High (?) Frequency Receivers

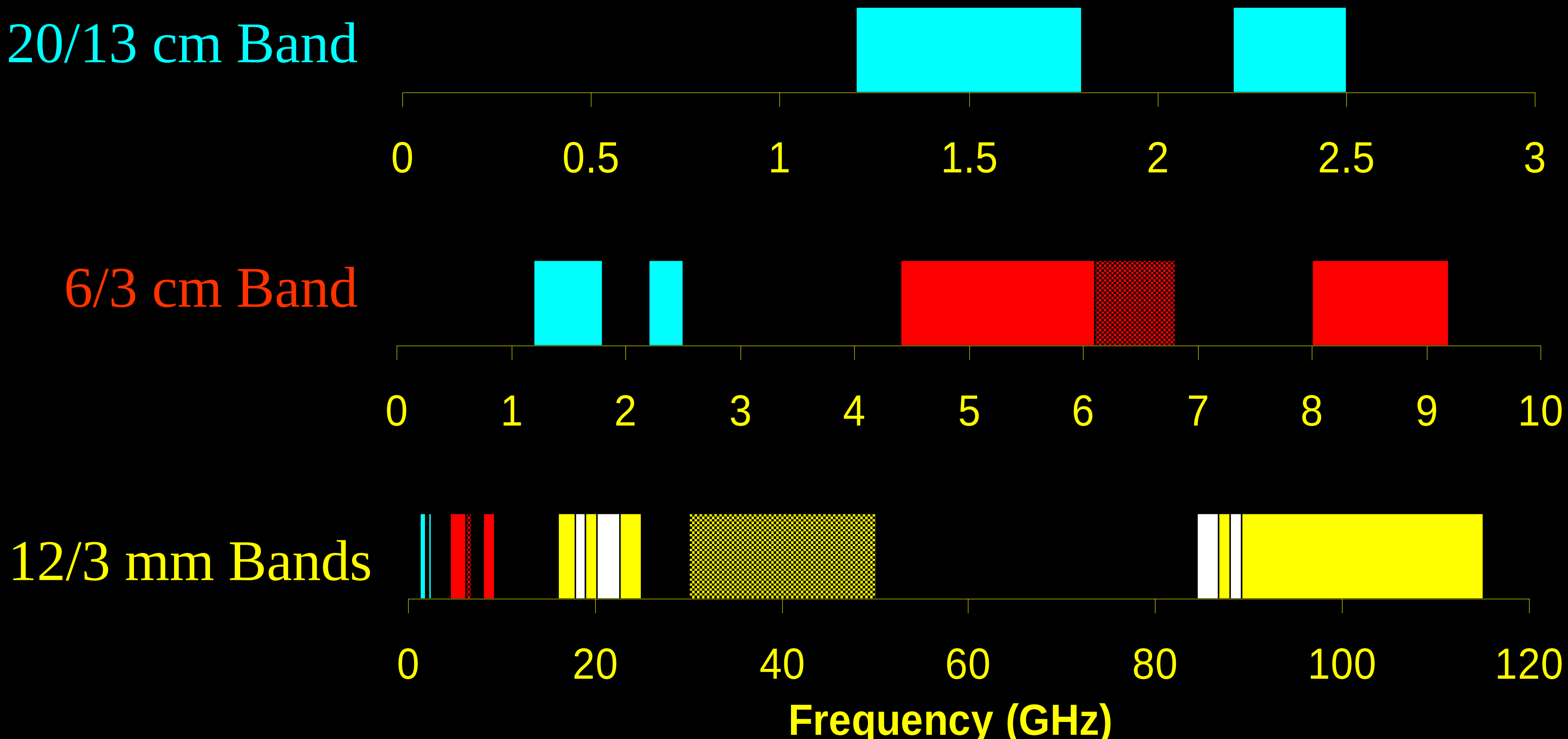
High (?) Frequency Rxs

……covering

- What is high frequency?
- Receivers
- Why would you want one?
- What’s it look like?
- Where’s it go?
- Why are they like they are?
- Examples

Australia Telescope Compact Array

Receiver Bands



Thanks to Russell Gough for the slide

Receiver : Do we really need one?

Receiver : Do we really need one?

Yes!

….because our senses can’t detect radio waves and the receiver system takes the unguided wave and transforms it into a guided wave that can be detected so as to provide data that can be studied.

What does a receiver look like?

A quick primer to avoid confusion


CTI-CRYOGENICS

Radiotelescope receiver

Receiver of presents


34
13

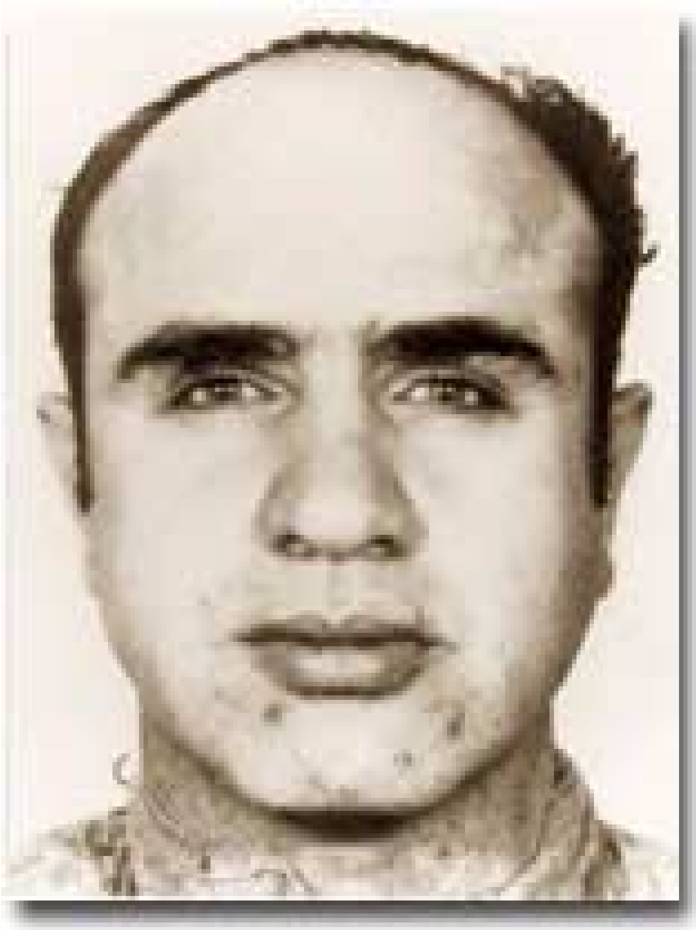
Wide radiotelescope receiver

Wide receiver


20/13

Radiotelescope receiver

Receiver in bankruptcy firm

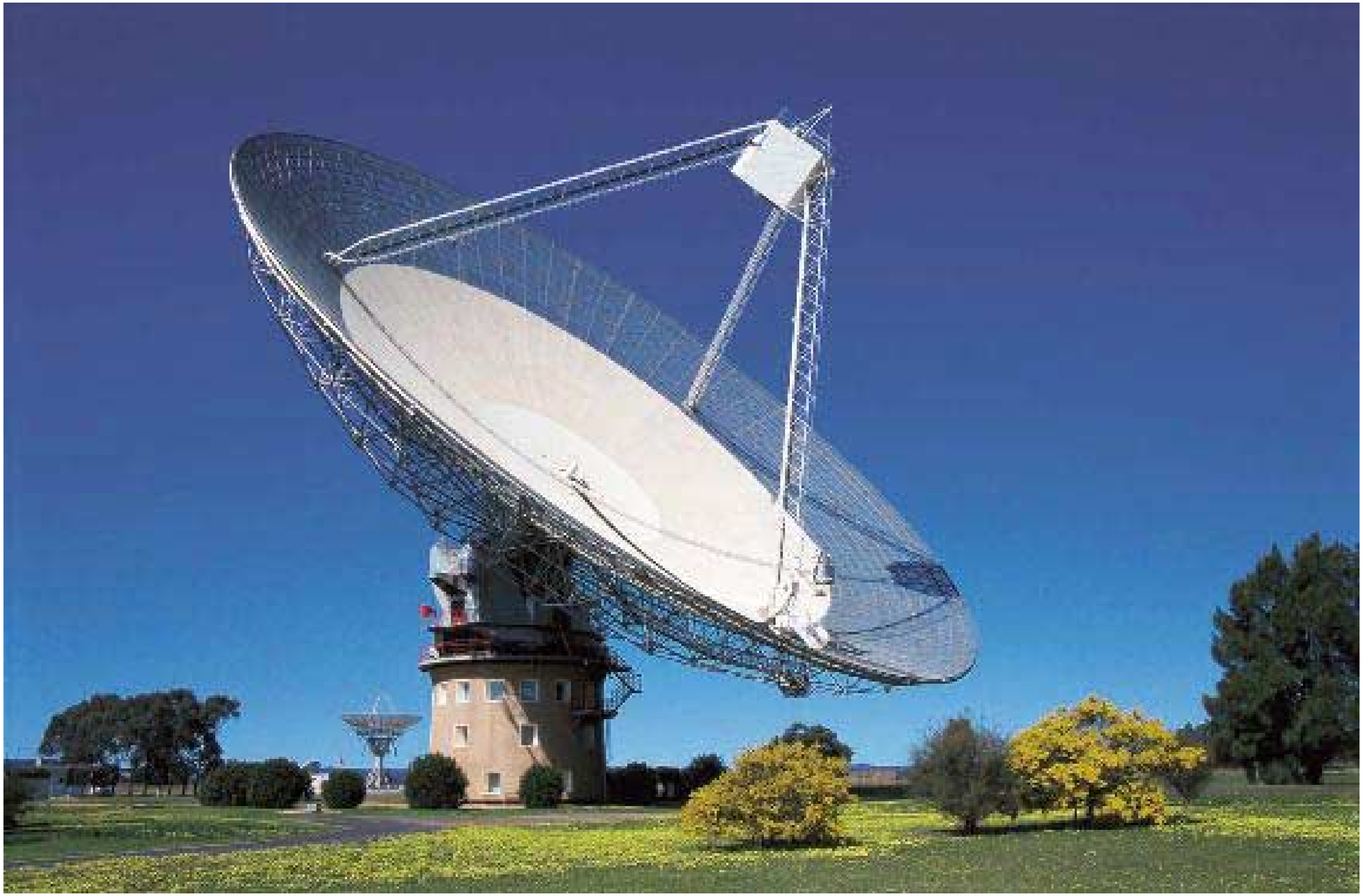


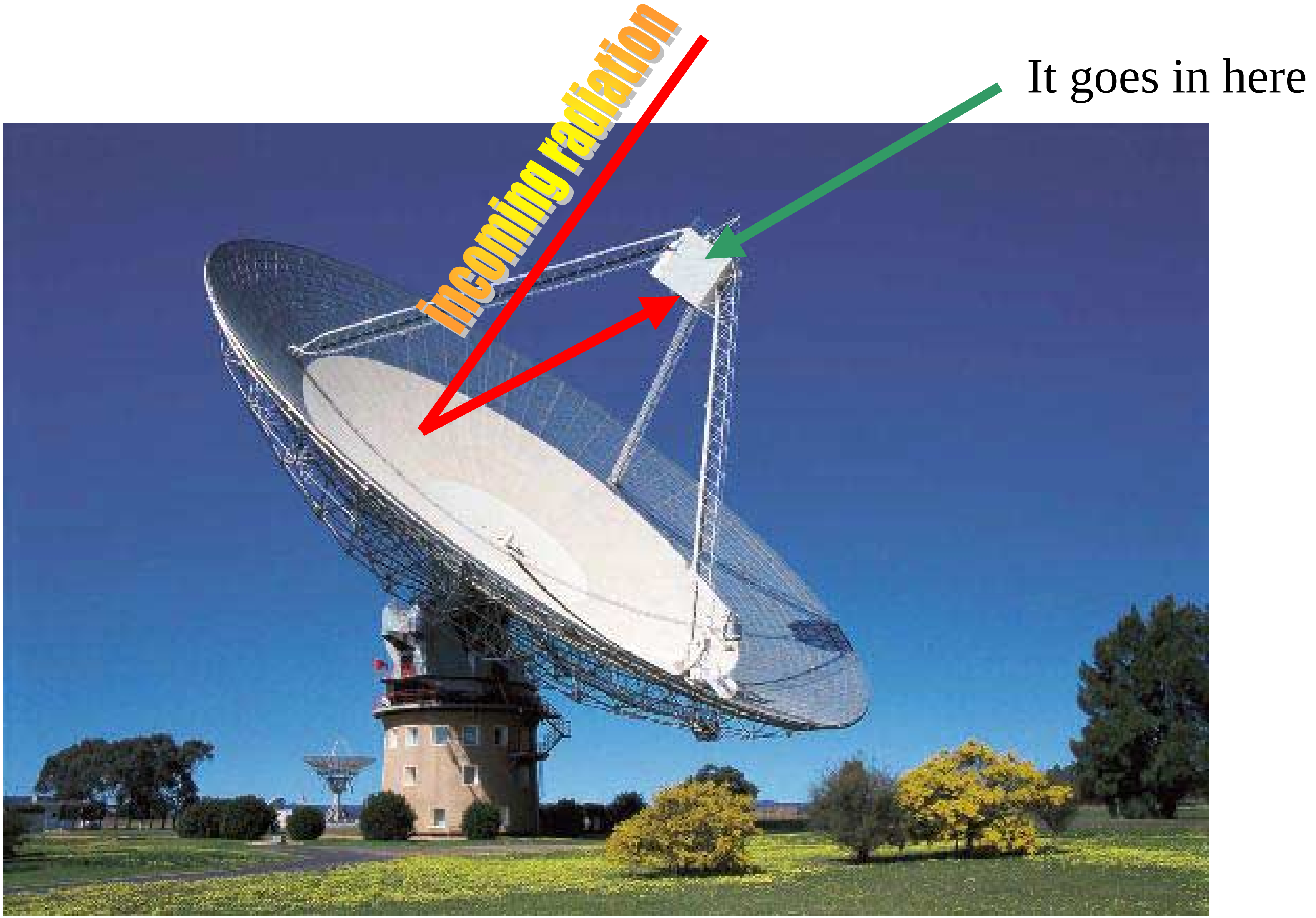
Receiver of stolen goods

Radiotelescope receiver

Where do these things go?

In a prime focus system like Parkes ……




Incoming radiation
It goes in here

In a Cassegrain system like Narrabri or Mopra……


incoming radiation
It goes in here

What is the signal like?

Charged particles change their state of motion when they interact with energy

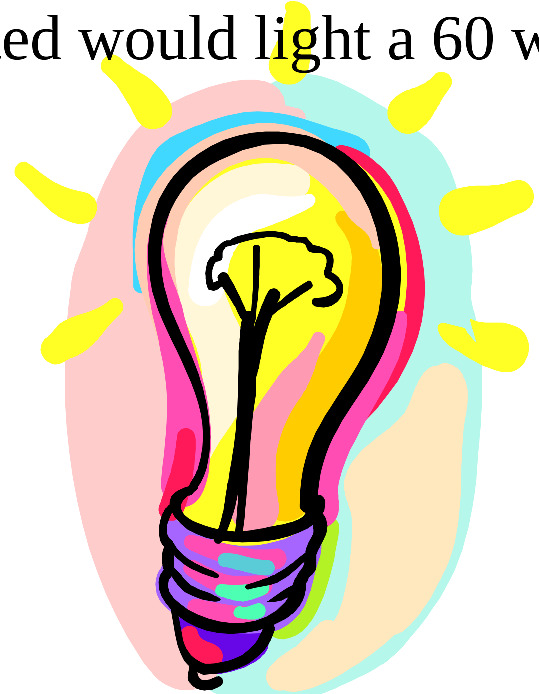
A change in state of motion gives rise to an EM wave

Matter is made of huge numbers of charged particles receiving energy being jostled and the radiation consists of unrelated waves at all frequencies and by analogy with the acoustic case it is called NOISE.

There is a general background and areas of enhanced radiation and energy

……..but it's bloody weak

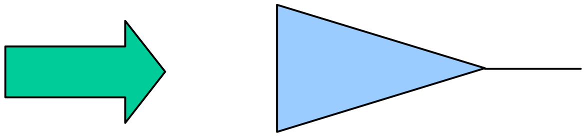
If Parkes, for its 40 years of operation, had operated non-stop observing 100 Jy sources (that's big) in a 1 GHz bandwidth (that's big too) the total energy collected would light a 60 watt light globe for a mere 67 milliseconds



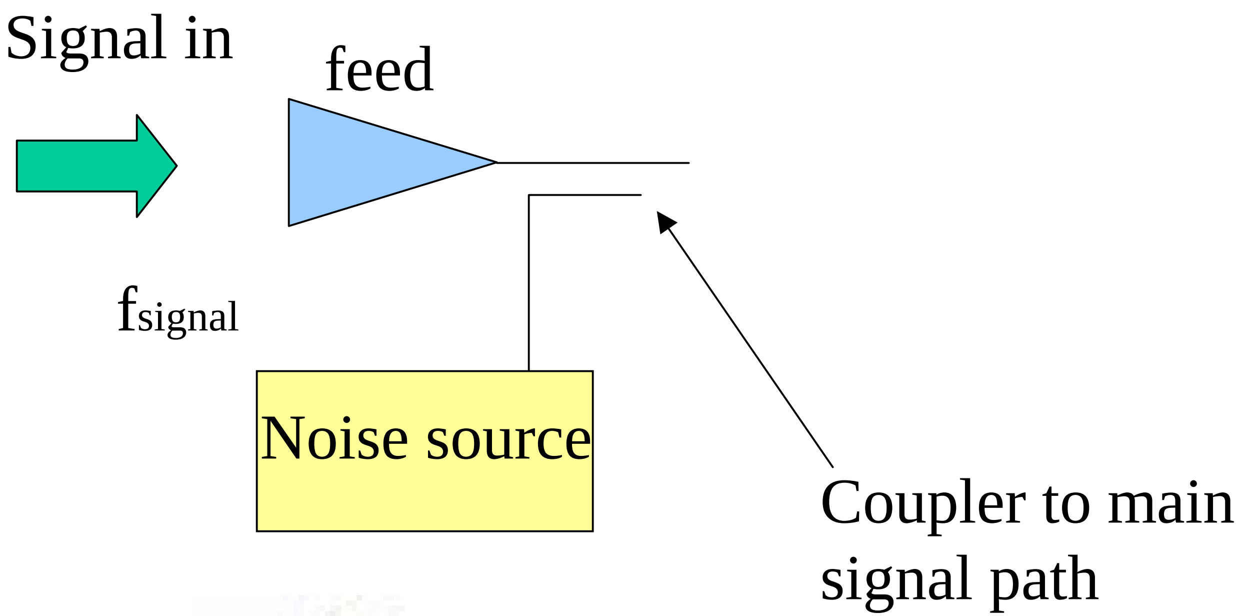
Is there a typical structure to them?

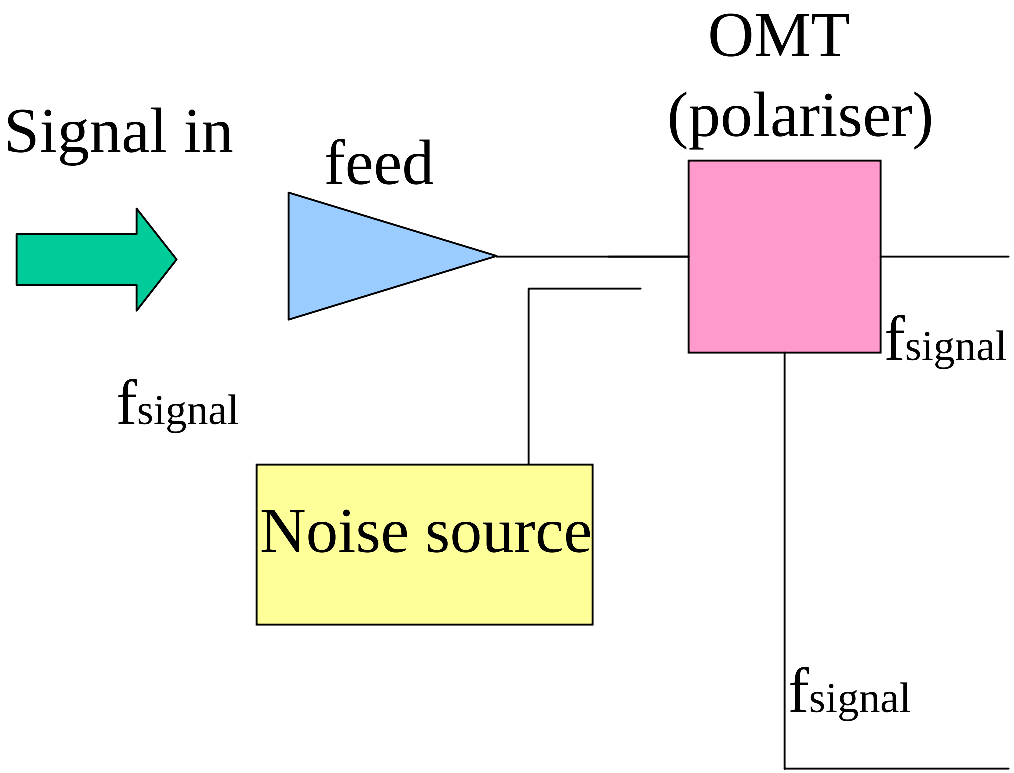
Signal in

feed

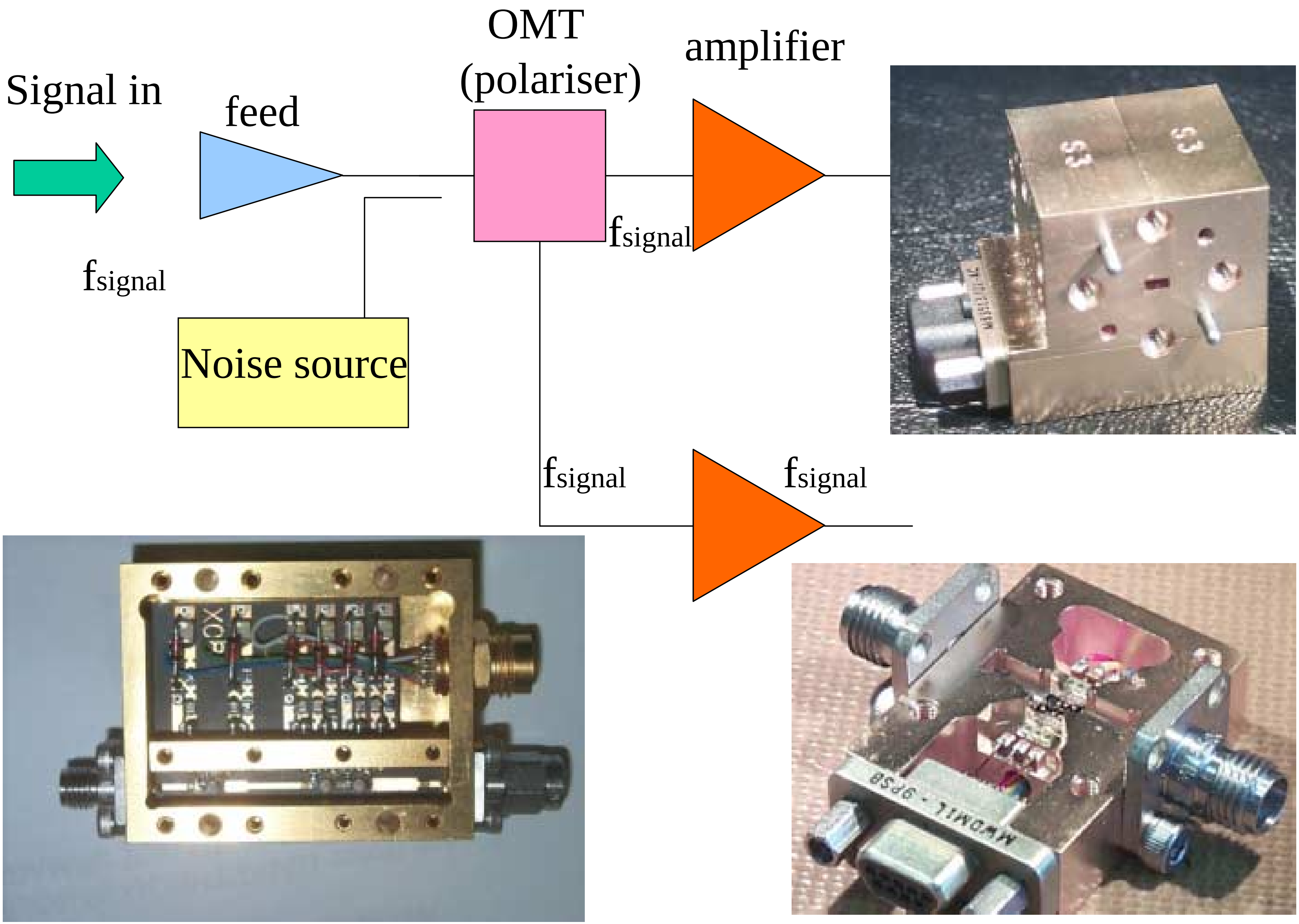


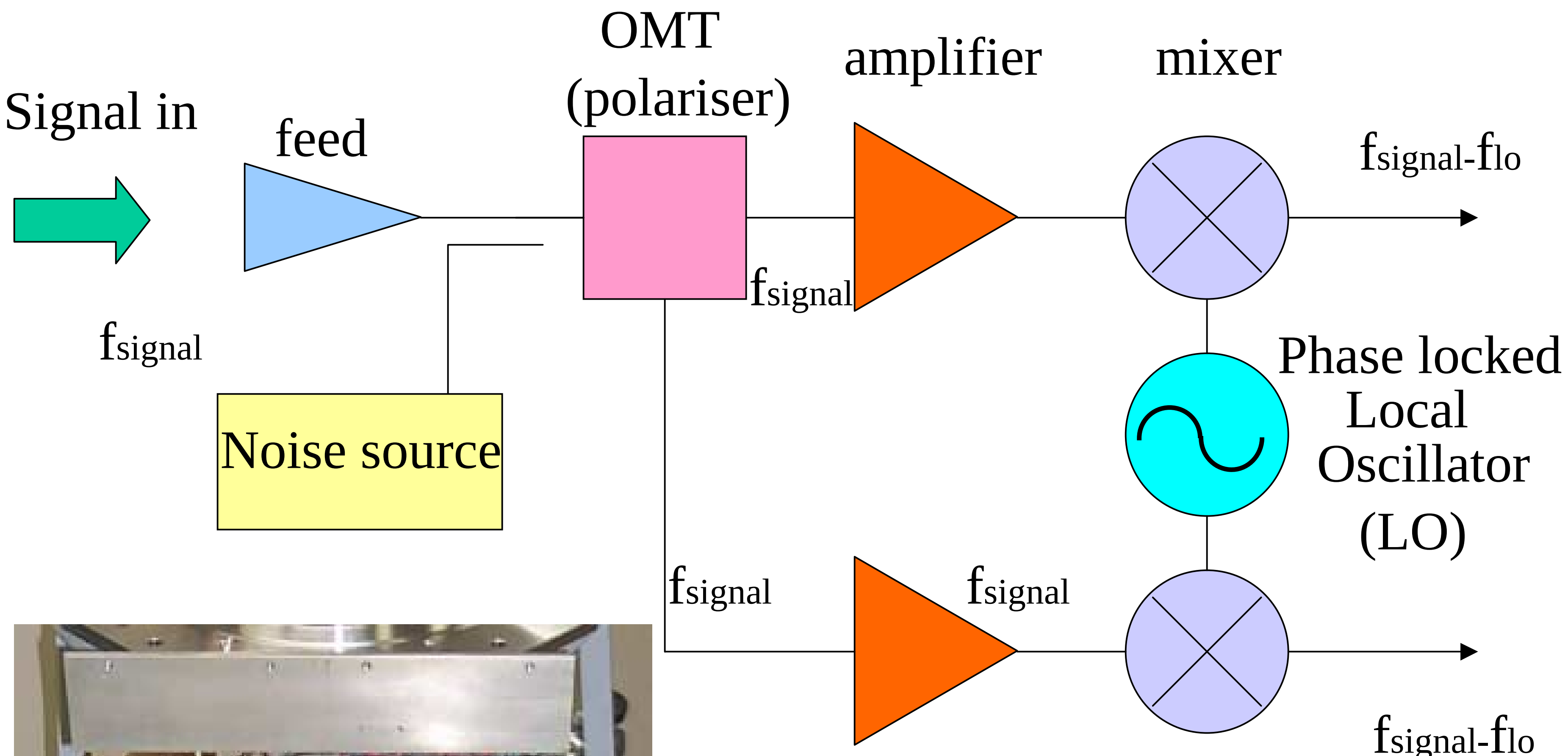
f_{signal}

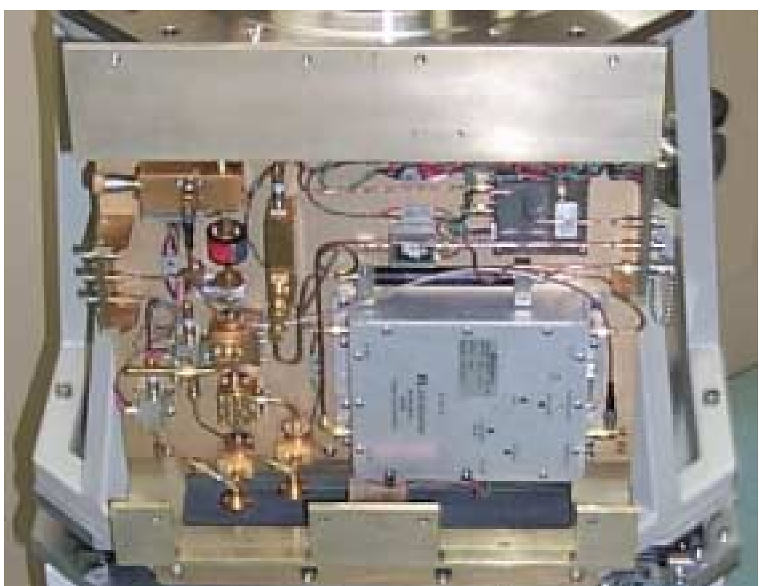

Signal in
feed
f_{signal}
Noise source
Coupler to main signal path



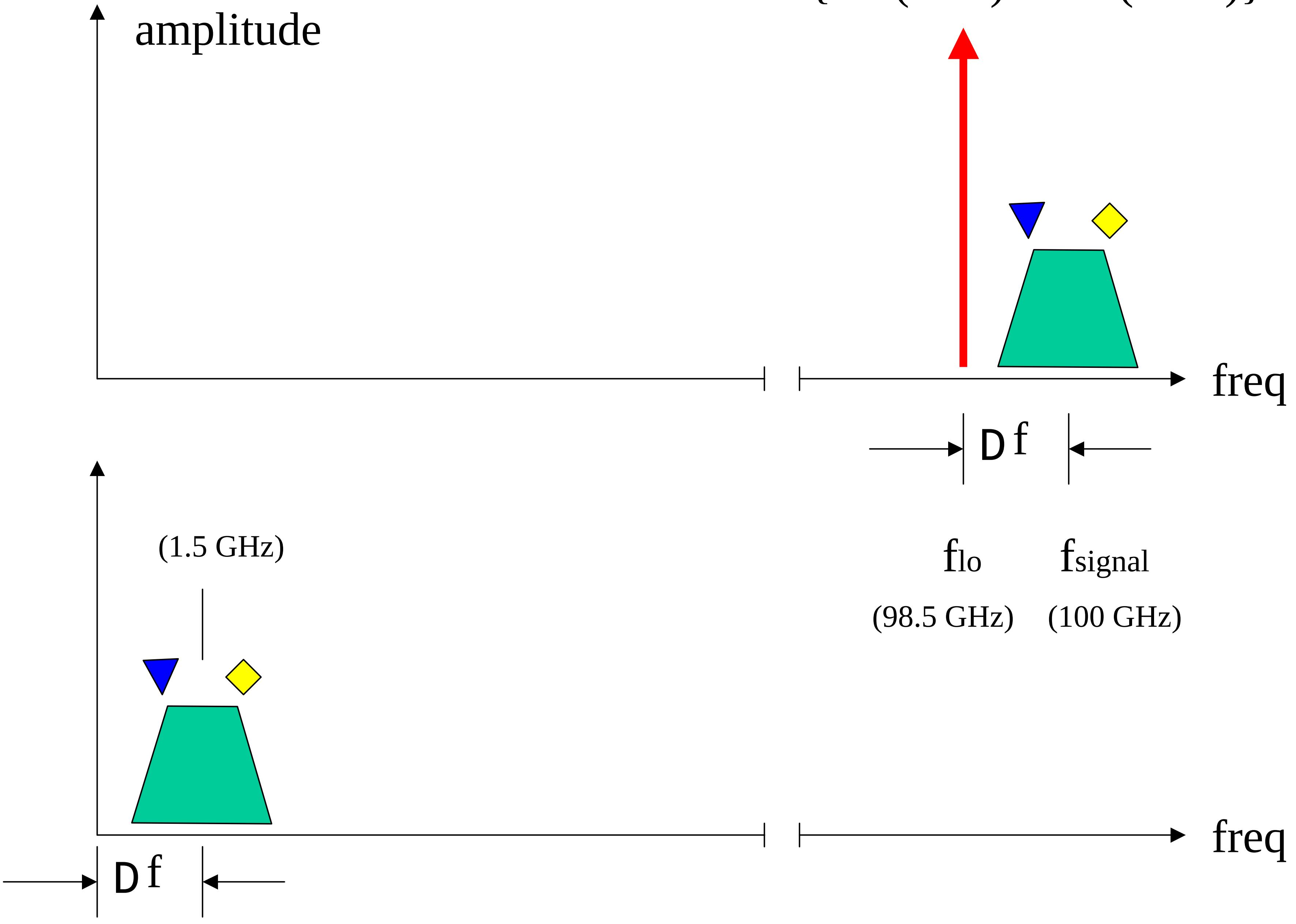
To get both polarisation components

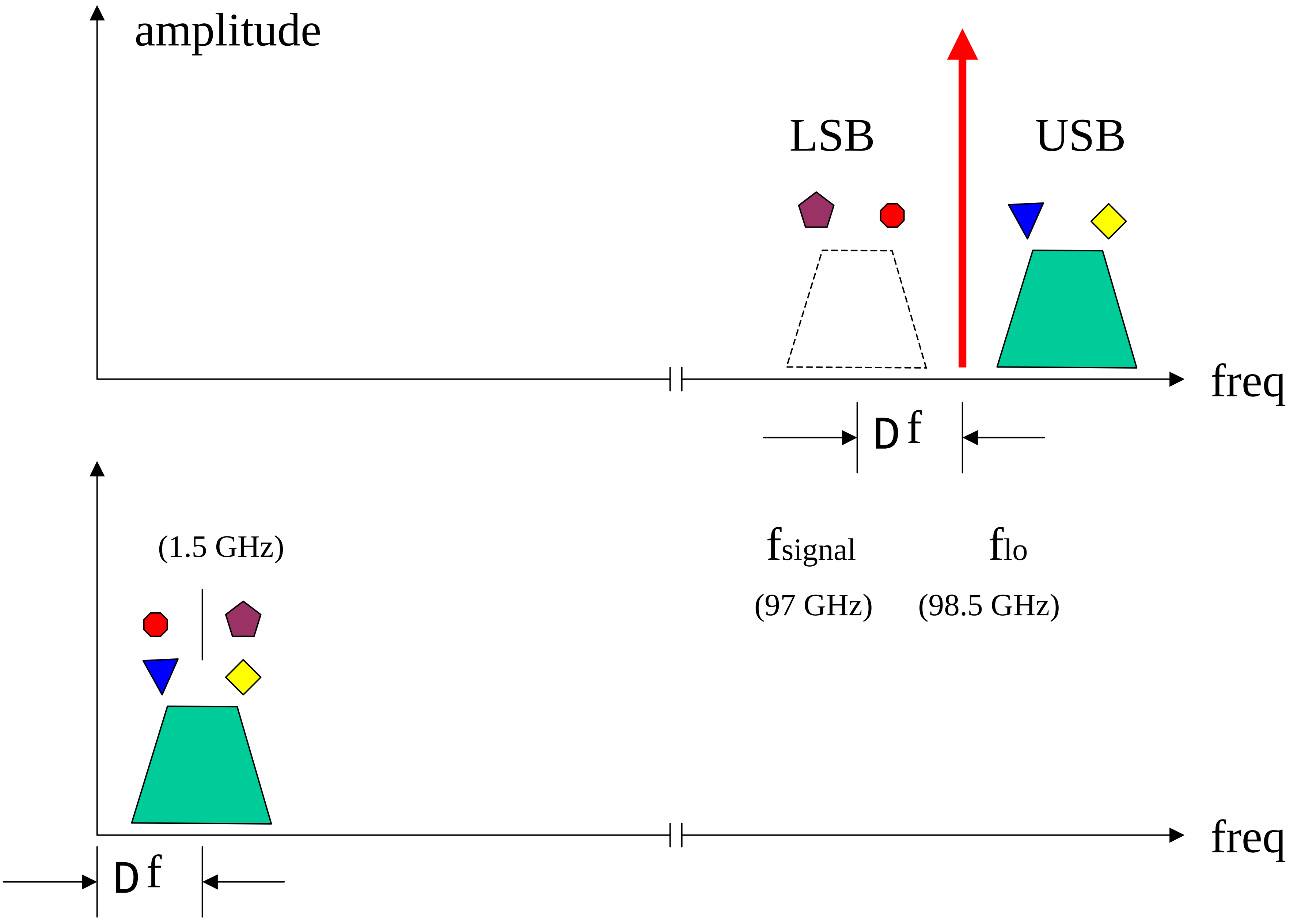

Signal in
feed
OMT
(polariser)
amplifier
f_{signal}
f_{signal}
Noise source
f_{signal}
f_{signal}

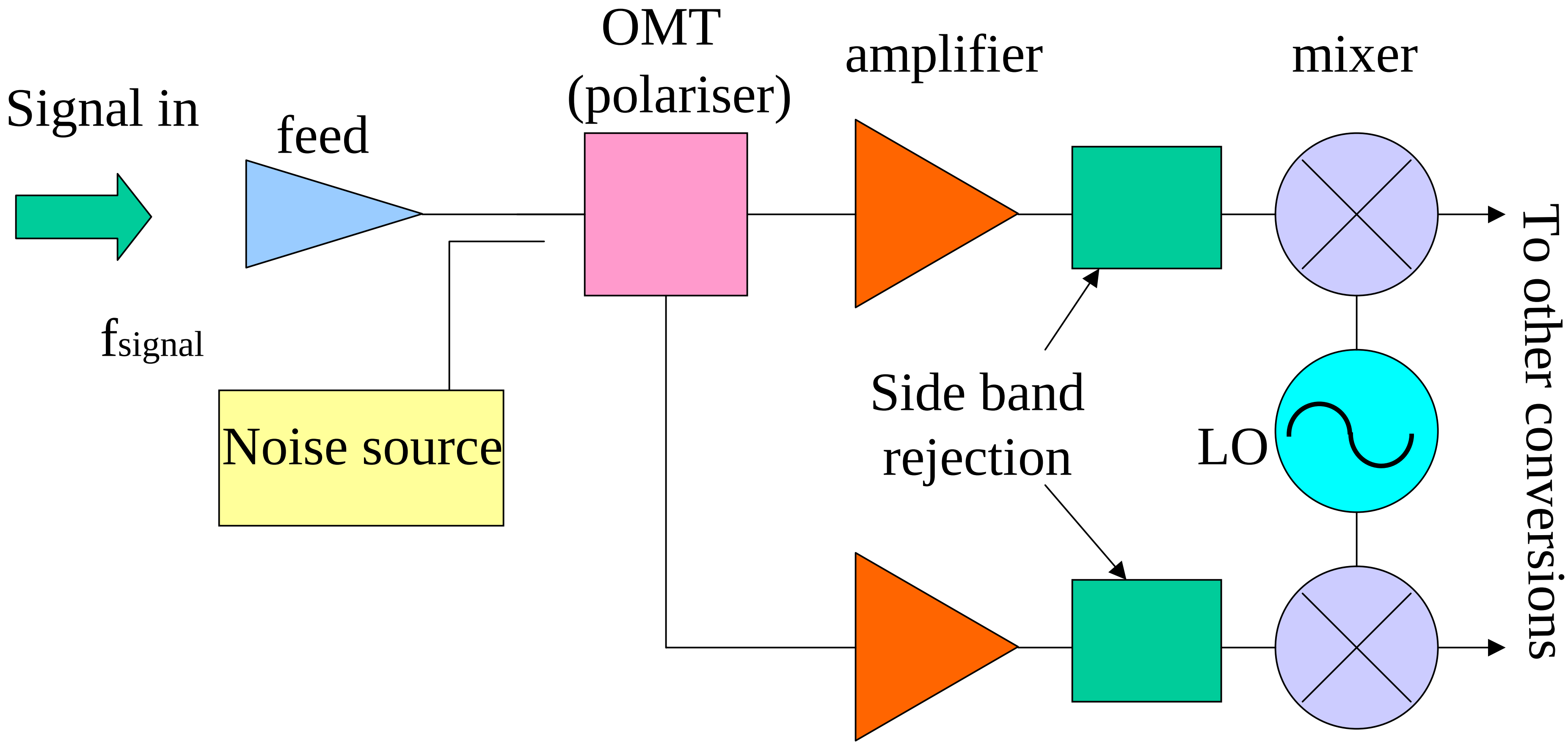




….to get the signal to a lower frequency where more established (cheaper) backend components and processing electronics handle the signal cosAcosB=1/2 {cos(A-B) + cos(A+B)}

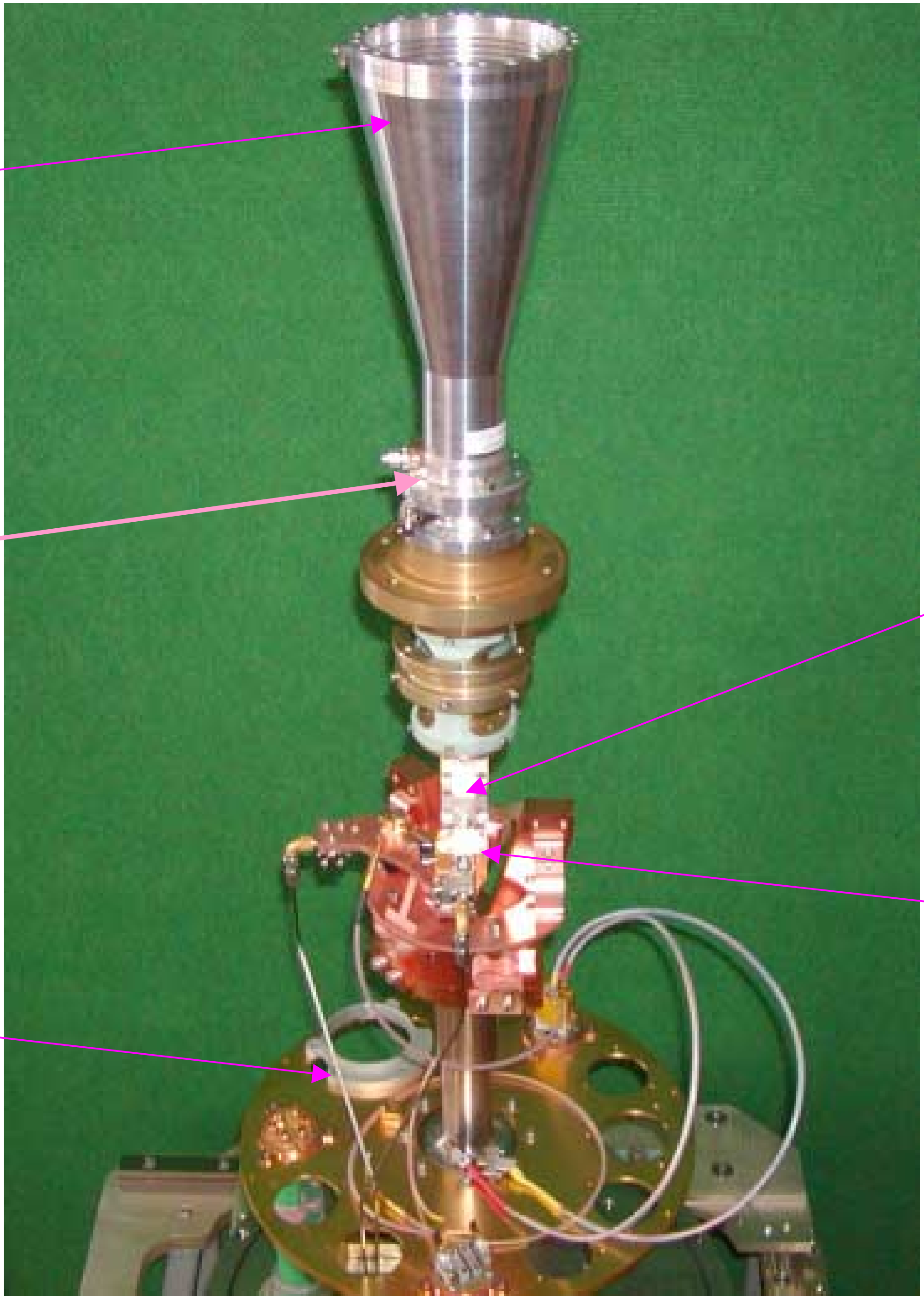



amplitude
LSB
USB
freq
D f
f signal
f lo
(97 GHz)
(98.5 GHz)
(1.5 GHz)
freq
D f


Signal in
feed
OMT
(polariser)
amplifier
mixer
f_{signal}
Noise source
Side band
rejection
LO
To other conversions

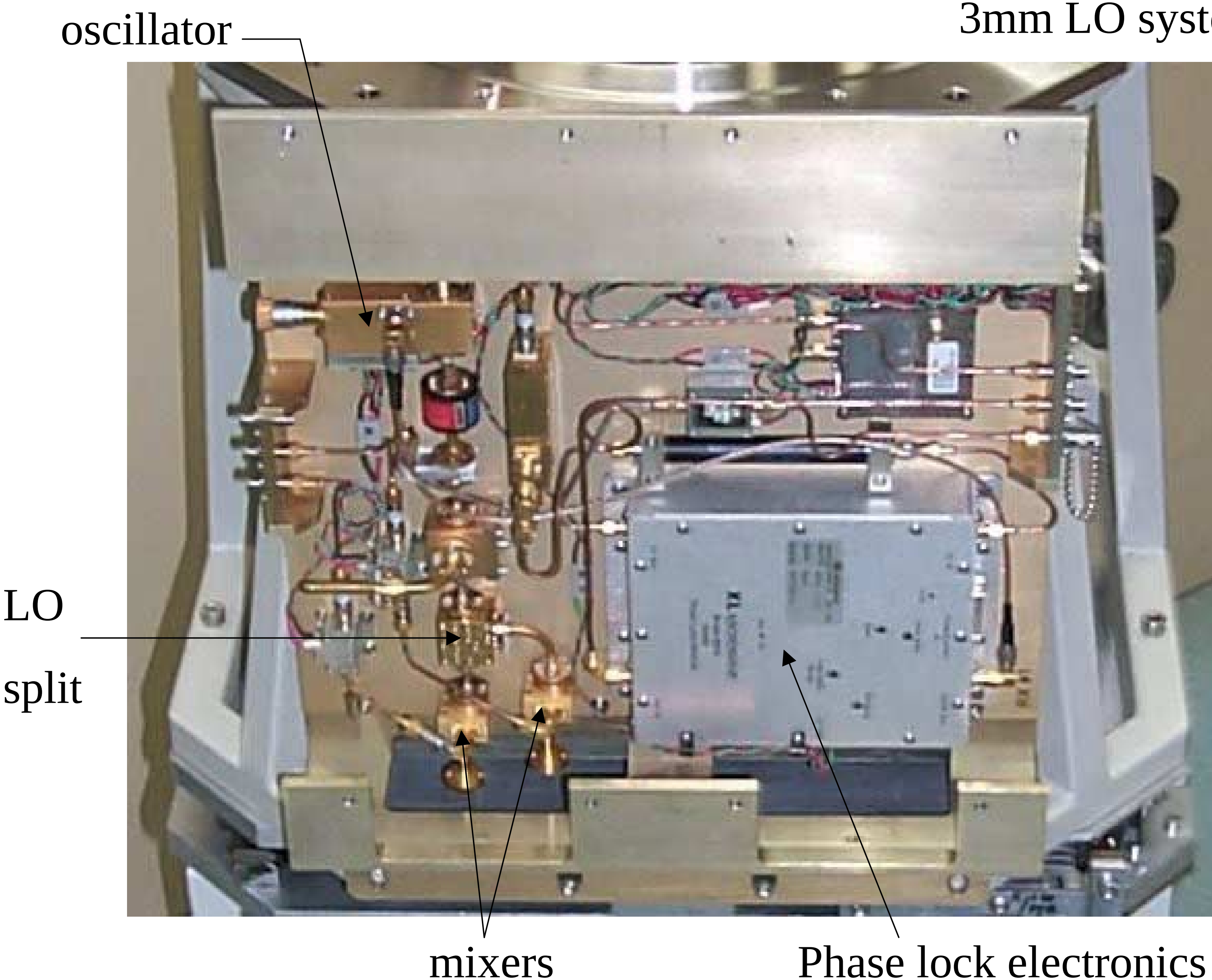
….so I am saying that this is a pretty typical structure of our receivers

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



12mm
components
Feed sits
up top here
Noise
coupler
OMT
Signal line
to mixer
amplifier

3mm LO system



Some of these receiver components are pretty small……..

……..we have seen the receivers are quite sizeable…..

……….so what is all the other crap for?

Apart from the complex support and monitor electronics….

……………………..we need to consider sensitivity to explain.

To measure the radiation we observe it for an interval long compared to most of the fluctuations and find the mean average power over the interval. Each observation will fluctuate about the true mean and this limits the sensitivity.

A rough estimate of the size of the fluctuations:

Random fluctuating quantity restricted to bandwidth Df is equivalent to a sequence of Df independent values in 1 sec.

Averaging a sequence over t seconds means t* Df values

Fluctuations in the mean of n independent readings ~ $n^{-1/2}$ so our mean power fluctuations will be DP/P ~ $(t * Df)^{-1/2}$

or $$DP \sim \frac{P}{(t * Df)^{1/2}}$$

…but the components in the signal path contribute to P because they are matter with thermal energy.

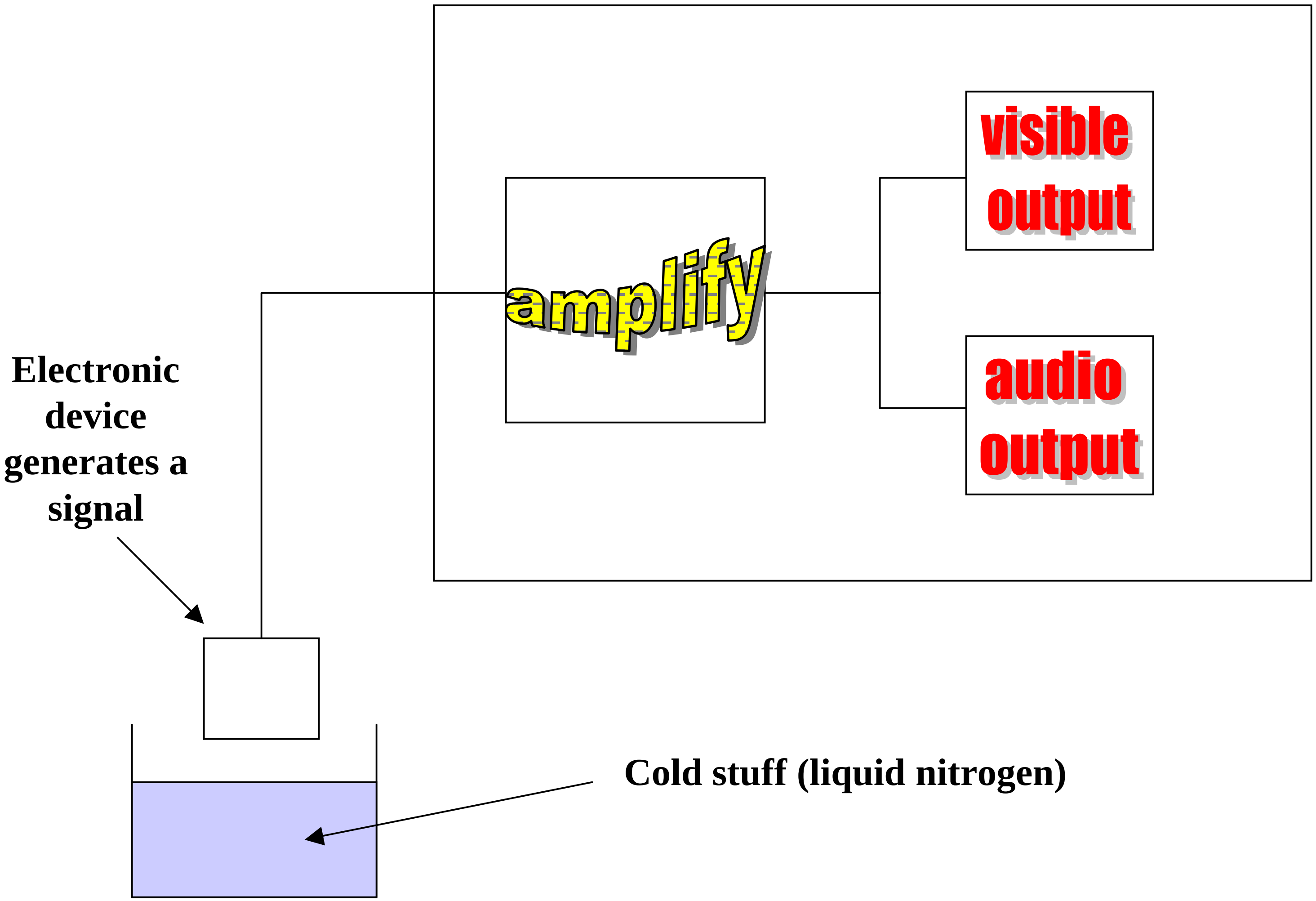
$$P = Psig + Prec$$

So the components' contribution masks the signal. It is like trying to measure the change in water level of a swimming pool when dropping a child in during free-for-all time at a swimming carnival

To reduce their masking effect we reduce their thermal energy by cooling them!

The following demonstration displays this.

Reduce noise by cooling

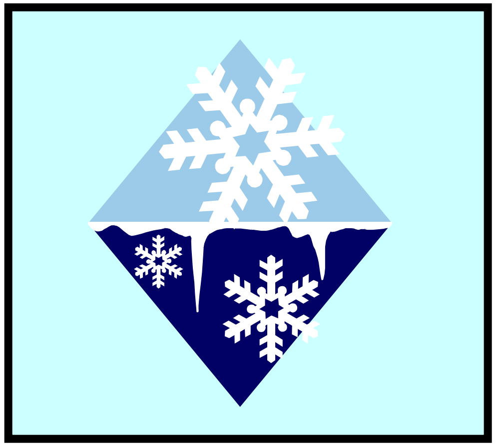


So we need way cool gear to get some cooling and keep things cold

*Refrigerator and compressor (He as working fluid)

*Keep heat transfer from the outside minimal

*Watch out for the axis of evil in conduction, convection and radiation



Way cool gear

There is a good reason for the structure…..

Nyquist came up with the theorem which relates noise power to the temperature (T) of a matched resistor which would produce the same effect through

$$Pn = k\ T\ \Delta f$$

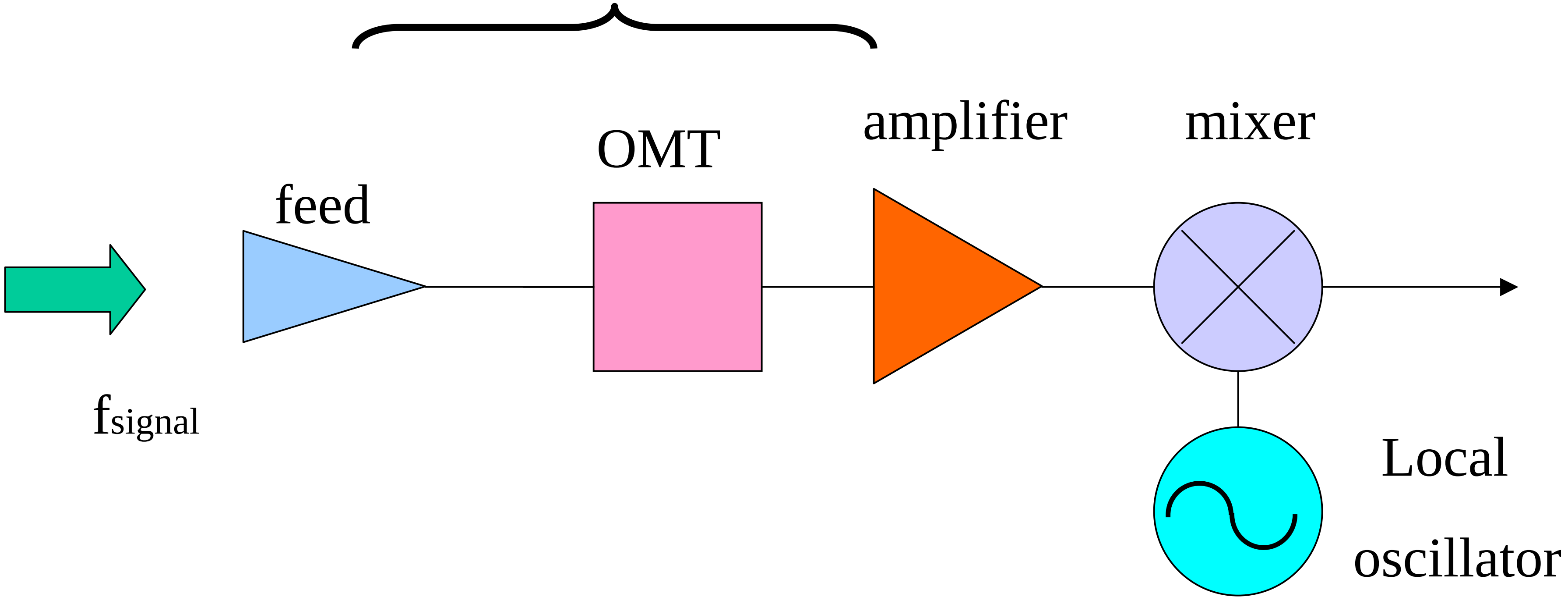
So a device or system is assigned a noise temperature by considering the device or system noise free and seeing what temperature resistor at its input would produce the same noise output

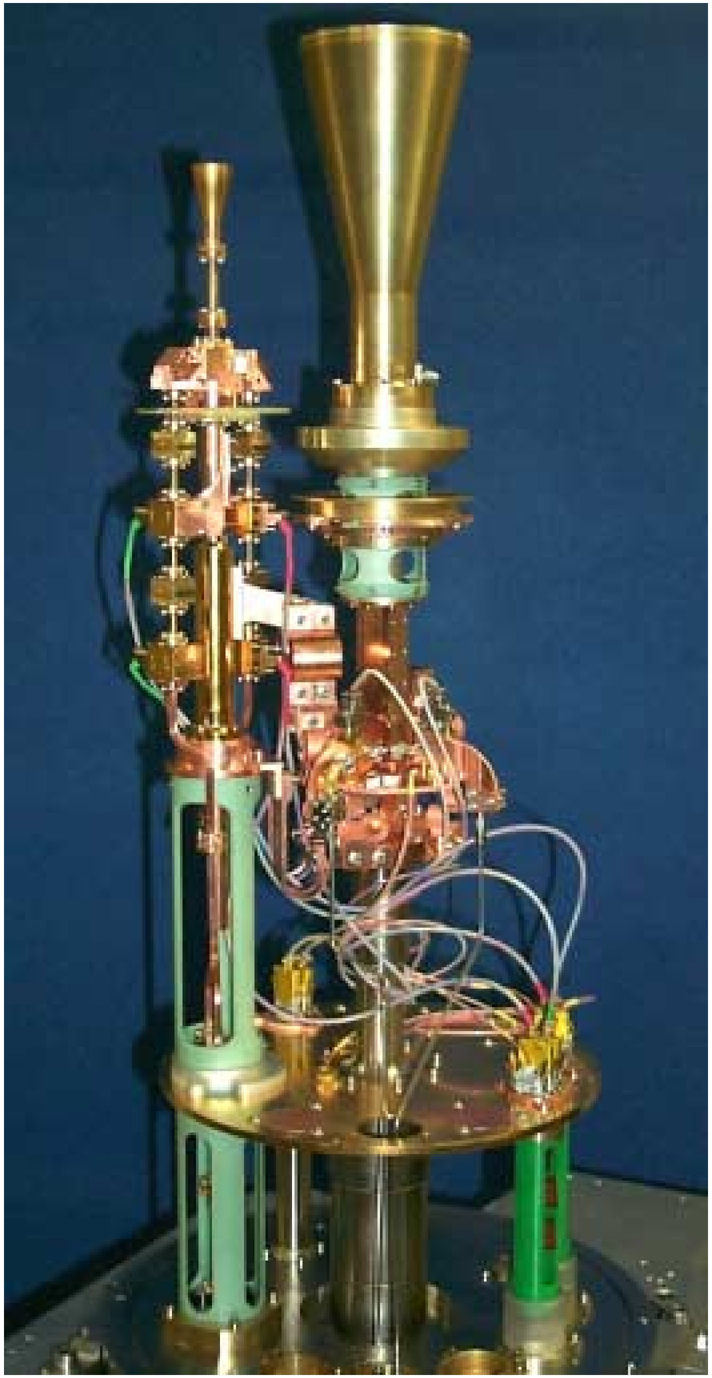
For example we talk of our receivers having a noise temperature of 20 K which more correctly should be stated that the receiver behaves as a matched resistor at an absolute temperature of 20 Kelvin

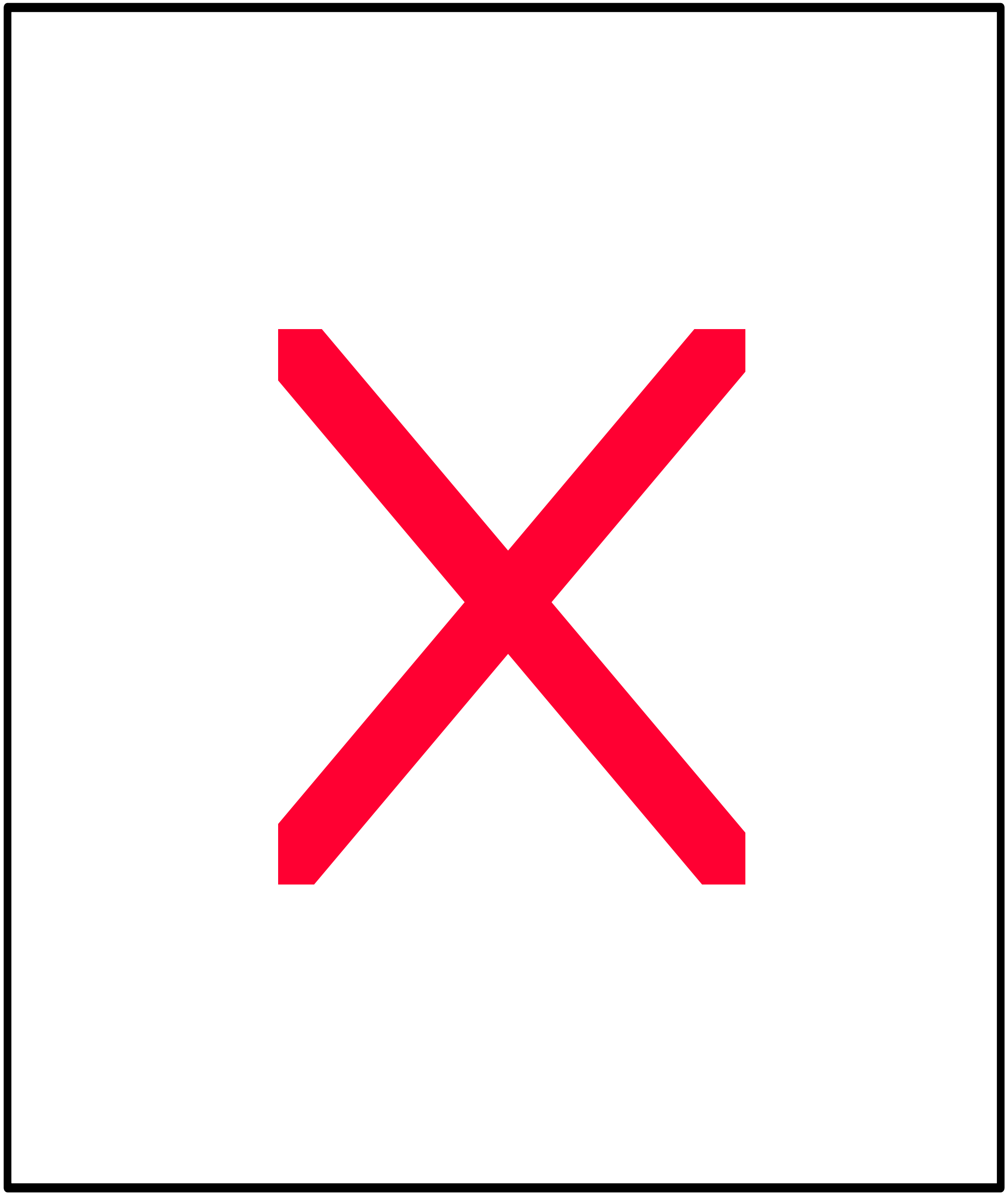
Further for systems in cascade it can be shown

$$Teq = T1 + \frac{T2}{Gain1} + \frac{T3}{Gain1*Gain2} + \ldots\ldots$$

This highlights the desire for cooling and for low loss, low noise, high gain components at the front of a system.







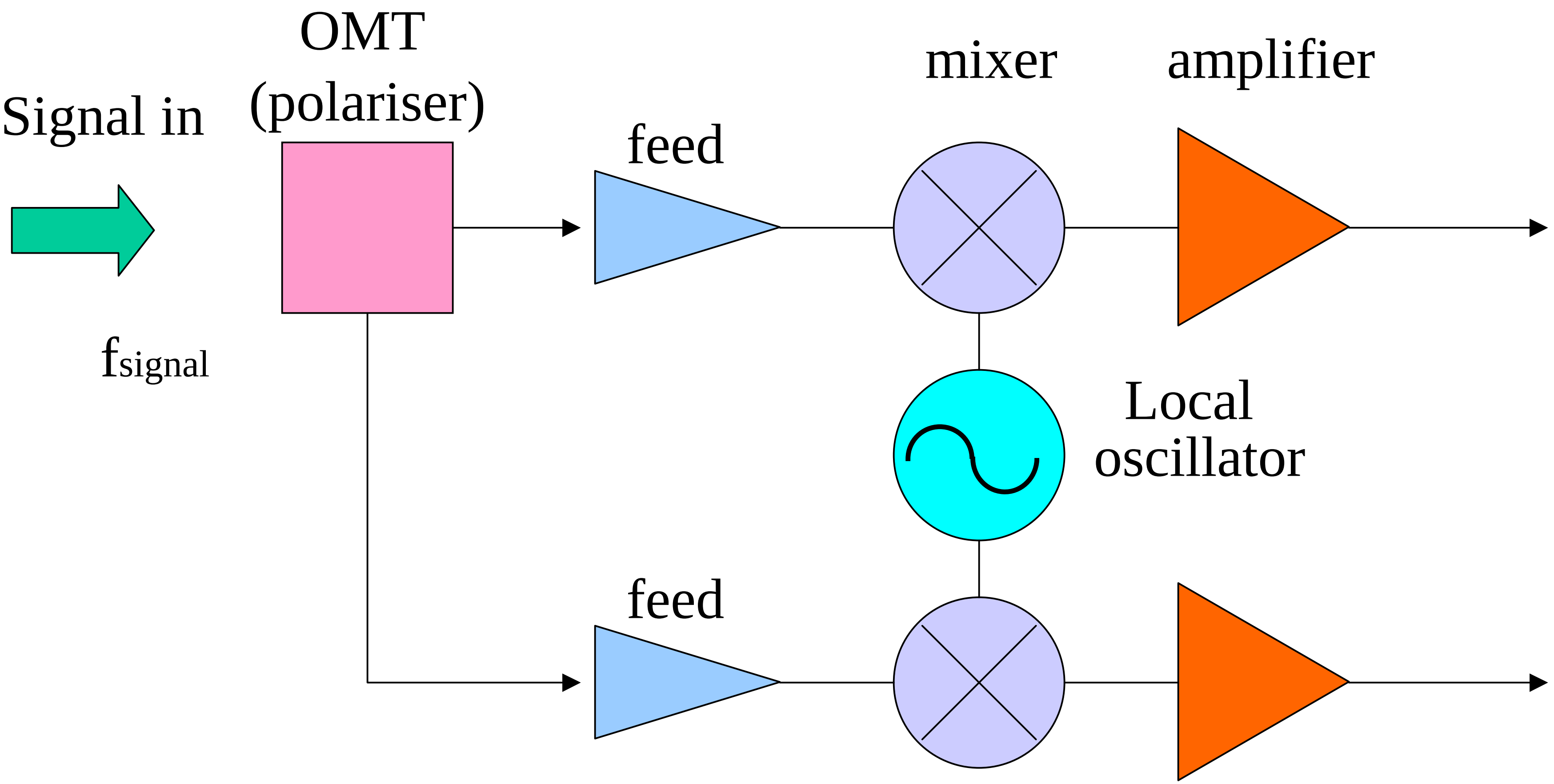
What’s special about these higher frequency receivers is………..

The active components currently used in most millimetre, radioastronomy receivers are superconductor-insulator-superconductor (SIS) mixers and discrete Gallium Arsenide (GaAs) or Indium Phosphide (InP) transistors.

The monolithic microwave integrated circuits (MMICs) we have developed can replace all the discrete components of an amplifier with a single chip which can be mass produced allowing cost savings and greater reproducibility and reliability.

Indium Phosphide technology has become the first choice of our millimetre devices because of its lower noise, higher frequency response and superior cryogenic performance

After all I said before…….



……….the Mopra mm receiver is different as are others……

Historically, when amplifers aren’t available –whack in a mixer anyway and do some science. This is currently true for receivers operating above 100 GHz.

Many have Guassian beam optics for signal acquisition and LO injection

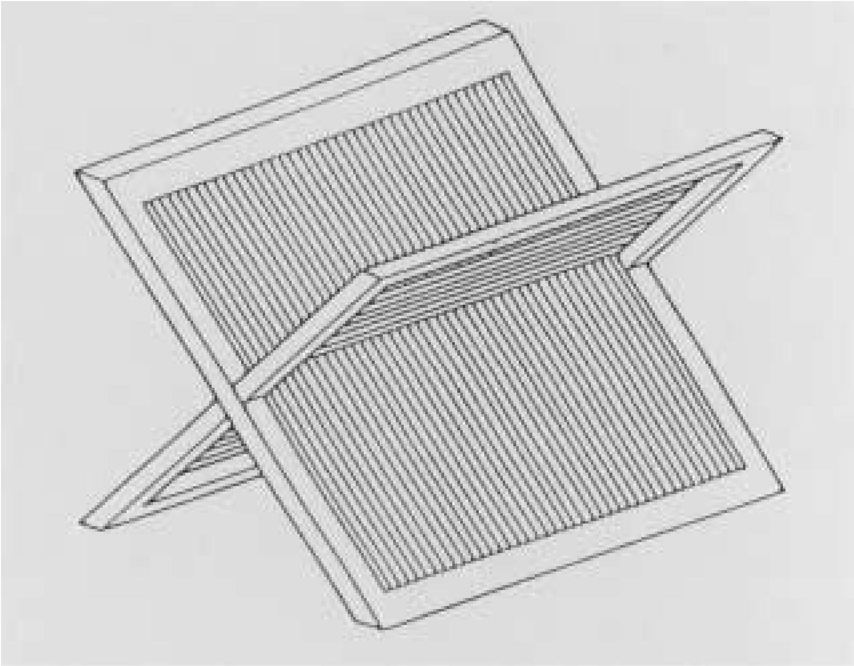
The Mopra receiver has low noise SIS (superconductor-insulator-superconductor) mixers as opposed to the more conventional diodes.

They require an extra cooling section to maintain them at 4K

They are followed up by cooled, low noise, high gain amplifiers

They are not broadband so some tuning is necessary across the band

The polarisation splitter is not a waveguide structure but rather a set of grids crossing at right angles and having closely spaced wires – each grid having wires running orthogonally to the other



It is incorporated in a Guassian beam optics path that was necessary because the feed, internal to the dewar, was unable to be positioned at the focus.


Optics
box
grids