The World's Largest Telescopes*

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Physkiss - Session 2

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*will be replaced by LISA in 2030s

DISCLAIMER: None of the material in this talk is original!

Most material (including figures) are taken from :

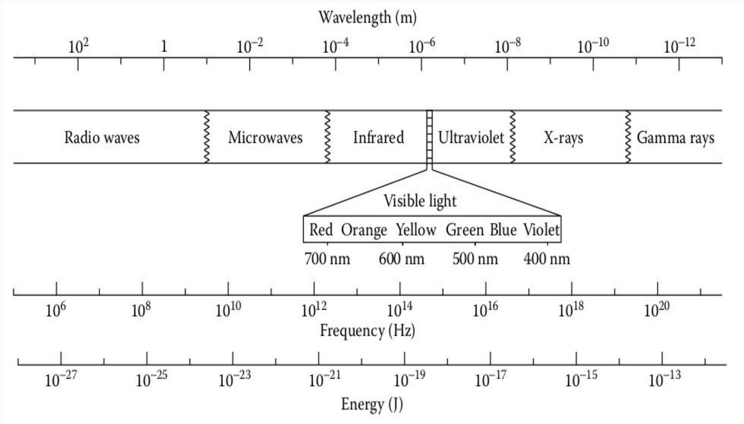
Fundamentals of Radio Astronomy by Marr, Snell, Kurtz (2 Volumes)

Other References include:

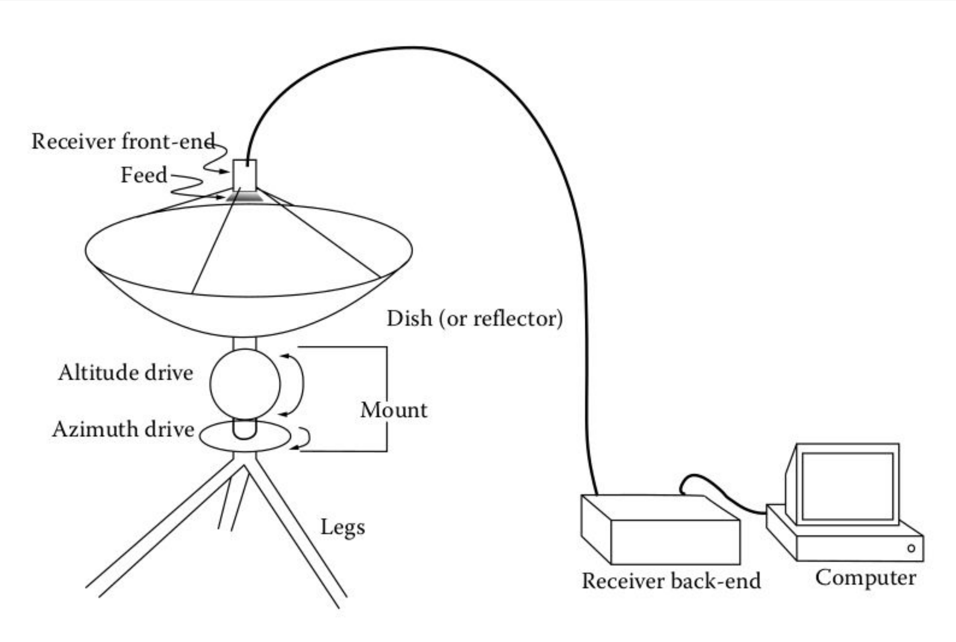
Essential Radio Astronomy by Condon and Ransom
An Introduction to Radio Astronomy by Burke, Graham-Smith, Wilkinson

The Radio Regime

- Spans a huge range of frequencies.
- No single telescope configuration can cater to all frequencies.
- Almost all objects radiate in radio; from the intergalactic and interstellar medium to galaxies and stars and even the big bang!



The Radio Telescope



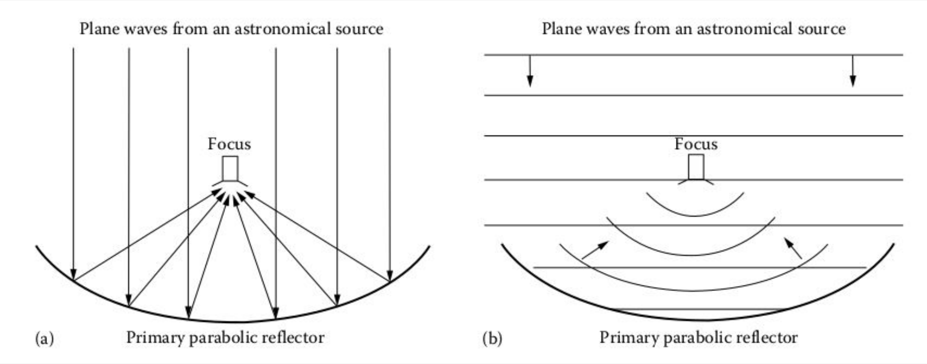
Reflectors

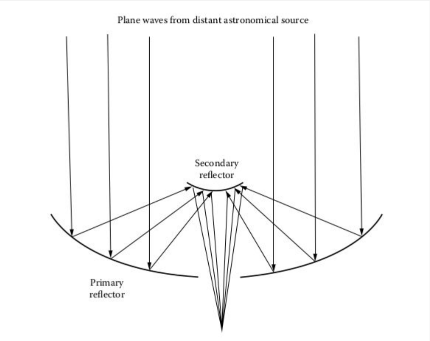
- Reflectors are parabolic; they focus incoming radiation to a point (the focus).

- Two setups - primary and Cassegrain (*ie.* primary + secondary).

- Primary collects and focuses radiation. Power proportional to area:

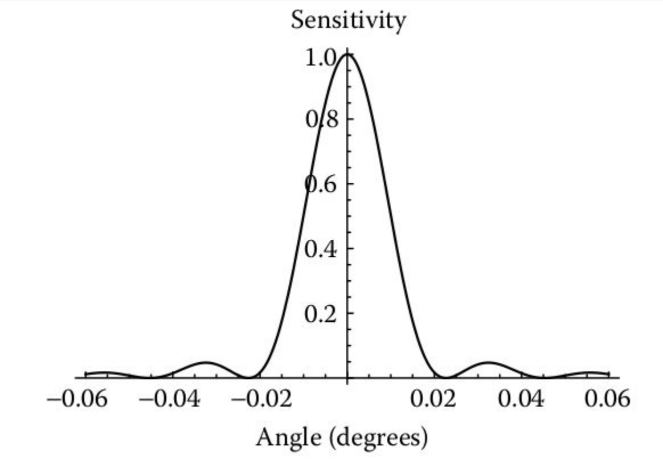
$$P = F_\nu A_{eff} \Delta\nu$$





Reflectors

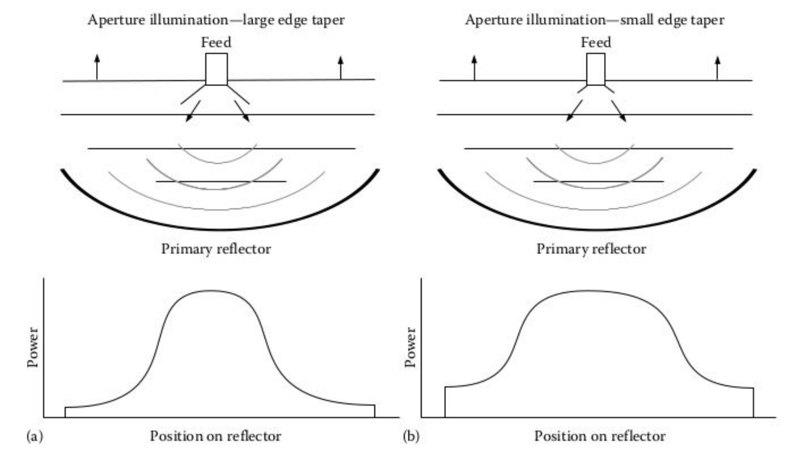
- Primary reflectors also provide for directivity. Determined by beam pattern.
- Beam pattern is diffraction limited (Airy function). Has main beam and side lobes.
- Resolution ~ wavelength/diameter.
- Larger reflectors not only collect more power, but also have more resolution.



Uniformly illuminated reflector with a diameter of 40 m observing at 1.4-cm wavelength

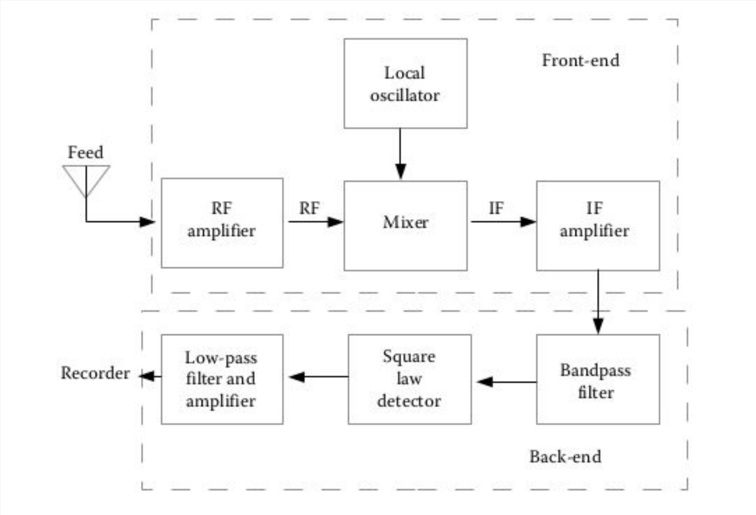
Feeds

- After collecting the radiation, we need to convert to waves in transmission lines.
- We use feeds (or waveguides/antenna).
- Feed will have its own beam pattern, and also resolution.



Receivers

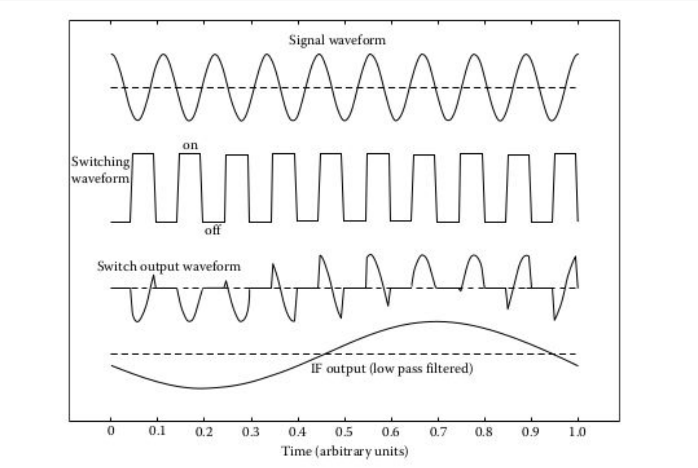
- Define the frequency passband.
- Feeds couple the free radiation into transmission lines (waveguides).
- Many components along the transmission line.



Schematic diagram of the receiver

Receivers - Front End

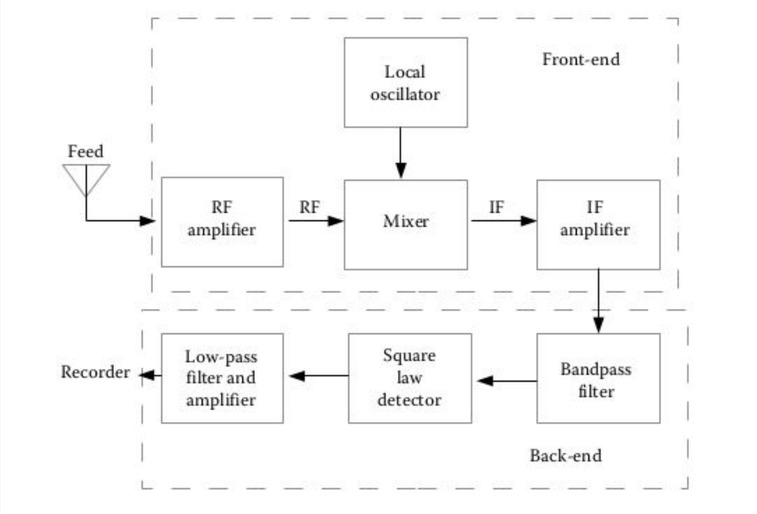
- Amplifier is characterized by its power gain $G = P_{out} / P_{in}$
- High frequency components experience higher loss and are costlier to build. Solution - convert HF to LF.
- Use Mixer with an oscillator! Will produce beat frequency.
- Amplify again with IF amplifier.



Mixing

Receivers - Back End

- Now we need to measure the power in the EM waves.
- Apply a bandpass filter to filter out unwanted frequencies and to make a precise measurement of flux density.
- Shine the EM waves on diodes that produce current proportional to square of the amplitude.
- Amplify again!



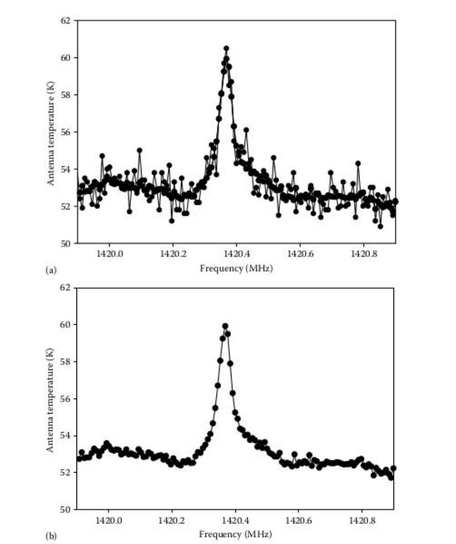
Schematic diagram of the receiver

Noise

- So many components, hence a lot of noise. Quantified by temperature $T = P/ (k \Delta\nu)$
- The power of astronomical source is characterized by antenna temperature T_A.
- Most of the power is noise in receiver. The total noise temperature T_N is given by $T_N = T_{N1} + T_{N2} / G_1 + T_{N3} / (G_1 G_2)$
- Hence, total power $P = G k (T_A + T_N)$. Generally $T_A << T_N$.
- Make switched observations to eliminate offset caused by noise!

Switched Observations

- Calculate power on-source and off-source at regular intervals.
- This enables us to subtract out noise temperature; but fluctuations still remain.
- Solution: Observe for more time and take average! Noise ~ *1/sqrt(N),* but true signal remains same. Hence SNR ~ *sqrt(N)*

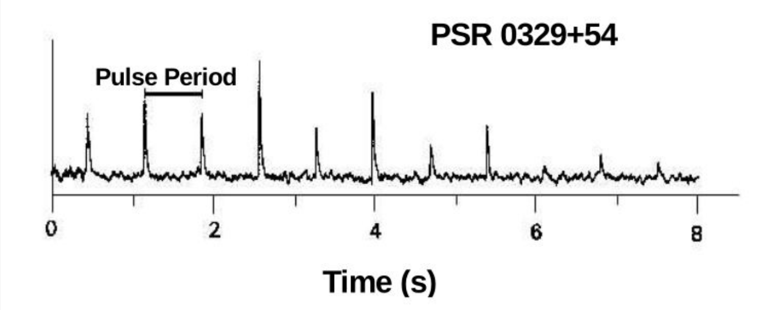


One Miraculuous Source: Radio Pulsars

- Pulsars are like lighthouses: they sweep the earth at very precise time intervals.

- The averaging prescription is very useful here.

- The longer you observe a pulsar, the more handle you have on its pulse profile due to the *sqrt(N)* scaling of the SNR.



Thanks For Listening!

Any Questions?

Please Stay Safe and Healthy!