Analogue Signal Processing

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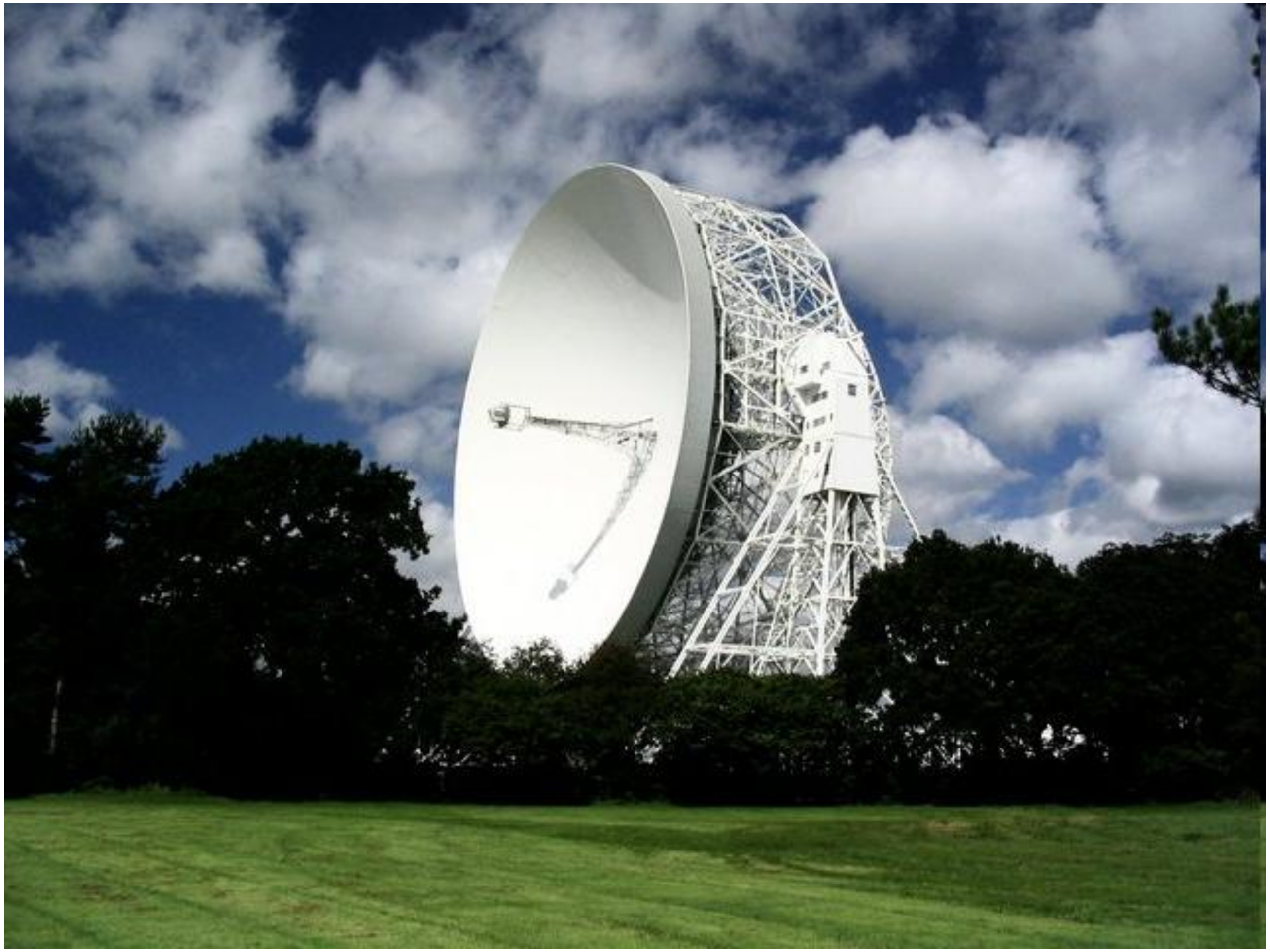
Antennas

- Reflecting telescopes
- The aim is to try get all the photons from a dish into one waveguide/horn by focussing all the signals from one direction.
- This gives us a strong signal but from only one direction.
- Can have an array of such waveguide/horns which are then sensitive to several directions



Antennas

- An alternative is a phased array where there is no dish but collect signal directly with:
- Horns
- Dipoles
- Bunny-ears
- Vivaldis etc

Orthomode Transition (OMT)

- This is inserted in the waveguide and is used to convert the e/m waves into electrical oscillations in some sort of stripline or some sort of probe
- These devices can be single ended or balanced depending what sort of device you want to drive next
- There are many such designs and the chosen one depends on the sort of bandwidth and polarisation required

Polarisation selection for circular required for interferometers

- It is possible to combine the polariser with the OMT into what is called a Septum polariser. Here a carefully shaped sheet of metal is inserted into the waveguide in such a way that it converts each hand of circular polarisation into two linears that are orthogonal to each other that can then be detected by the OMT probes

polarisers

- The Septum polariser is neat but unfortuately of limited bandwidth say 10%
- The way round this is to use an OMT which can be very wide band and just collect the linear polarisation
- These signals can then be combined to make the system sensitive to circular polarisation with a hybrid which also can be made with a broadband
- For ultra low noise this hybrid needs to be after the low noise amplifier but normally this is not done for reasons of polarisation stability

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Low Noise Amplifiers (LNAs)

- The first active element after the polariser and OMT is the LNA
- The whole name of the game is to get the ultimate low noise
- We measure this noise with respect to the Jonstone Noise of a resistor
- The noise power from a resistor at temp T_o

  is : $kT_0\Delta f$

LNAs

- The noise power at the input of an LNA is $kT_R\Delta f$ where $\mathrm{T_R}$ defines the noise temperature
- Or $\left(\mathrm{N}-1\right)\mathrm{kT_0}\Delta\mathrm{f}$ using noise factor N.
- Thus $\mathrm{T_R}=\left(\mathrm{N}-1\right)\mathrm{T_o}$ so we aim for N close to 1
- This is the Raleigh-Jeans approximation

Designing LNAs

- The most important things we have to consider are gain and corresponding noise figure
- We want to maximise gain and minimise noise figure.
- The most critical parameter is the match impedence
- At the conjugate match impedence the maximum power is delivered to the input

Designing LNAs

- This match impedence is not necessarily equal to the system impedence
- Even worse we want the condition that as much noise of the LNA as possible comes out of the input and is not amplified by the LNA.
- This is a third impedence

Design of LNAs

- So we have 3 sets of impedences
- The system impedence is controlled by the architecture of the design
- For stripline this is governed by the width to depth of the line
- The other two impedences are controlled by the properties of the active device (transistor) that we are using

Design of LNAs

- G_s is the source reflection coefficient which give a noise factor N
- N_{min} the minimum noise figure occurs when $G_s = G_{opt} R_n$
- R_n is the noise resistance
- N_{min}, R_n and G_{opt} are the noise parameters of the device or transistor

Design of LNAs

- This leads us to the conclusion that the optimum noise performance does not occur when we match the input
- Surely this cannot be right because some of our golden signal from the sky will not get into the transistor but will be reflected out of the input

Design of LNAs

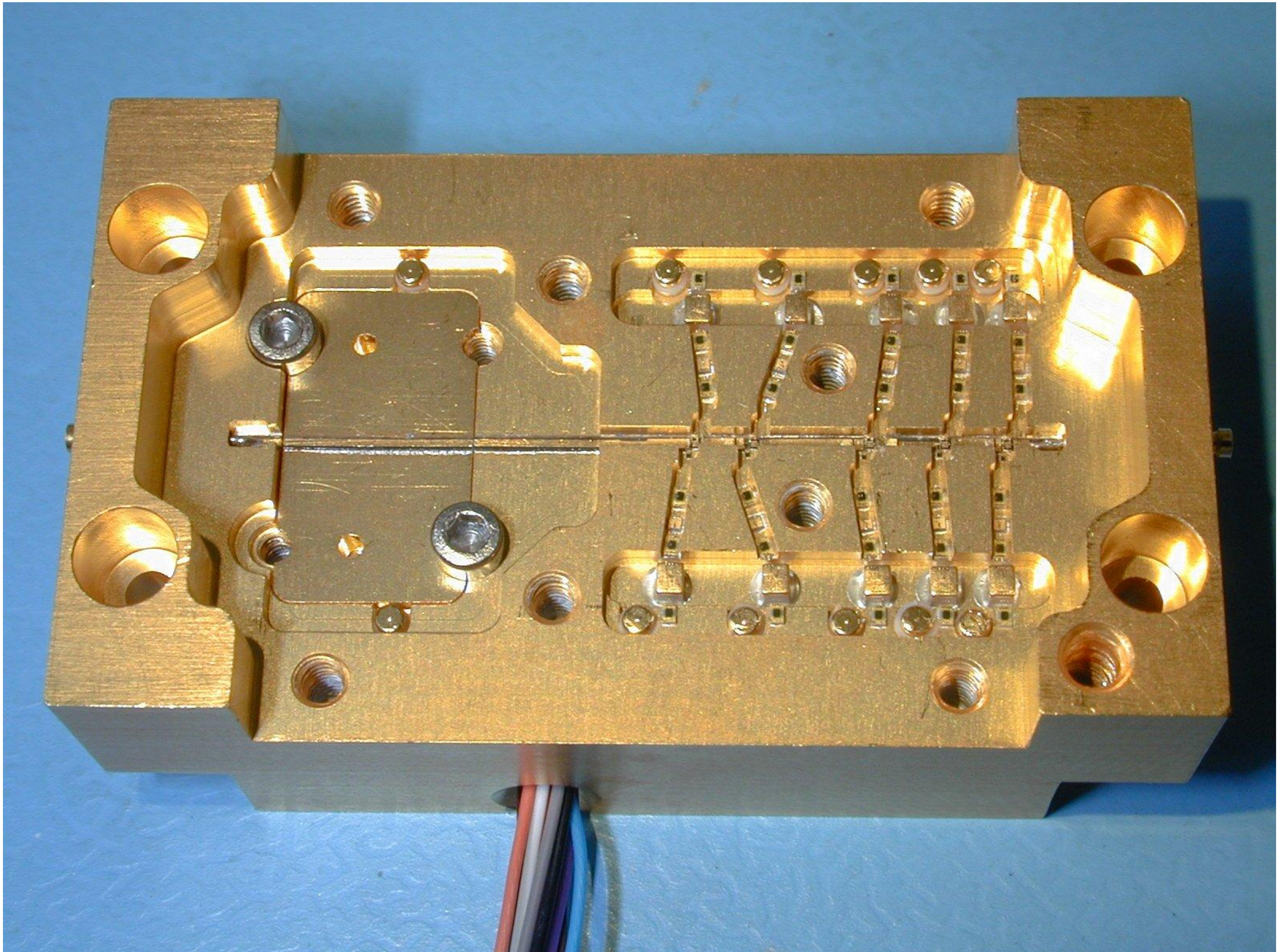
- Using the Q and A ideas of Sander Weinreb NRAO
- If an LNA has a poor input power match, high VSWR will this degrade the system noise figure?
- No NF and input power match are not directly related. If amplifier has a low noise figure with a 50Ω source impedance it will give a low system noise figure even if it has a high input VSWR

Design of LNAs

- But if most of the input signal is being reflected by the amplifier and NF is a measure of the noise-to-signal ratio, couldn’t you get a better NF by matching more of the sigal into the amplifier
- Yes, you can get more signal power into the amplifier by matching but the noise power going into the amplifier will also increase in such a way that the noise-to-signal and NF are degraded

Design of LNAs

- For high frequencies the condition for high gain and low noise is rather similar
- But for low frequencies 5 GHz and below they are very different and to build a workable amplifier one has to use an isolator with a 50Ω impedance



Receiver overall

- A) Radiometers we need to filter the signal and detect it
- We find 1/f instabilities from the amplifiers and the atmosphere
- Need to switch against a reference
- This can either be another sky channel as in WMAP or a reference load as in Planck

Receiever overall

- B) Interferometers: here we have multiple signals from 2 or more telescopes.
- We multiply the telescope voltages together and finish up with just the correlated signal and some noise
- The gain instabilities are largely removed by the correlation technique

Filters

- For all these receivers filters are required to define the bandwidth. The other parts of the receivers will work over a much wider band but not properly
- The gain and noise and match will go off and all sorts of nasty things happen
- Thus at some point in the receiver it is necessary to have a good filter to define the band

Filters

- There are different types: Butterworth, Tchebychev but to name two
- These can be realised in: stripline, waveguide and other cavity modes and lumped element

ADC

- Finally these days we nearly always convert these analogue signals to digital with an ADC or A to D as we used to call them