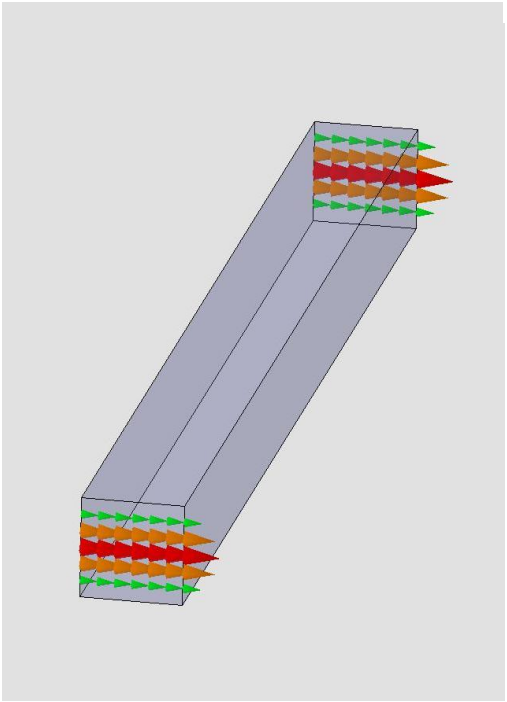
Where do they go?

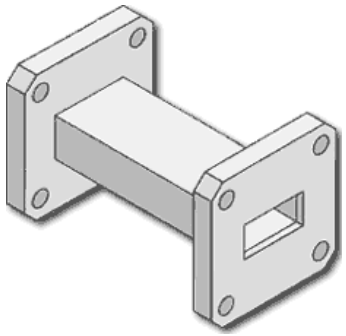

Incoming radiation
At the focus
of course

Waveguides

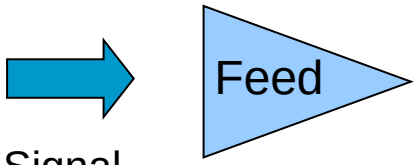


- Replace cables at high frequencies
- Operate like optical fibres for microwaves
- Only work over a limited frequency range
- Can support signals with two polarisations

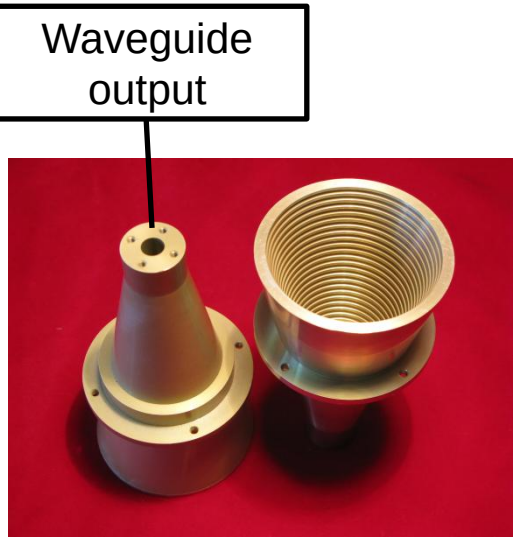


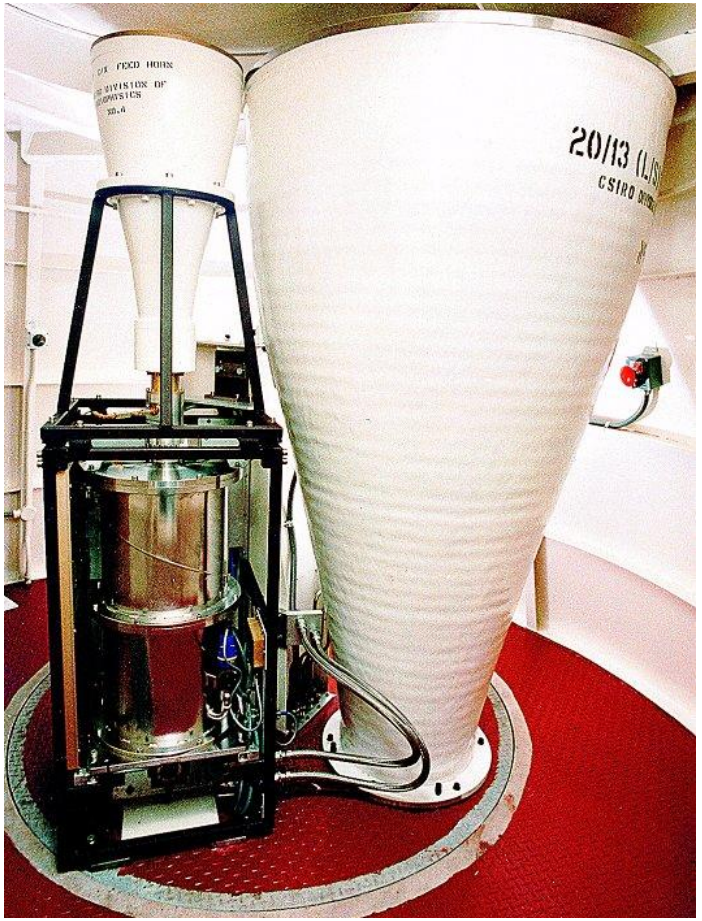


Receiving the signal – Feed horns

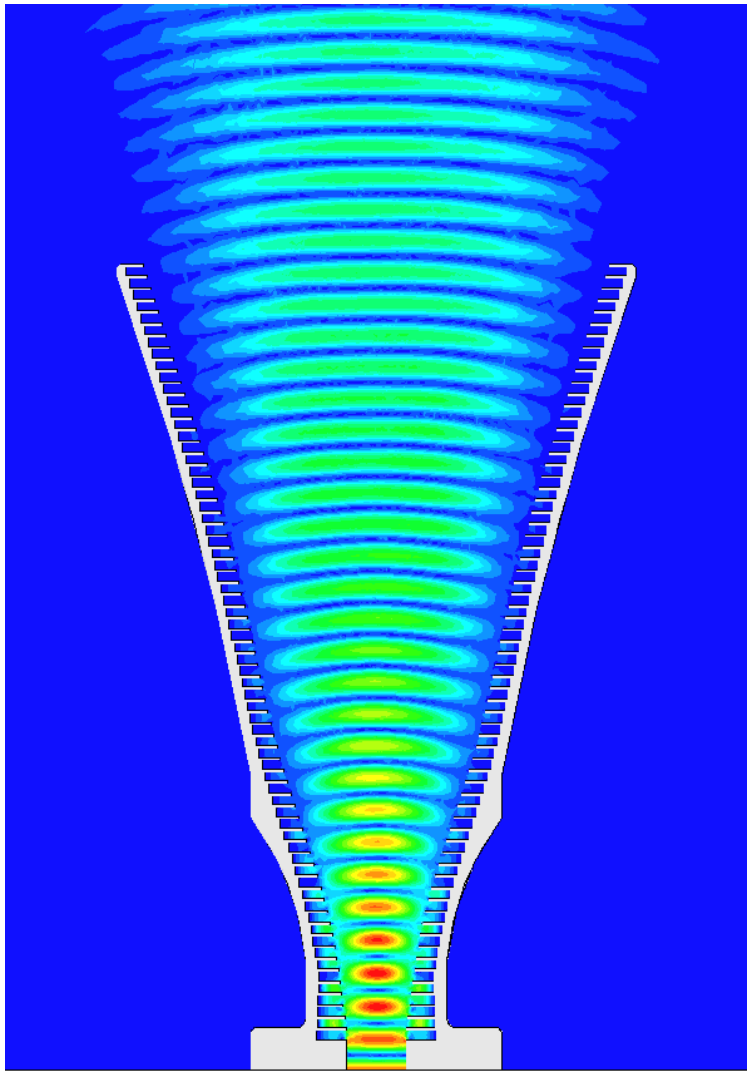


Captures the focused microwaves into a waveguide output

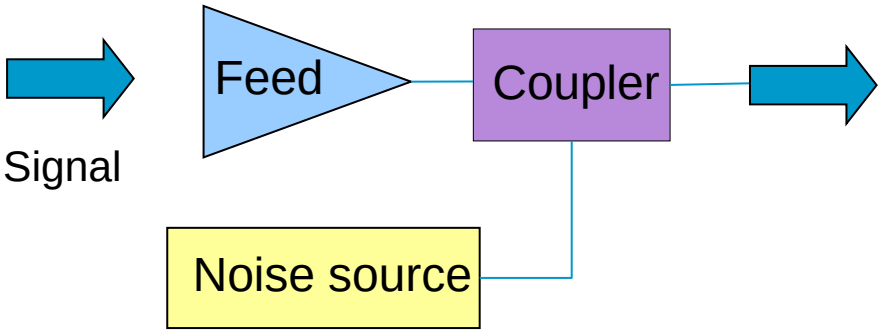


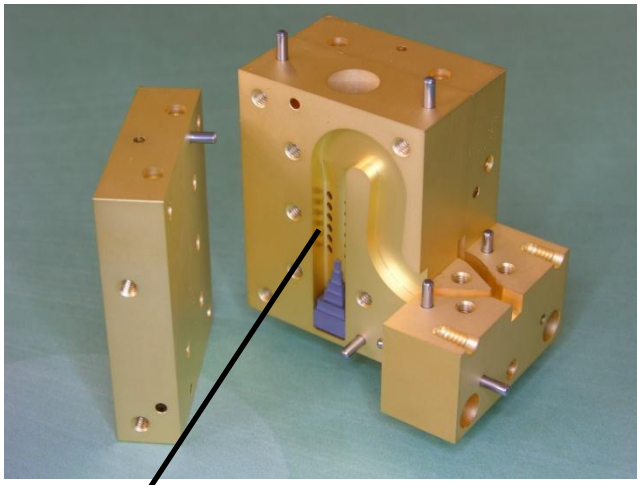


Feed Horns



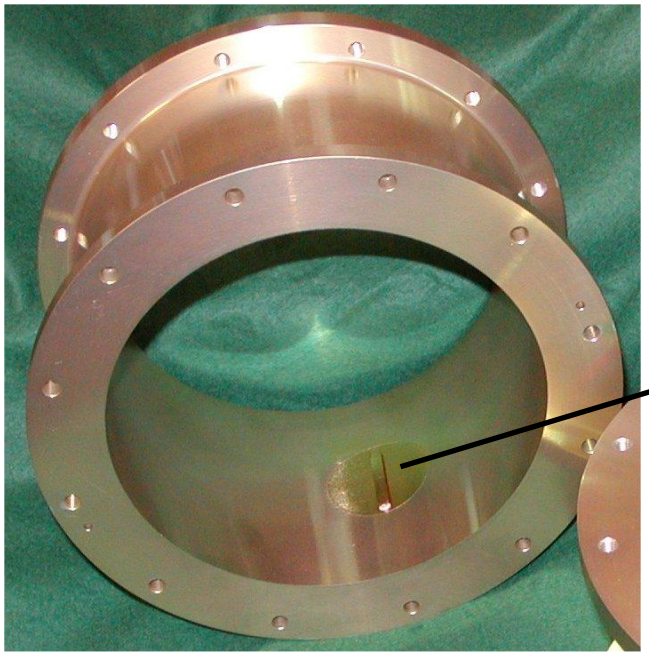
Coupling noise into the System





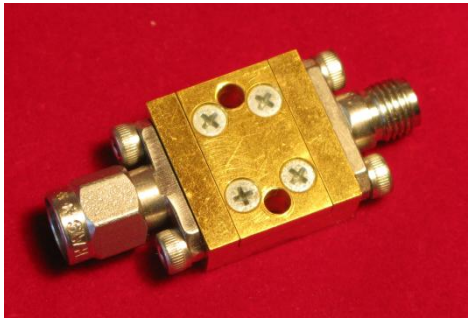
Noise coupled in through small holes

7mm waveguide coupler



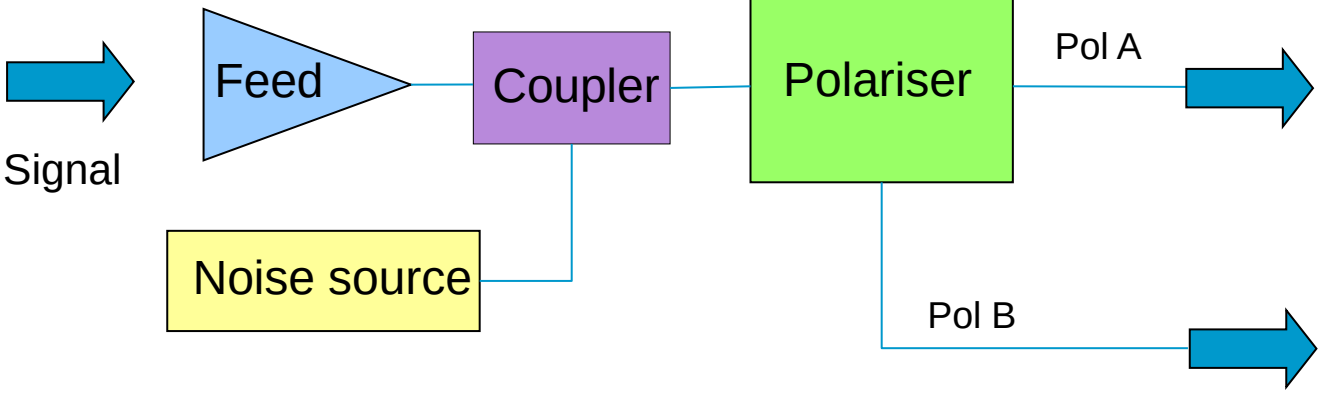
Noise coupled in through vane

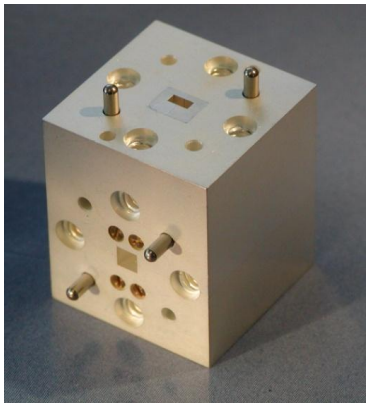
21cm waveguide coupler

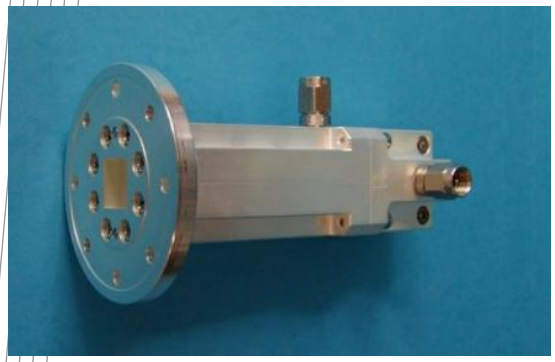


12mm noise source

Separating Polarisations – Orthomode Transducers (OMTs)







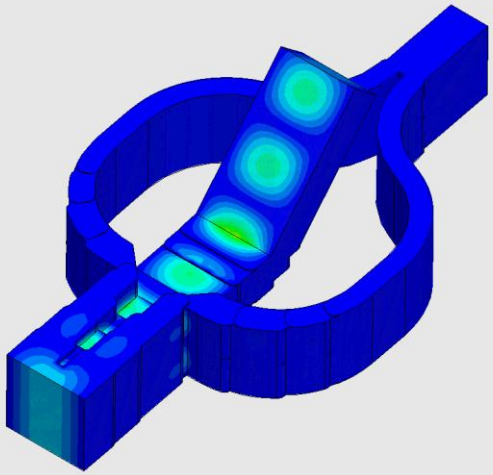
12mm Orthomode transducer

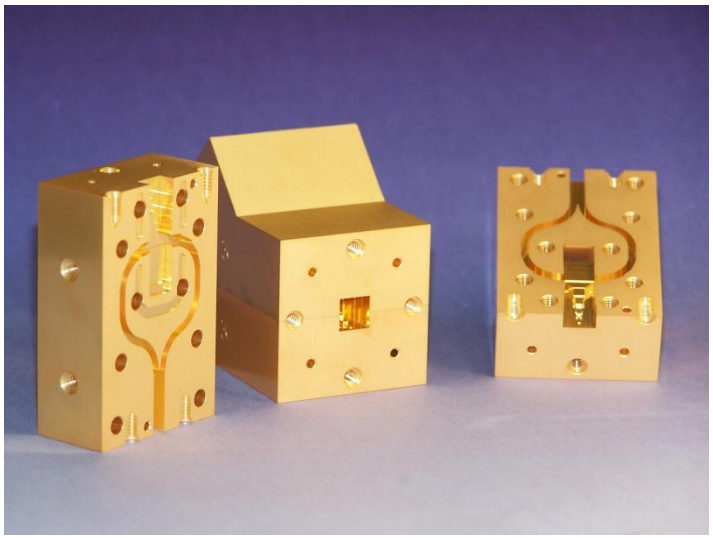
Separates incoming signal into two linear or circular polarisations

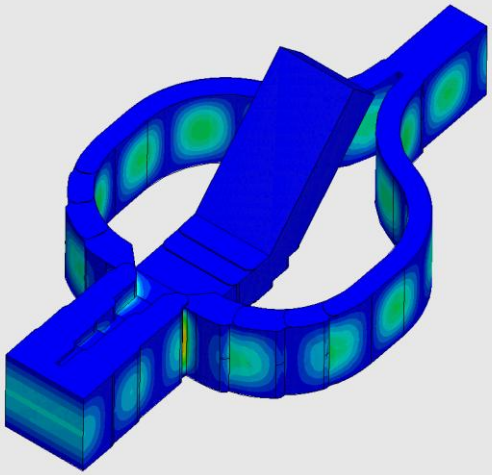
Linear OMTs are more effective over broad frequency bands (usually)

4cm Orthomode transducer

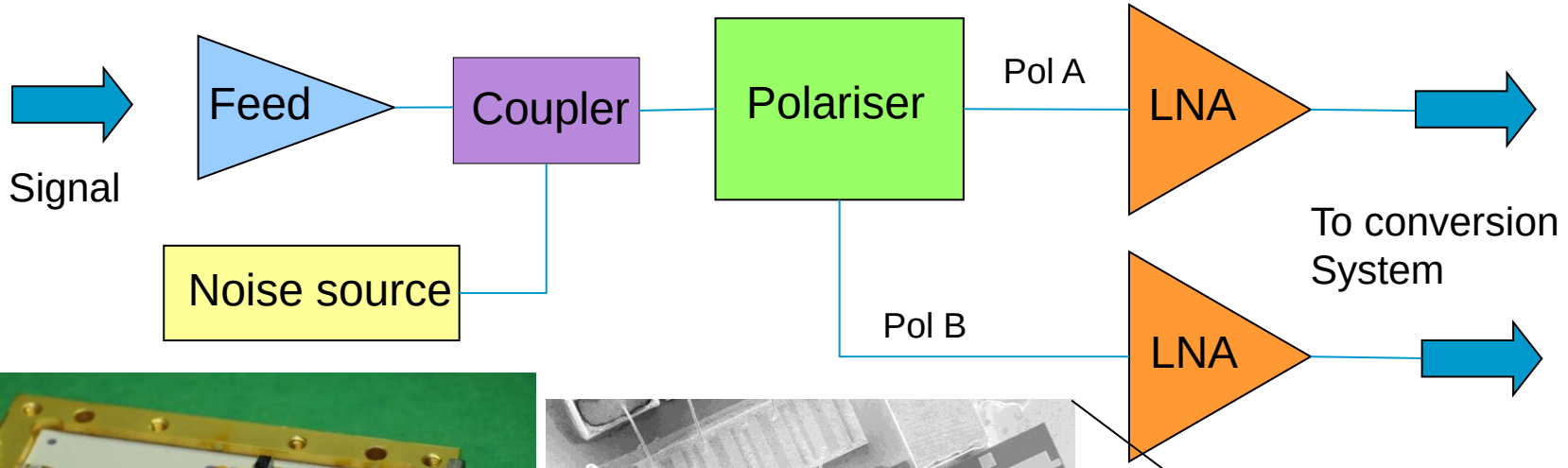
Separating Polarisations – Orthomode Transducers (OMTs)

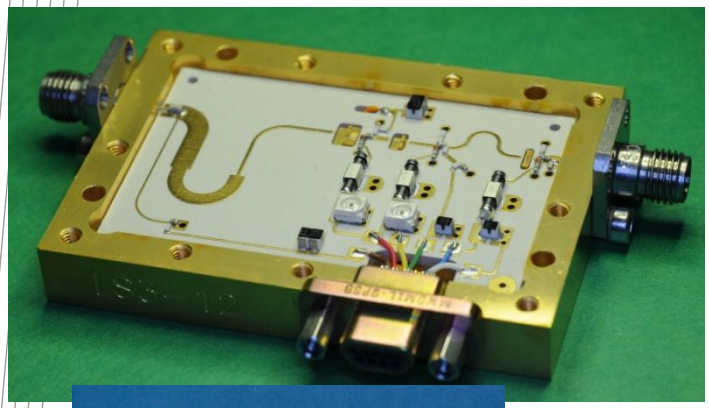


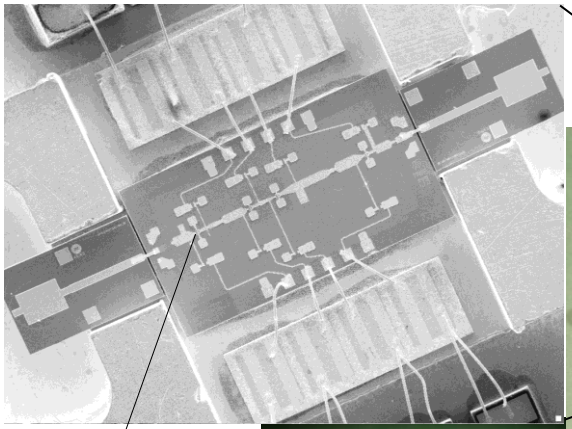


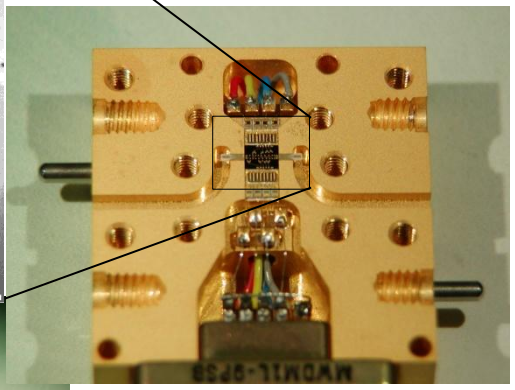


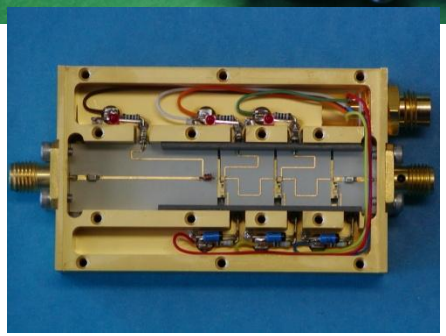
Low Noise Amplifiers (LNA)



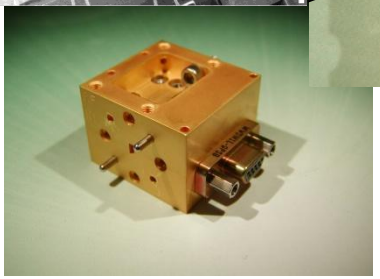






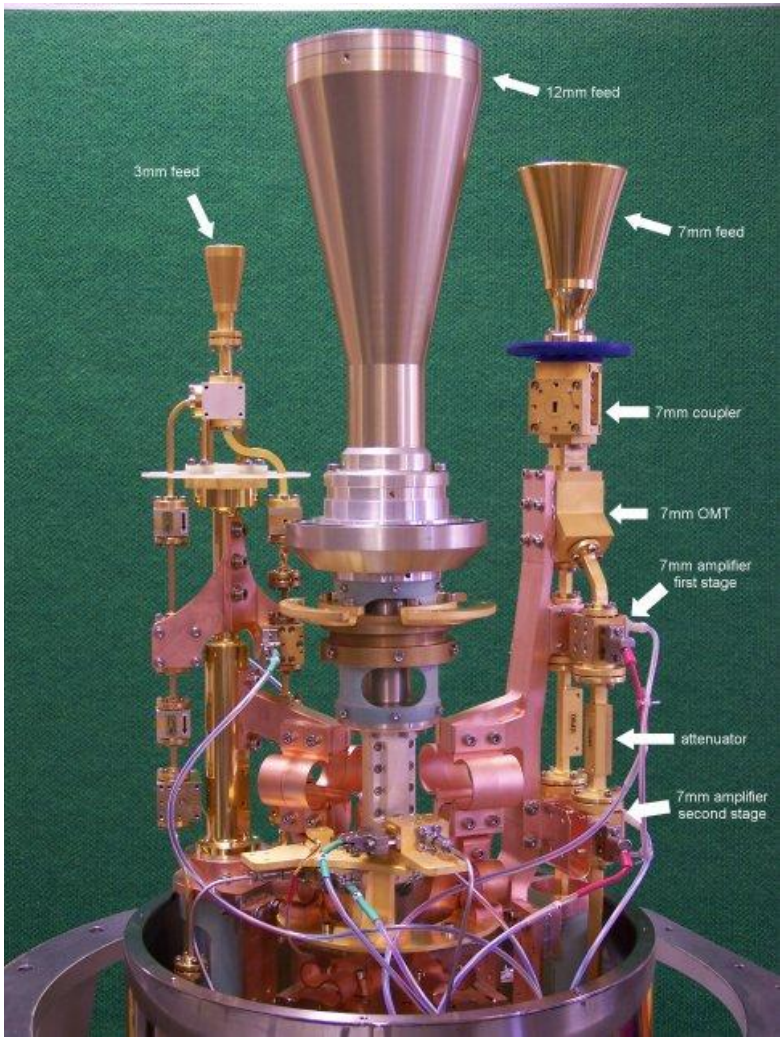


High Electron Mobility Transistor



….so though receiver topologies can be quite varied I am saying that this is a pretty typical structure of our receivers

…….and the 3/7/12 mm systems reflect this.

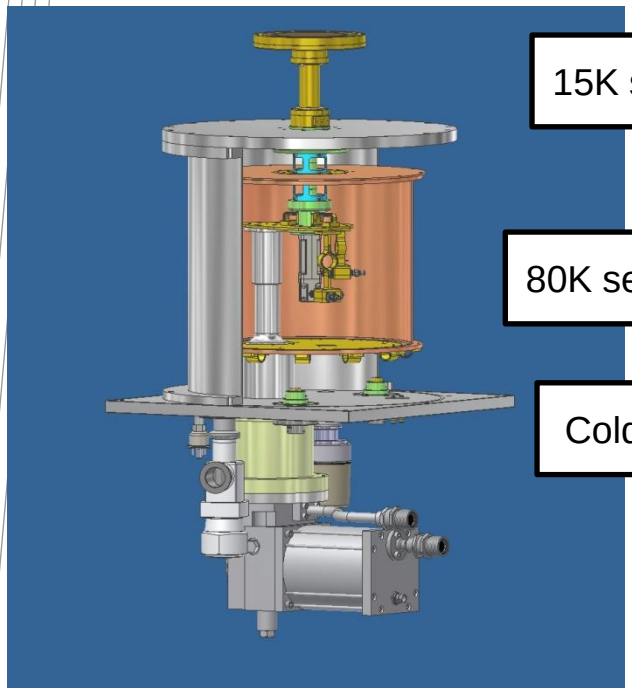

12mm feed
3mm feed
7mm feed
7mm coupler
7mm OMT
7mm amplifier
first stage
attenuator
7mm amplifier
second stage

What is the rest of the stuff?

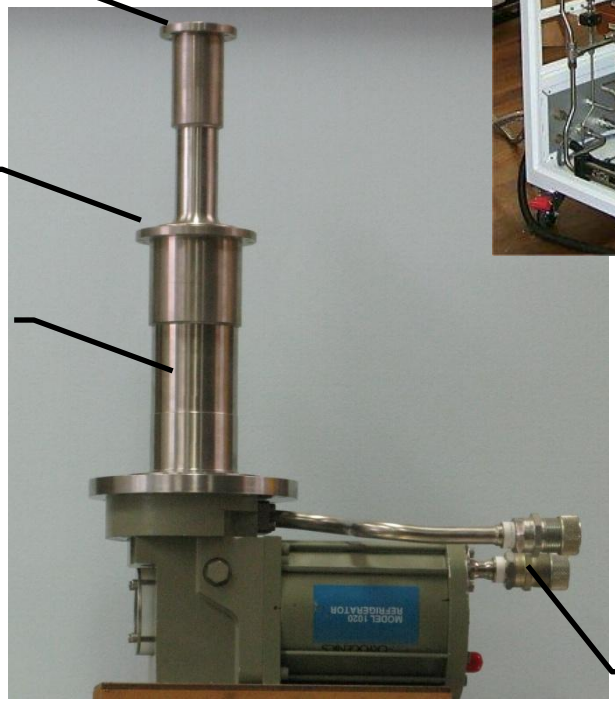
Electronics

- Supplies and monitors all amplifier voltages and currents
- Monitors system temperatures and pressures

Cryogenics

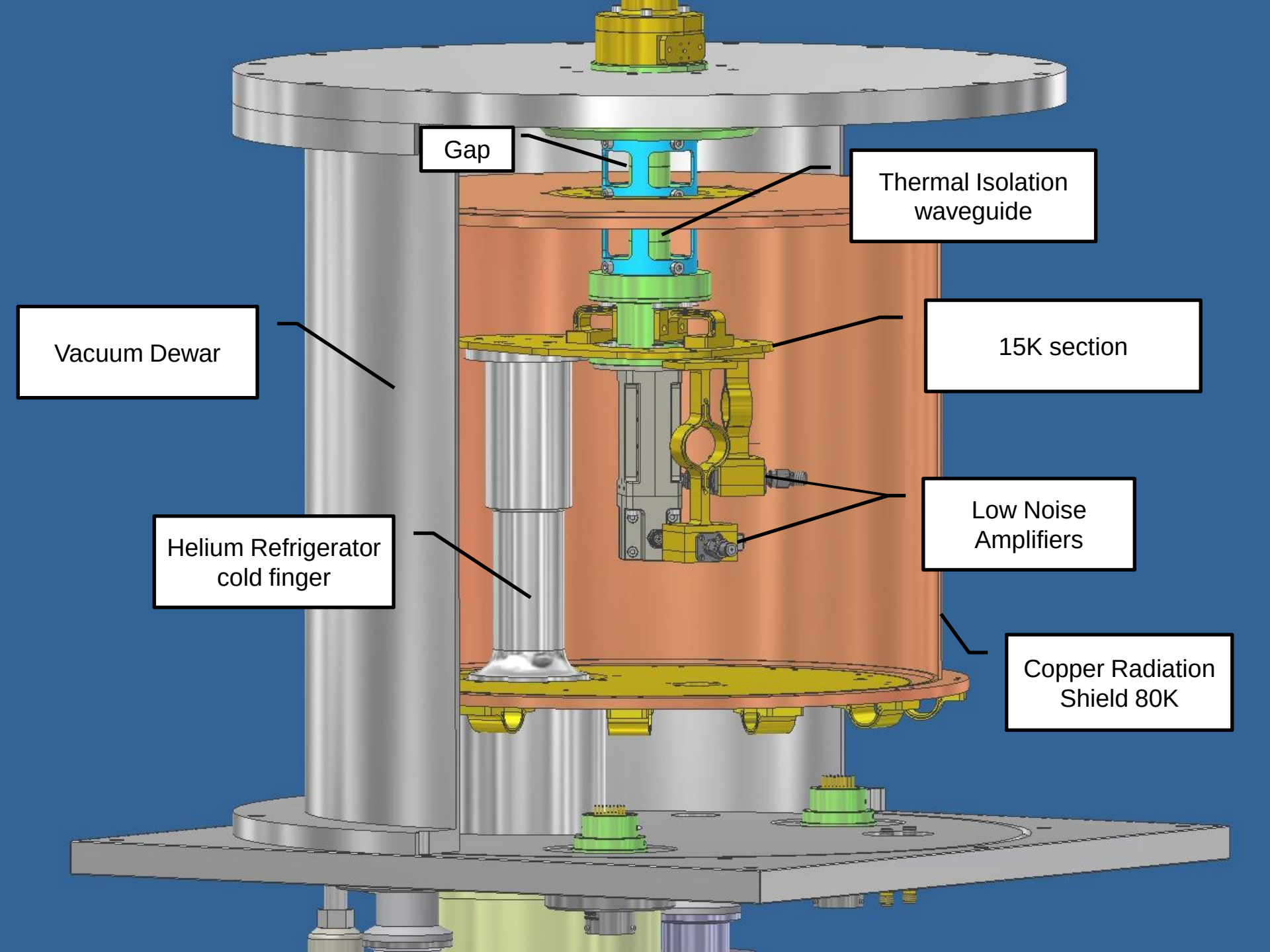


Refrigerator in the Parkes 12mm receiver



Helium Refrigerator

Helium Compressor


Gap
Thermal Isolation waveguide
Vacuum Dewar
15K section
Low Noise Amplifiers
Helium Refrigerator cold finger
Copper Radiation Shield 80K

….but why do we need to cool our receivers at all?

……well first

How weak is the signal?

10Jy radio source →

$10 \times 10^{-26}\,W\,m^{-2}Hz^{-1} \times 300m^2 \times 2 \times 10^{9}\,Hz$

$= 6 \times 10^{-14}\,W$

Effective area of an Australia telescope dish

Bandwidth of an Australia telescope digitiser

Your Hand →

$1.38\times 10^{-23}\,W\,Hz^{-1}K^{-1} \times 300K \times 2 \times 10^{9}\,Hz$

$= 8 \times 10^{-12}\,W$

Boltzmann's constant

Mobile Phone →

$\approx 1W$

Mobile Phone on the moon→

$\approx 1W \div 4\pi\,(3.8\times10^{8}m)^2 \div 5\times10^{6}Hz$

$\approx 10Jy$

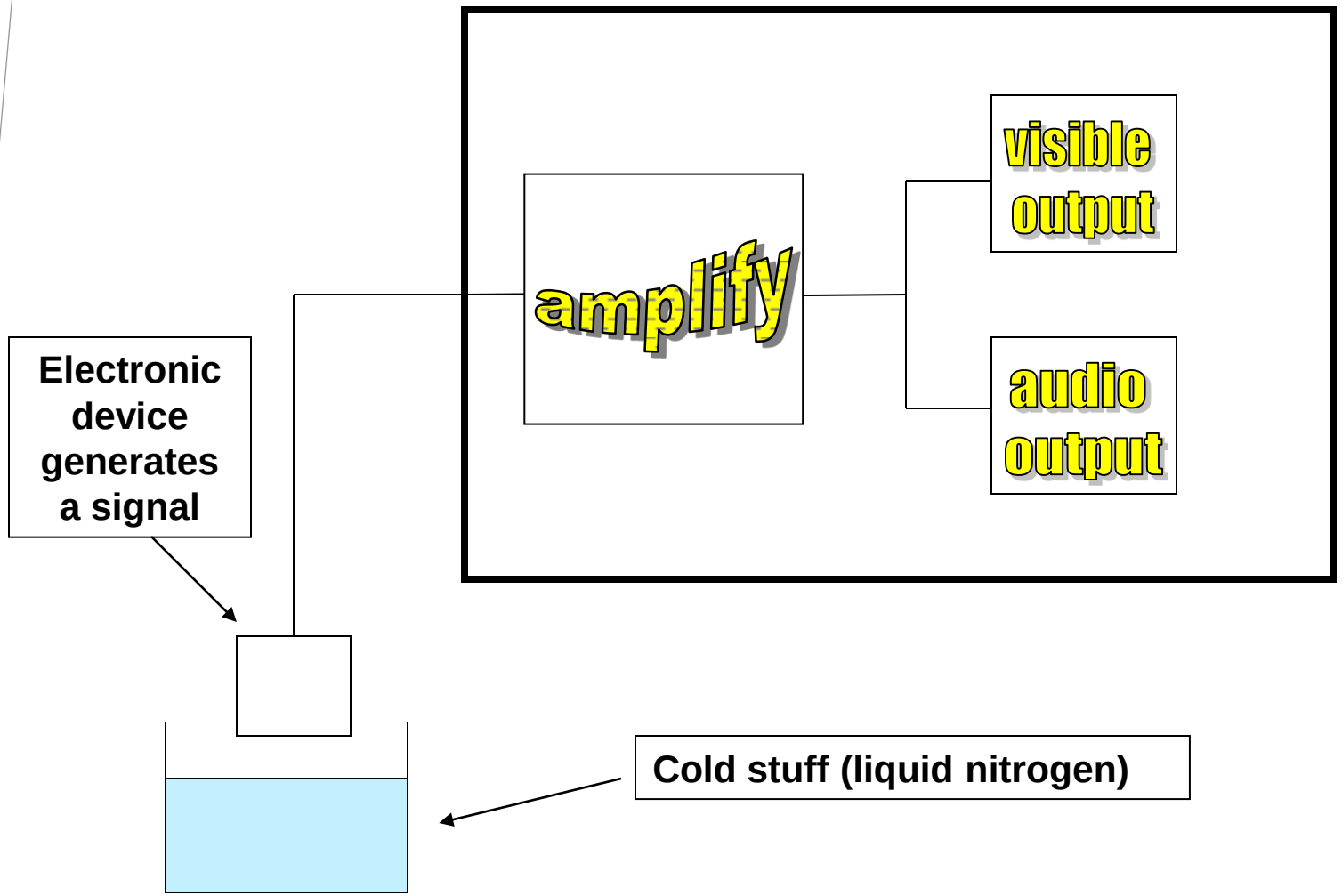
Lunar Distance

3G transmit bandwidth

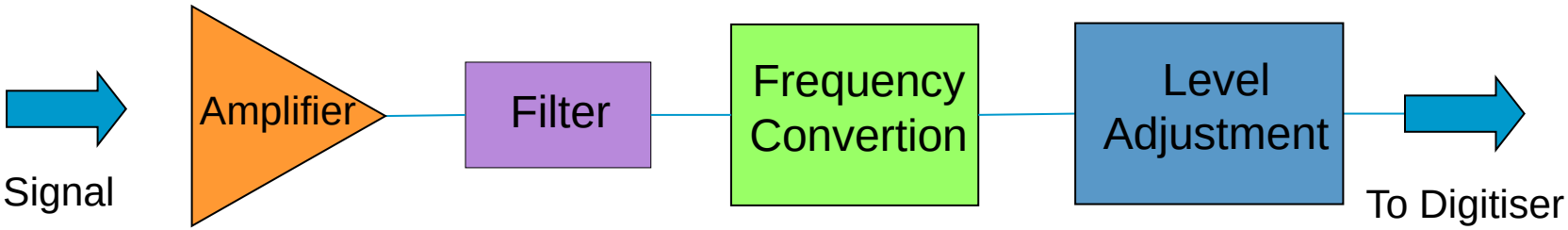
Like your hand all the components in the receiver system contribute a thermal noise signal which masks the astronomical signal we are trying to observe

By cooling the receiver we reduce these thermal sources of noise and improve the sensitivity of the receiver by 7-10 times

Reduce noise by cooling

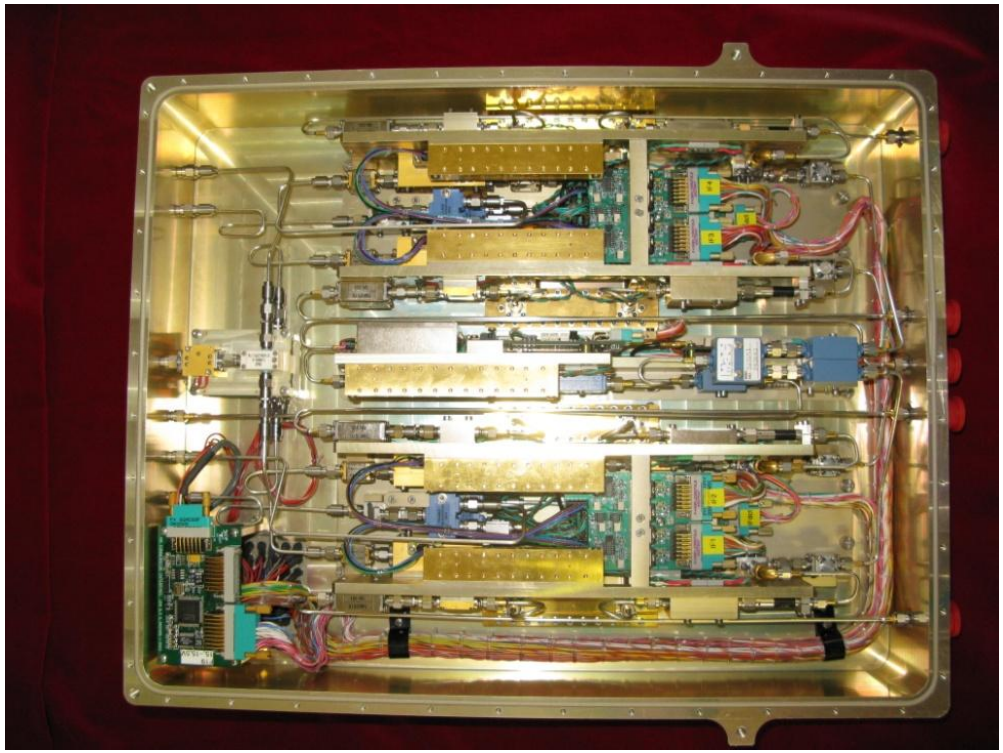


The Conversion System



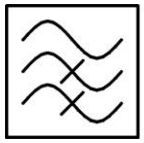
Contains:

- more amplification
- band defining filters
- frequency conversion
- level adjustment
- signal detection
- band shaping

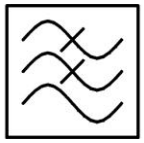


Filters

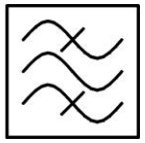
High Pass Filter



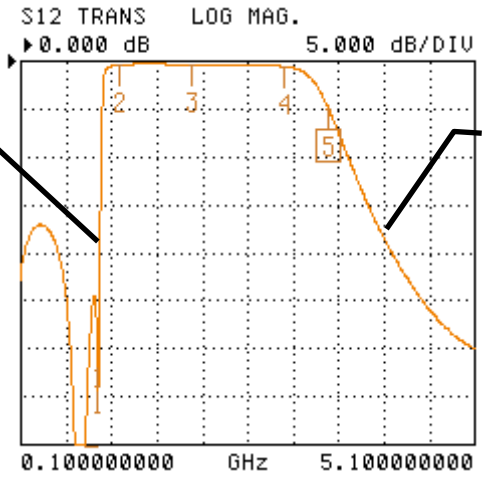
Low Pass Filter



Band Pass Filter

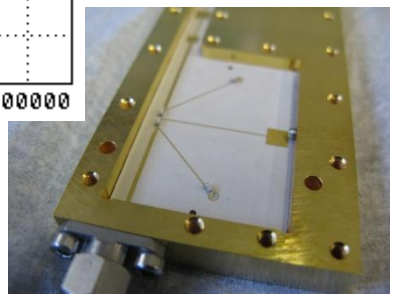


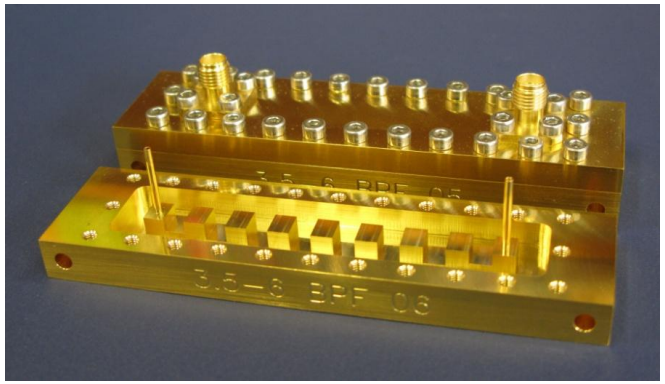
Hard roll off where necessary to stop strong interference



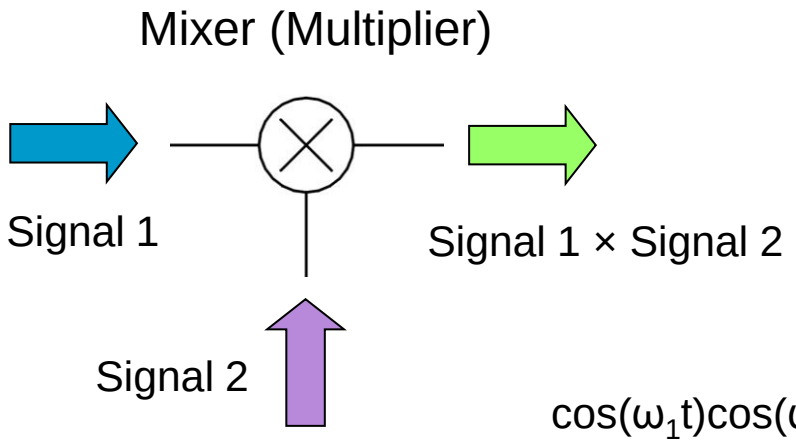
Slow roll off where possible so you can push the band edges

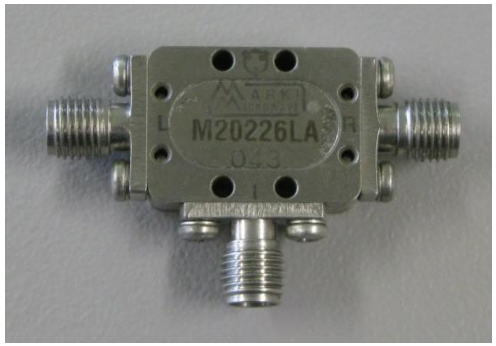
21cm band filter



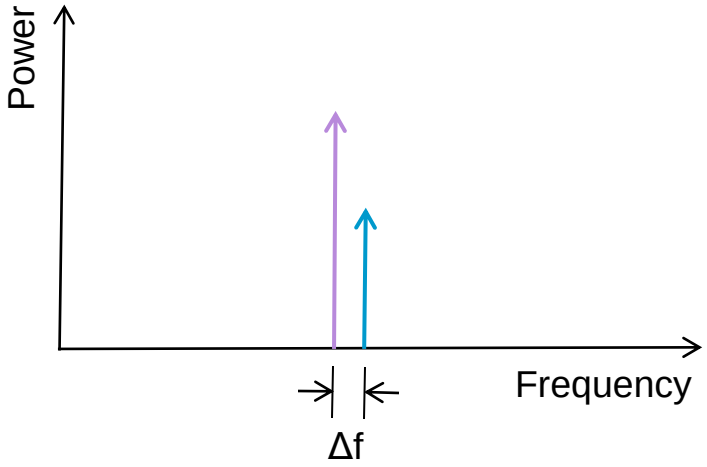


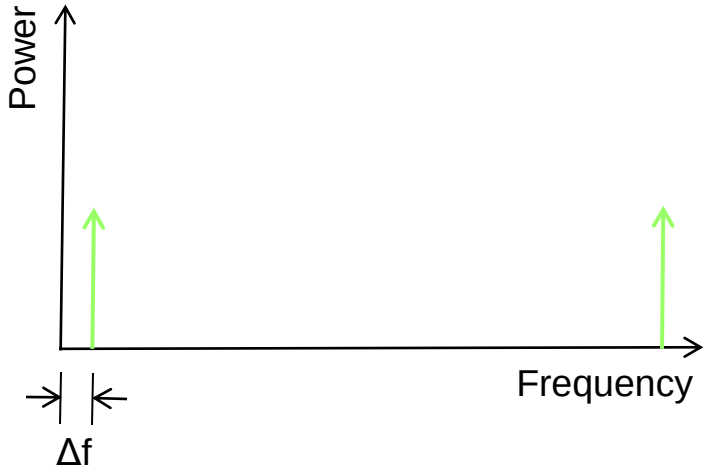
Mixing it down – Frequency Conversion





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





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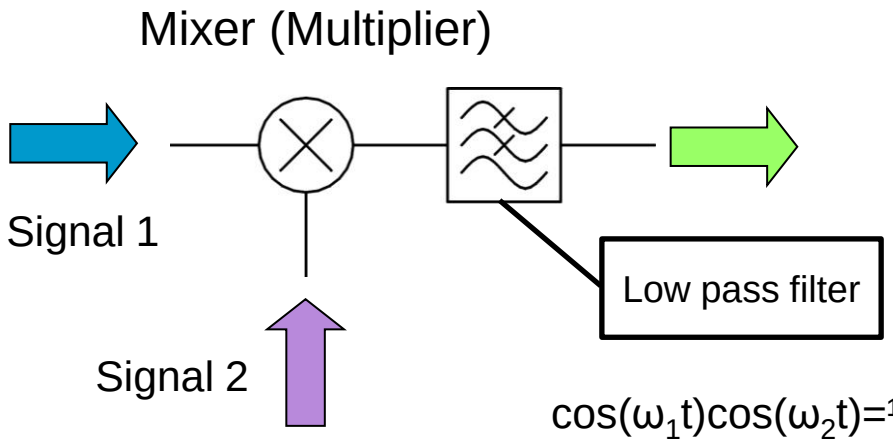

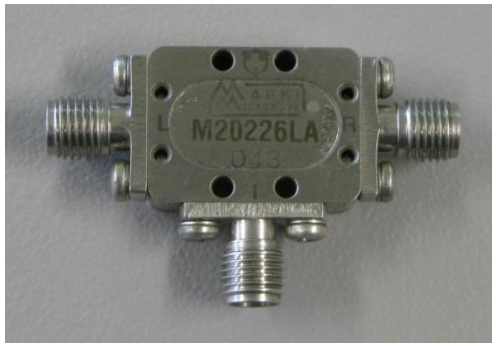

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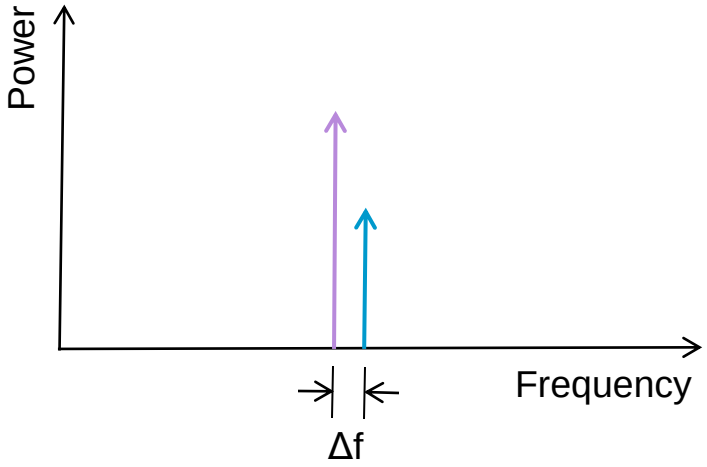

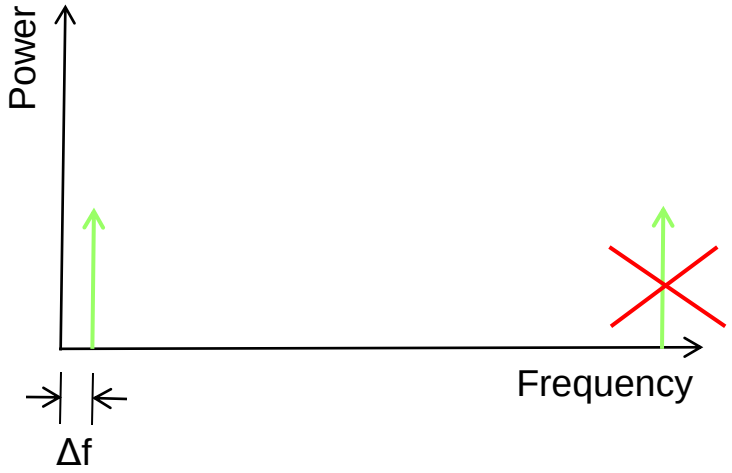

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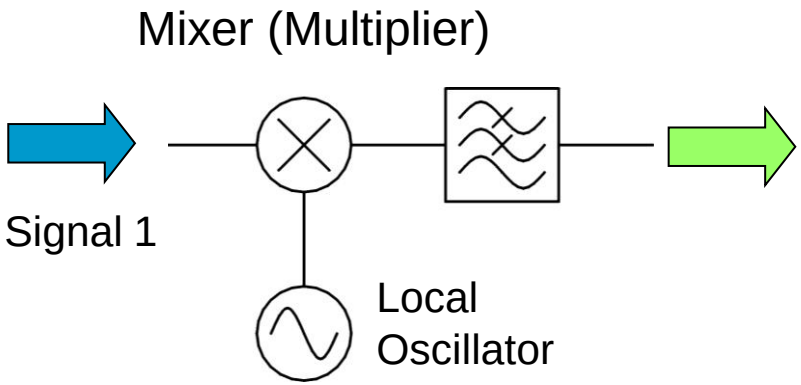
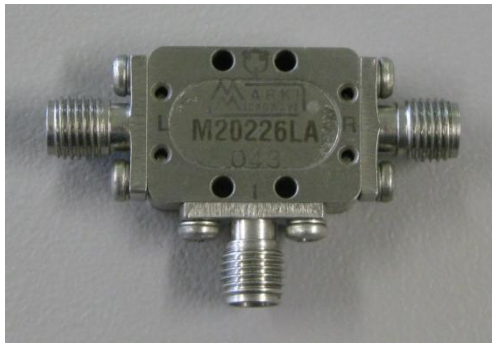
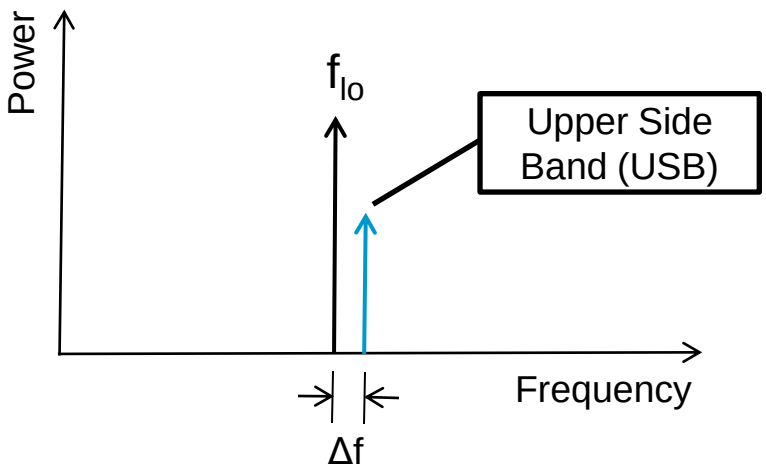




$\cos(\omega_1 t)\cos(\omega_{LO} t) \rightarrow \frac{1}{2}\cos[(\omega_1 - \omega_{LO})t]$



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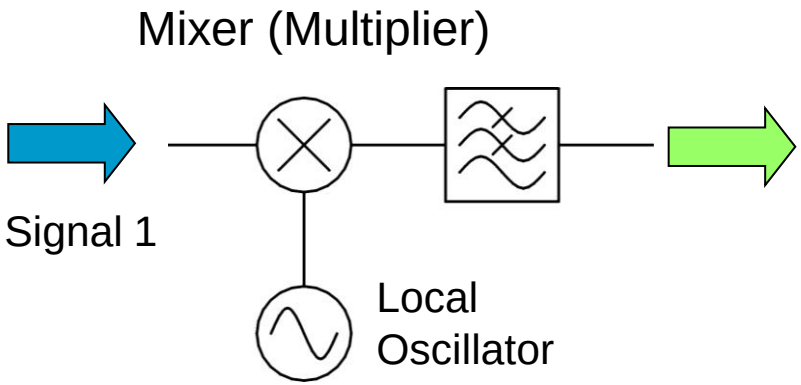

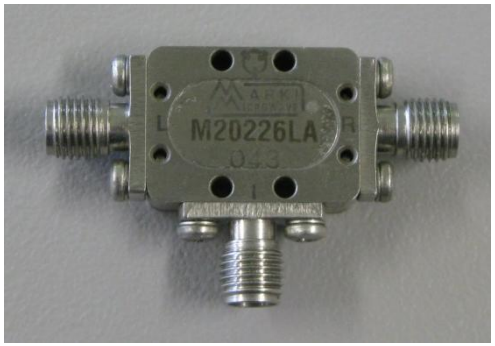

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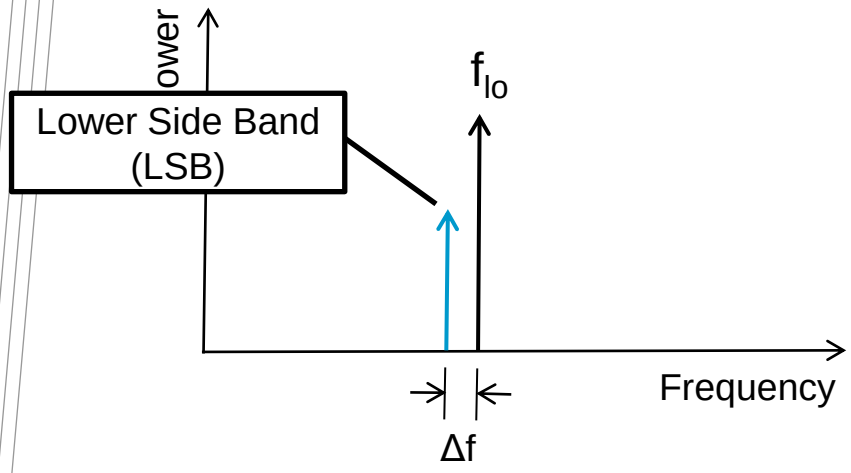
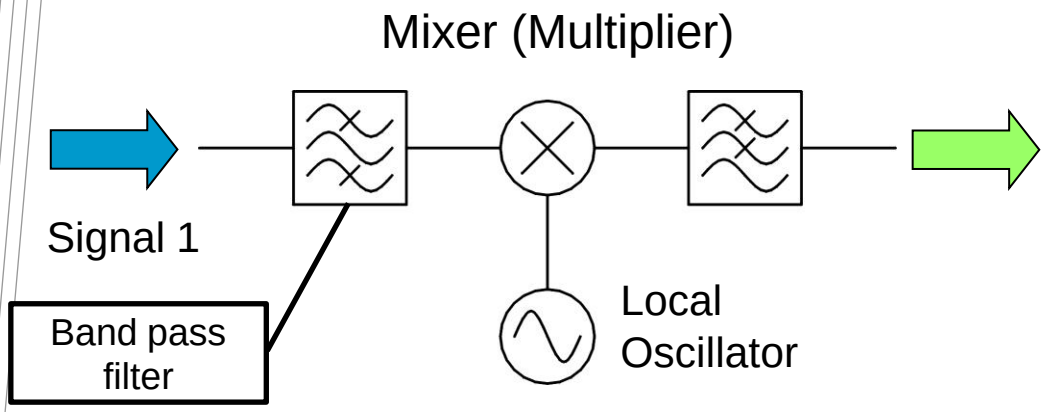
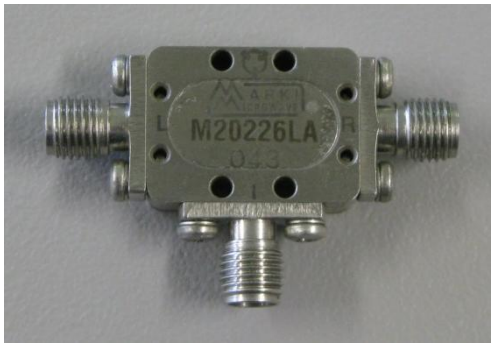
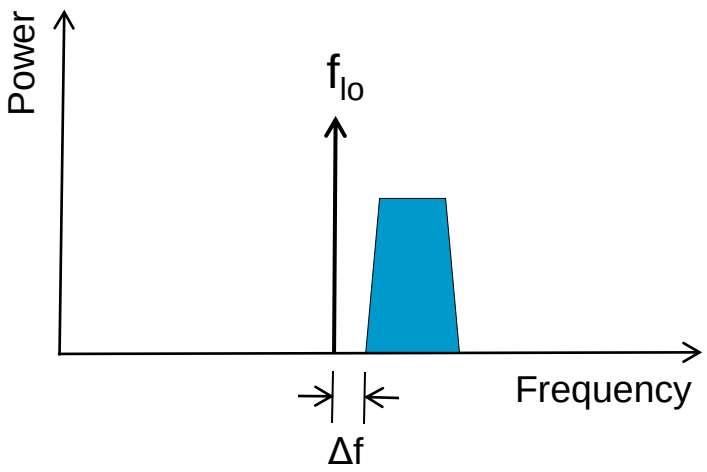
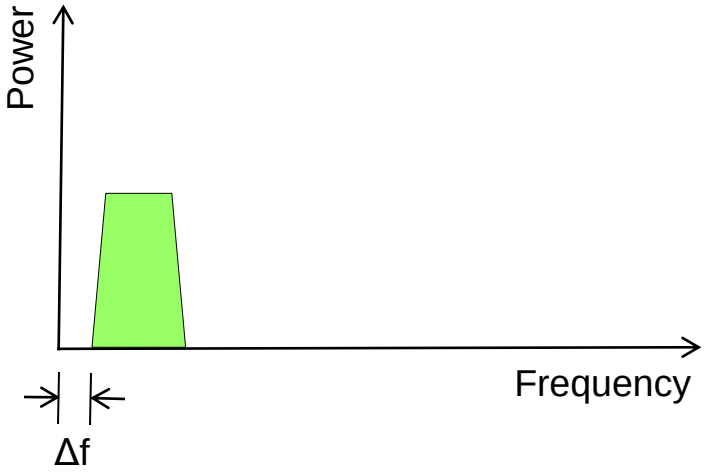


Mixing it down – Frequency Conversion

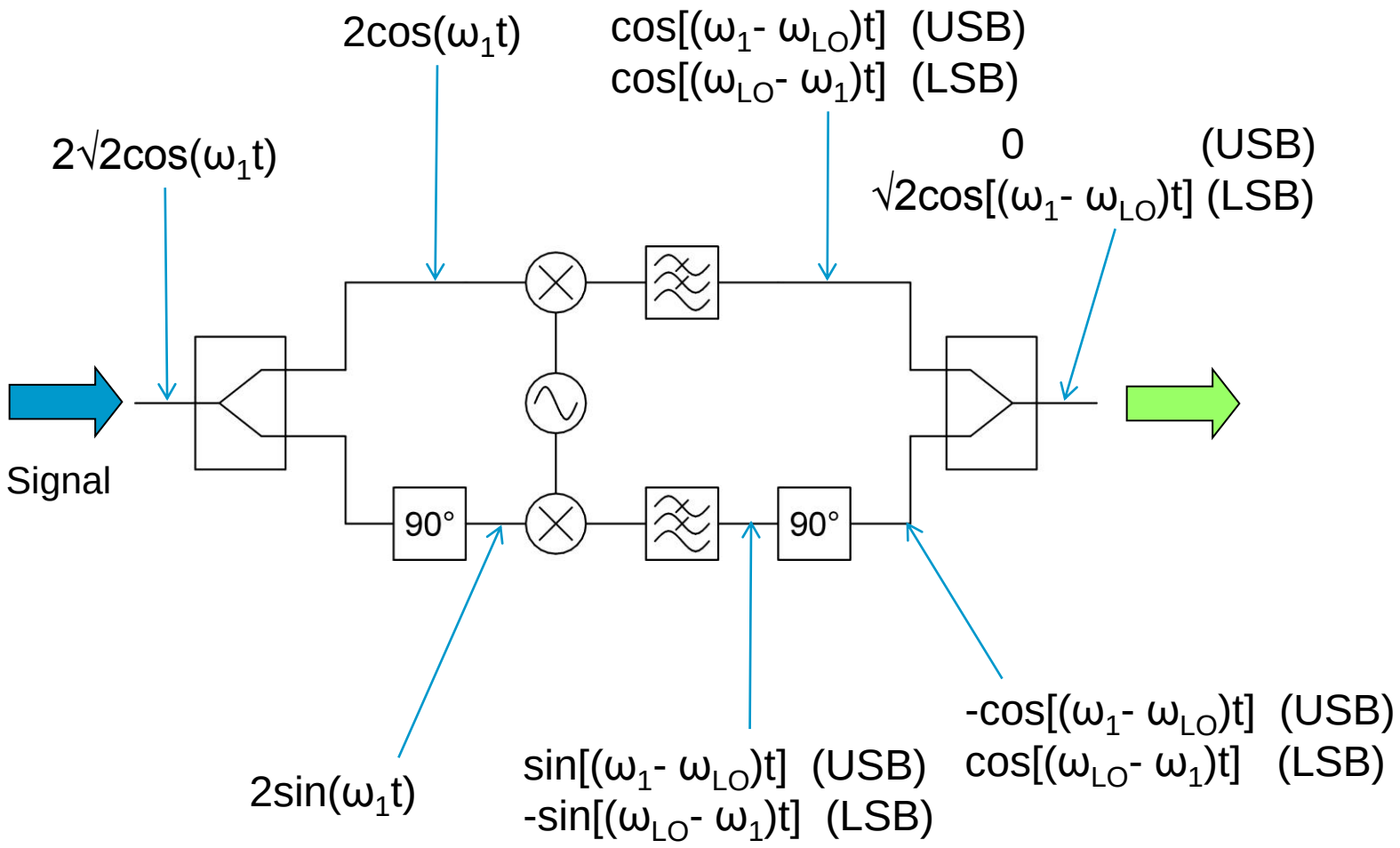




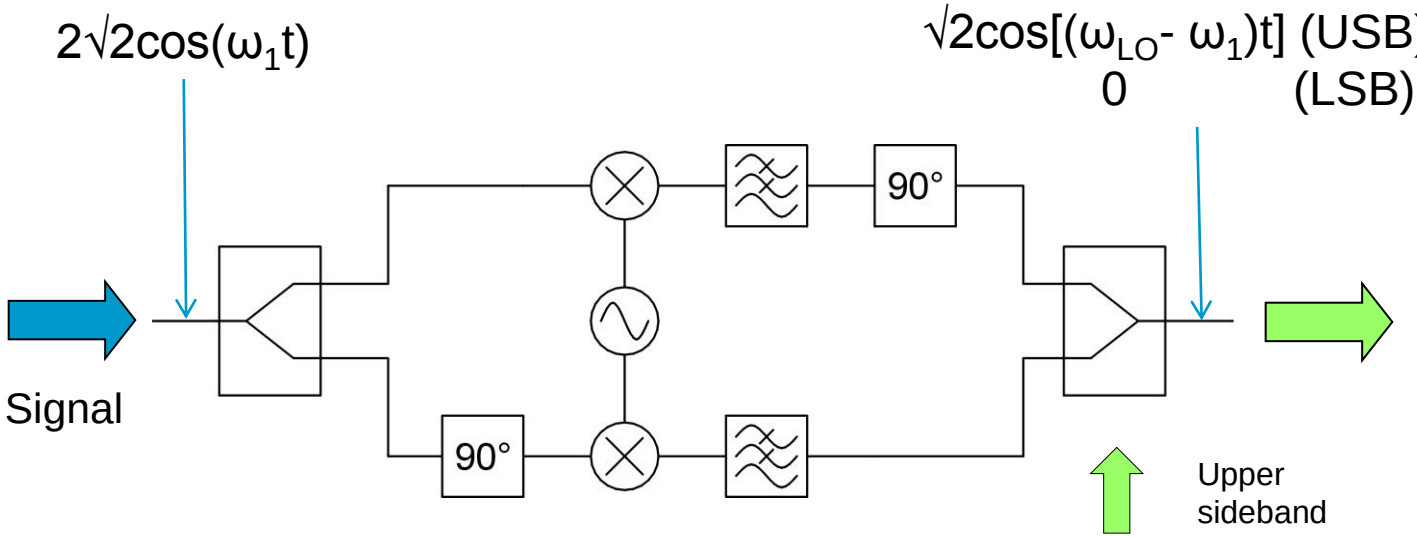


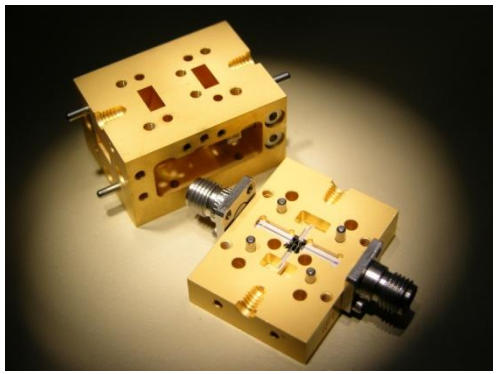


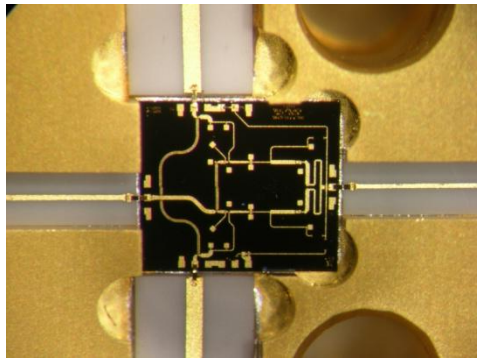
Single Sideband Mixers



Single Sideband Mixers

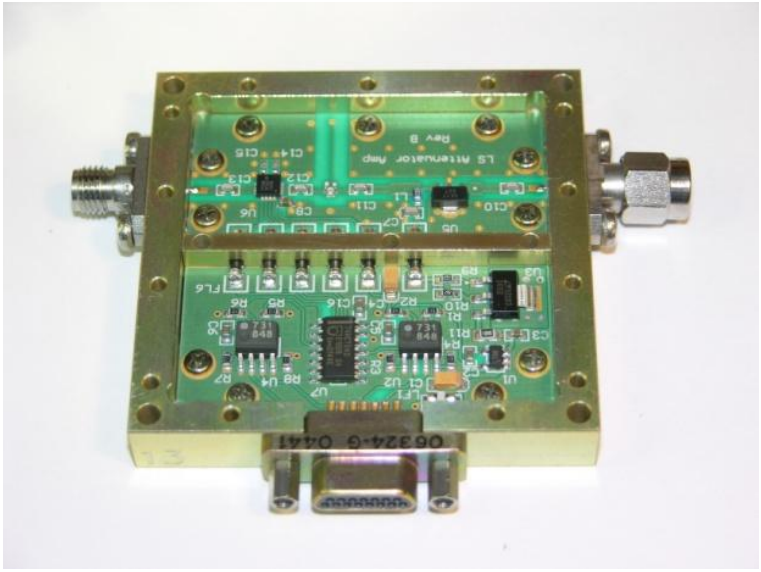






Attenuators – The Volume Knob

- Allow the signal level to be varied
- May be several in the system
- Usually set automatically

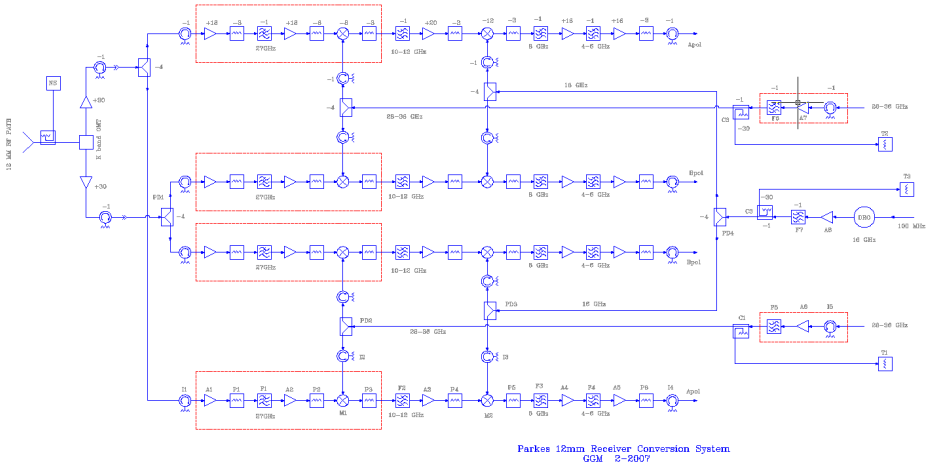


Just like some other systems if you turn the signal down too far all you get is noise and if you turn it up to far you get distortion!

Of course real systems are a little more complicated.....

They usually contain multiple conversions and many amplification and filter stages....

But that's the gist of it.



Things to remember

• Sometimes local oscillators leak if you look deep enough you might find one!

• Single sideband mixers can result in signals turning up at the wrong frequency, albeit at a very low level.

• Make sure your attenuators are set right. Too high and the system noise increases. Too low and you may distort your signal.

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