Radio Telescope Receivers

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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...

- Feed Horns
- Vacuum Dewar
- Control and Monitoring electronics
On the inside...
Detour: Reciprocity

Forward
\[ V_B = S_{BA} V_A \]

Reverse
\[ V_A = S_{AB} V_B \]

Reciprocal
\[ S_{BA} = S_{AB} \]
Corrugated

Smooth Walled

E-Field At Feed mouth

X and Y Feed Patterns

Gain

Theta [deg]
**Receiver Systems for Radio Astronomy**

**Signal**

**Feed**

**Coupler**

**Noise source**

Noise coupled in through small holes

7mm waveguide coupler

Noise coupled in through vane

21cm waveguide coupler

12mm noise source
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Signal

Feed

Coupler

Ortho-mode Transducer

Pol A

Pol B

Noise source

A output

B output

Input
Separating the Polarisations: The OMT
Noiseless Amplifier

\[ P_{\text{output}} \propto G\text{ain} \Delta f \]

Low Noise Amplifier

\[ P_{\text{output}} = G\text{ain} \Delta f k_B T_{\text{resistor}} \]

Noiseless Termination

Black body Termination

\[ T_{\text{equivalent}} = \frac{P_{\text{output}}}{G\text{ain} \Delta f k_B} \]
\[ T_{\text{system}} = T_1 + \frac{T_2}{\text{Gain}_{\text{LNA}}} + \frac{T_3}{\text{Gain}_{\text{LNA}} \times G_2} + \frac{T_4}{\text{Gain}_{\text{LNA}} \times G_2 \times G_3} \]
10Jy radio source $\rightarrow$ $\sim$1K additional noise

Your hand $\rightarrow$ $\sim$300K additional noise

Mobile Phone at 1 km $\rightarrow$ $\sim$1 $\times$ $10^{11}$ K !! (in primary beam)
## Noise contributions of a typical receiver

<table>
<thead>
<tr>
<th>Part</th>
<th>Room Temperature</th>
<th>Cryogenic</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sky + CMB ($T_{\text{sky}}$)</td>
<td>6K</td>
<td>6K</td>
<td>1</td>
</tr>
<tr>
<td>Spillover ($T_{\text{spill}}$)</td>
<td>3K</td>
<td>3K</td>
<td>1</td>
</tr>
<tr>
<td>Feed + OMT</td>
<td>10K</td>
<td>2K</td>
<td>5</td>
</tr>
<tr>
<td>LNA ($T_{\text{LNA}}$)</td>
<td>35K</td>
<td>5K</td>
<td>7</td>
</tr>
<tr>
<td>Rest of the System</td>
<td>1K</td>
<td>1K</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total ($T_{\text{sys}}$)</strong></td>
<td><strong>55K</strong></td>
<td><strong>17K</strong></td>
<td>~3</td>
</tr>
</tbody>
</table>
Refrigerator in the Parkes 12mm receiver

- 15K section
- 70K section
- Cold finger

Helium Refrigerator

Helium Compressor

Helium Lines
The RF System

Contains:
- More amplification
- Band defining filters
- Frequency conversion
- Level adjustment
- Signal detection
- Band shaping
$\cos(\omega_1 t)\cos(\omega_2 t) = \frac{1}{2}[\cos((\omega_1 + \omega_2)t) + \cos((\omega_1 - \omega_2)t)]$
Mixer (Multiplier)

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

Signal 1 → Local Oscillator

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

Upper Side Band (USB)

Power

Frequency

\( f_{LO} \)

\( \Delta f \)
Mixer (Multiplier)

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

Local Oscillator

Signal 1

Lower Side Band (LSB)
Signal 1

Band pass filter

Mixer (Multiplier)

Local Oscillator

\[ \Delta f \]

\[ f_{lo} \]

\[ \Delta f \]

\[ \text{Power} \]

\[ \text{Frequency} \]
The modern radio telescope
0.000001 megapixels
Digital beamformer

Weighted (complex) sum of inputs
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Thank you

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