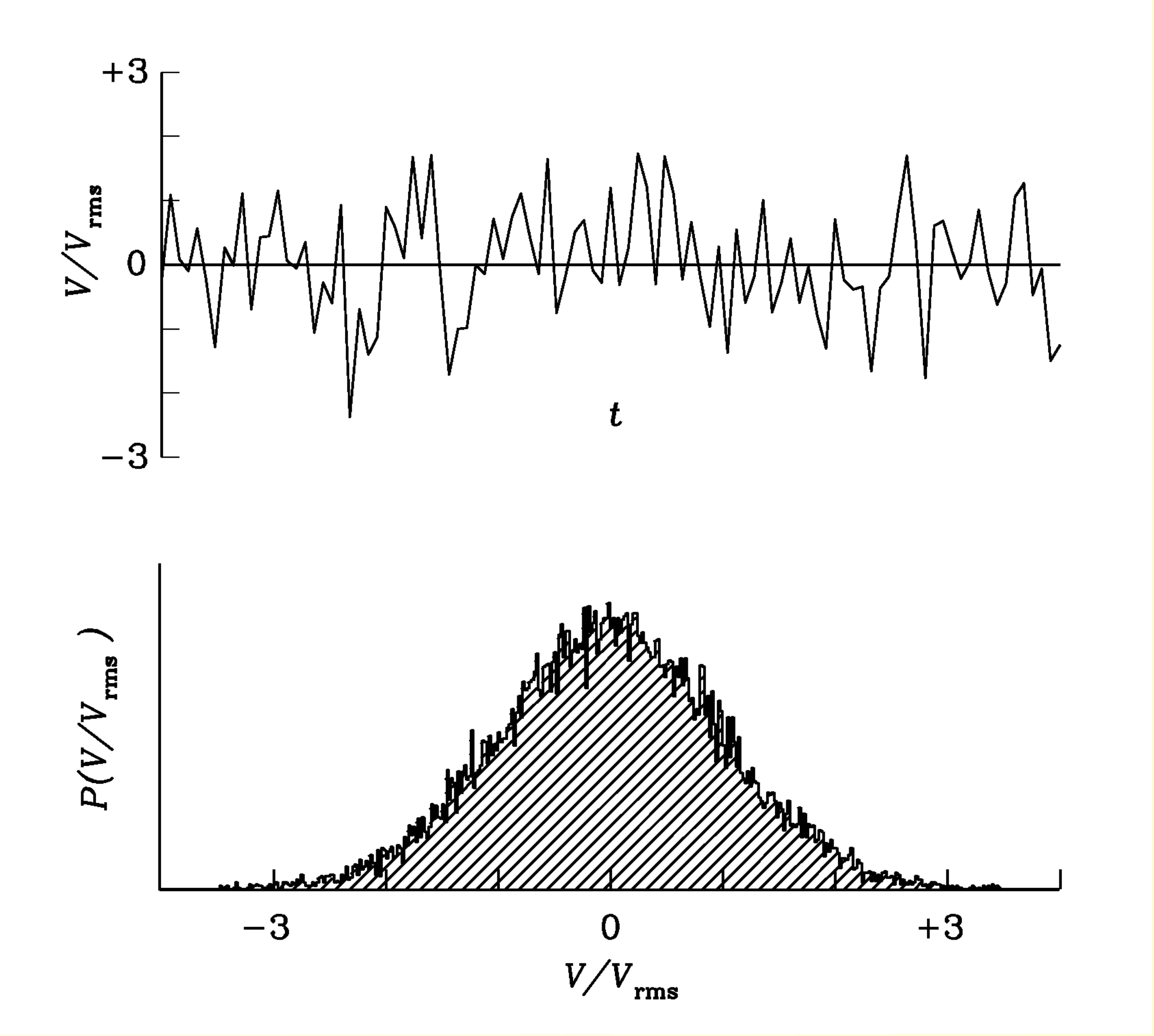
Radiometry

- What we observe is NOISE!
- We take band limited (filtered) noise from the sky and make maps of where it comes from
- Assume the noise has gaussian probability distribution.
- for N samples noise uncertainty goes as

$$uncertainty \propto \frac{1}{\sqrt{(N)}}$$

Like this



For bandwidth $\Delta\nu$

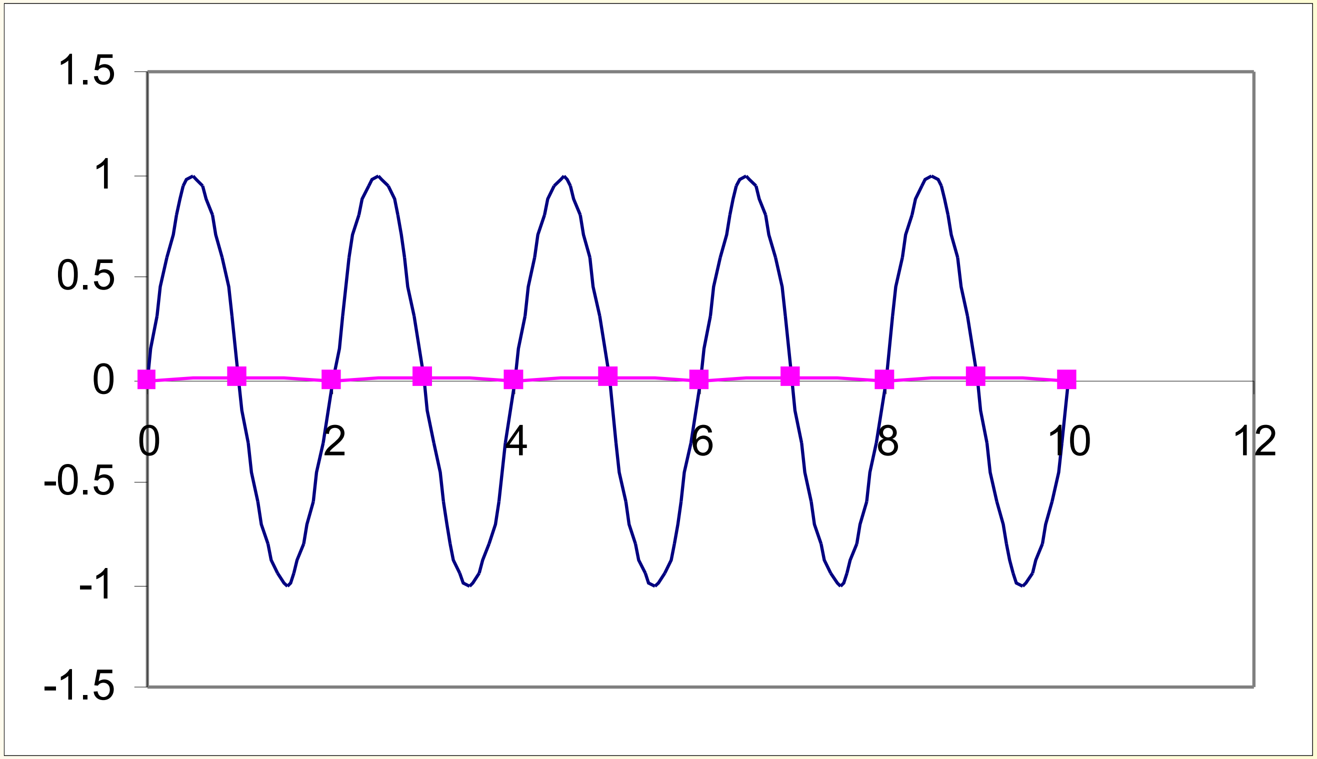
- Number of **independant** voltage samples in a time interval τ from Shannon's law (alias Nyquist Shannon Sampling theorem)

$$N = 2\tau\Delta\nu$$

- This is fundamental to signal processing and information theory, essentially it says how much information there is in our signal
- Formal proof needs Fourier analysis
- There is a good wikipedia article

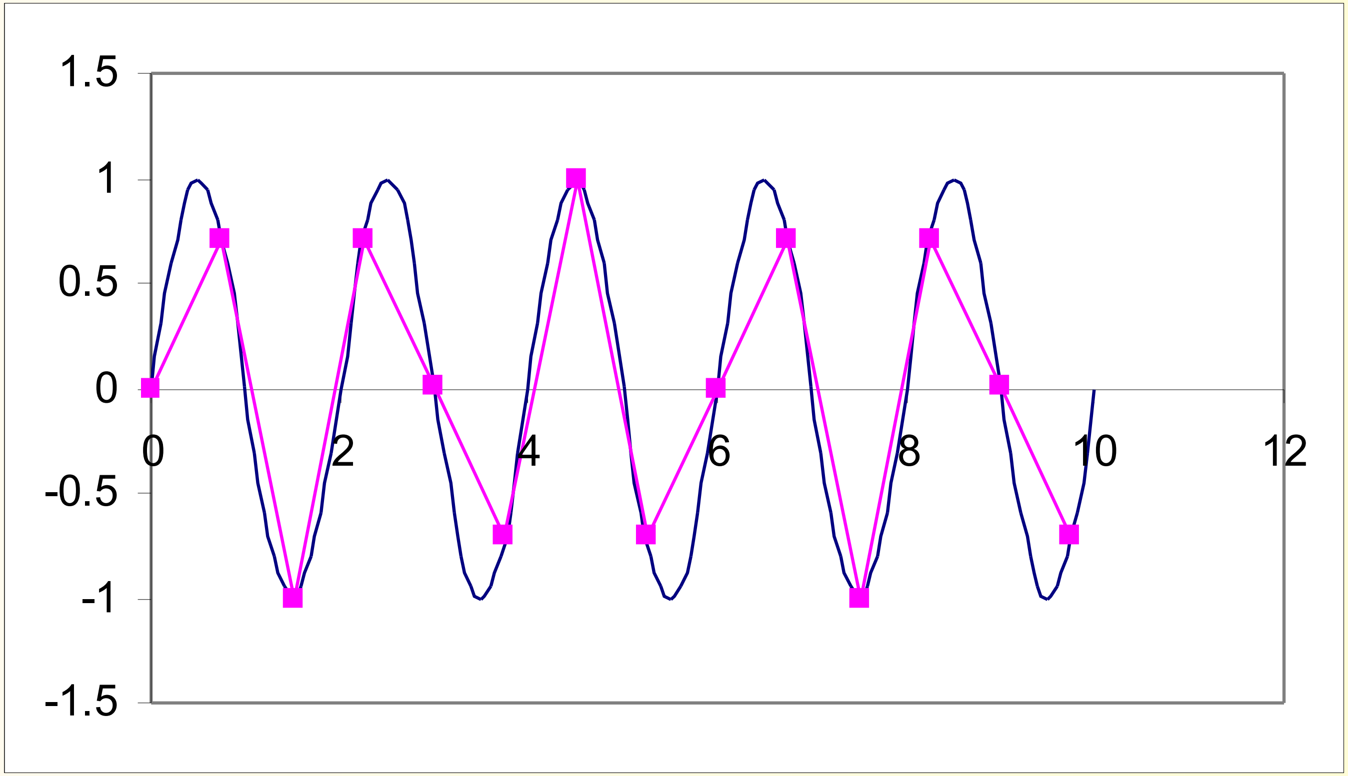
Sampling

- Sampling at half frequency



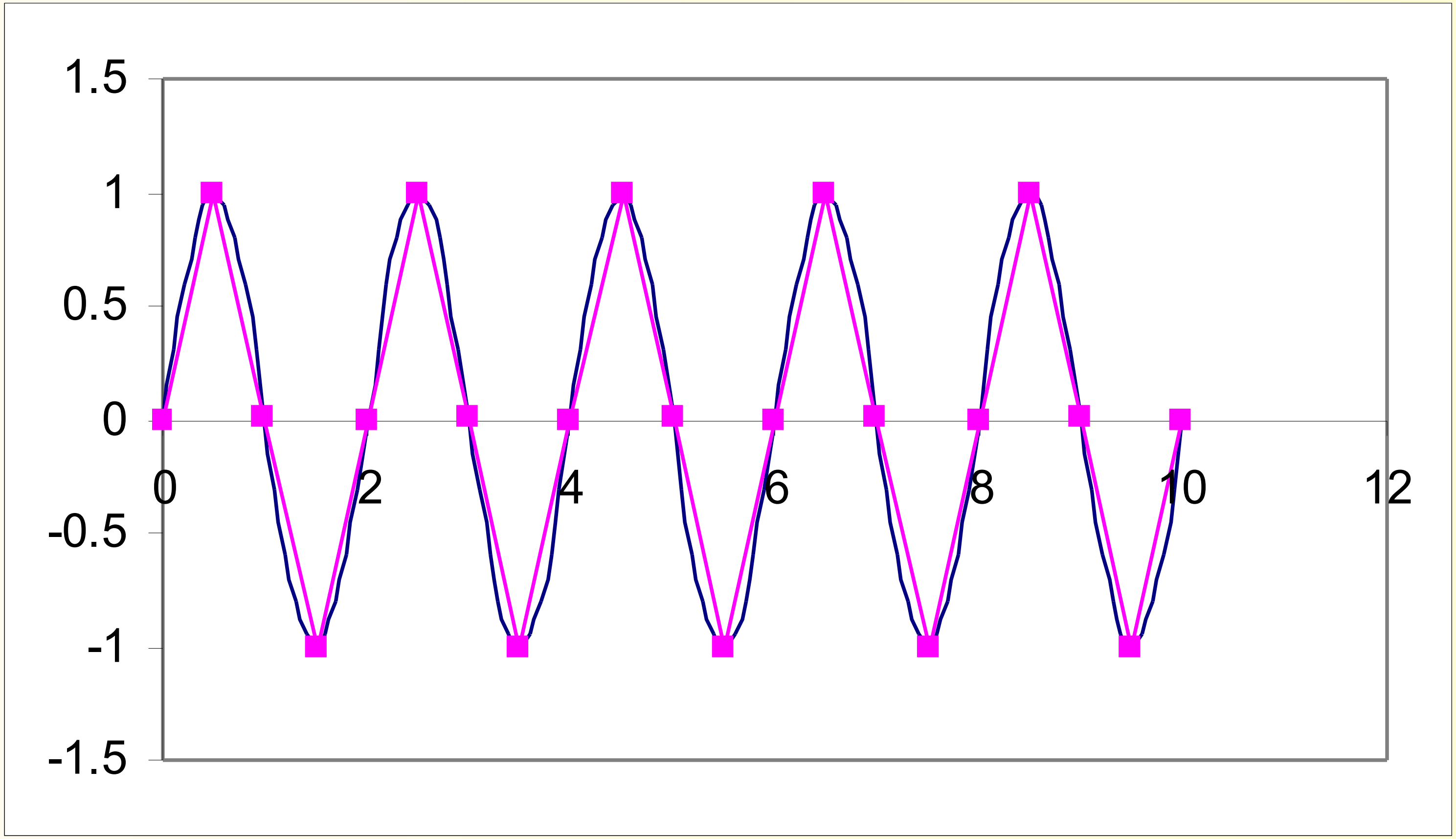
Sampling

- Sampling at 2/3 frequency



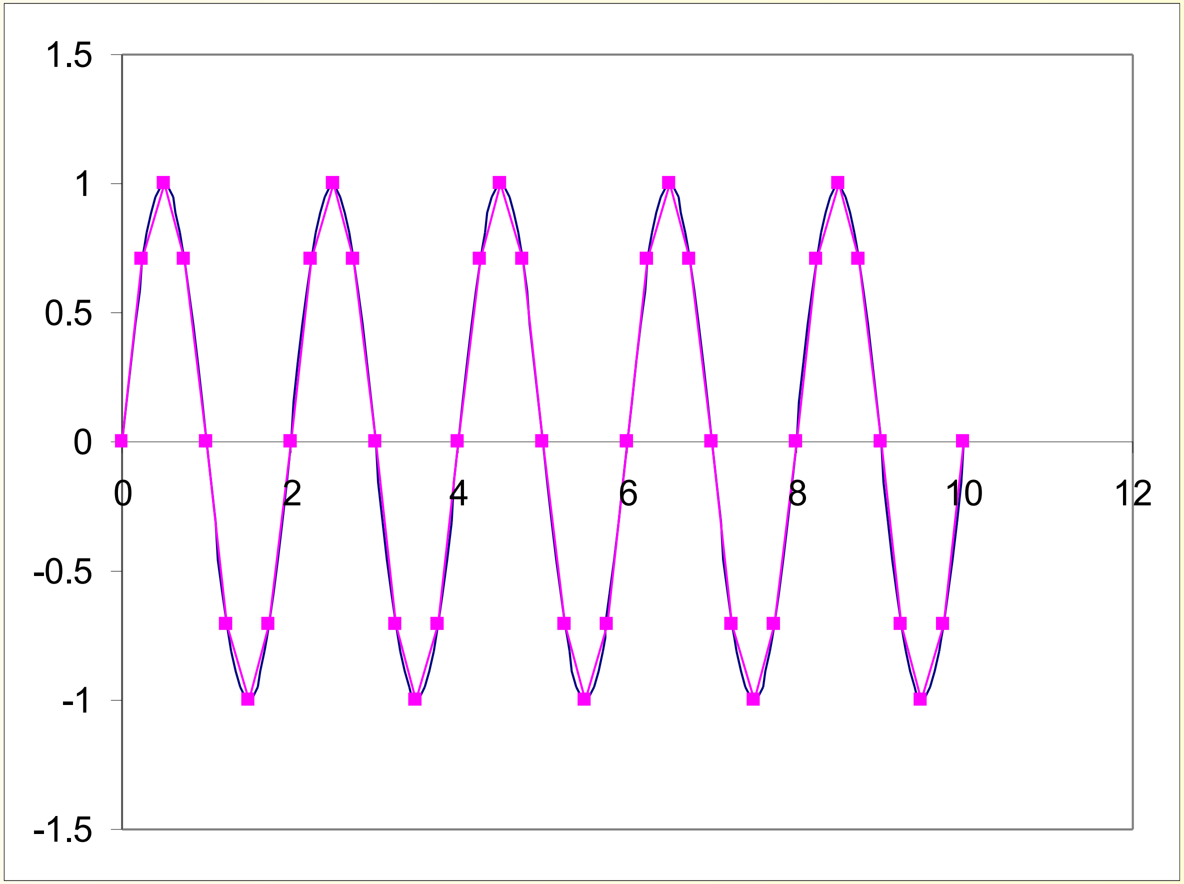
Sampling

- Sampling at frequency



Sampling

- Sampling at twice frequency (Nyqiust rate)



demo

- There is an audible demo of some of this stuff at

  http://ptolemy.eecs.berkeley.edu/eecs20/week13/aliasing.html

Power

- The noise power (resistor, low freq)

  using noise equivalence $P_N = kT_N$

  so $T_N \equiv \frac{P_N}{k}$

- So we can define system noise temperature

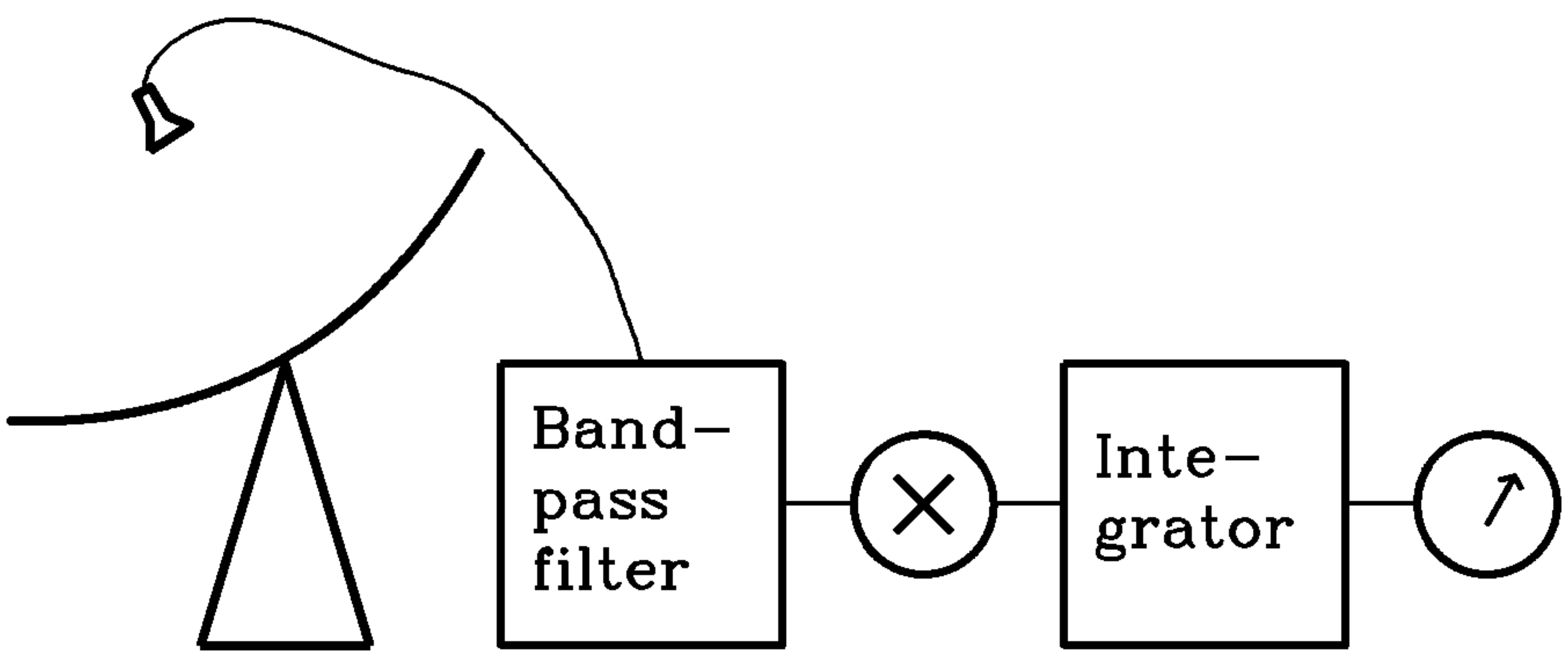
$$T_{sys} = T_{cmb} + \Delta T_{source} + T_{atm} + T_{spillover} + T_{rec} + \ldots$$

- Often the part from the source is smallest, so we would like all the others to be stable

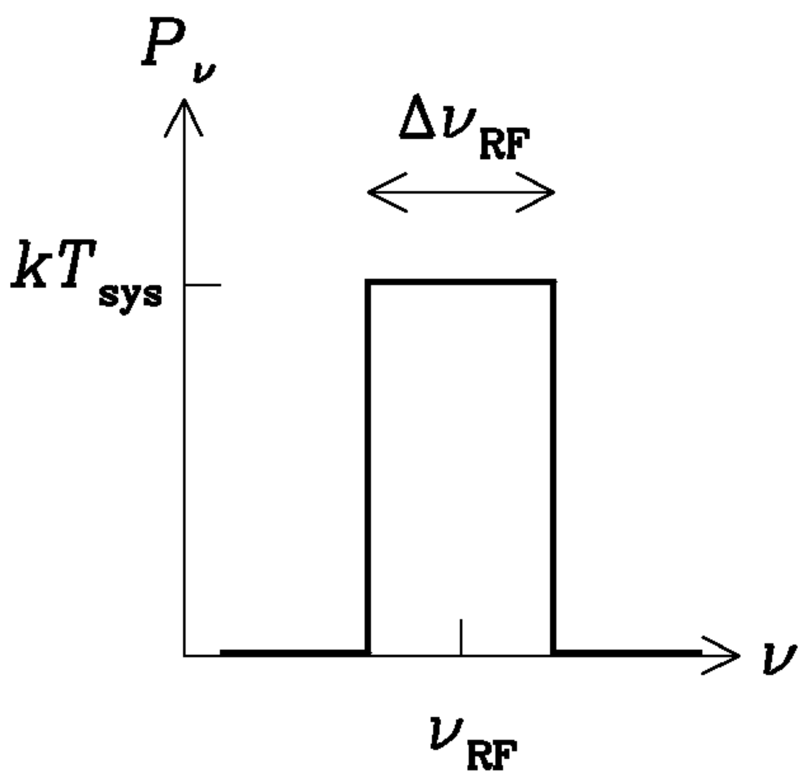
Values..

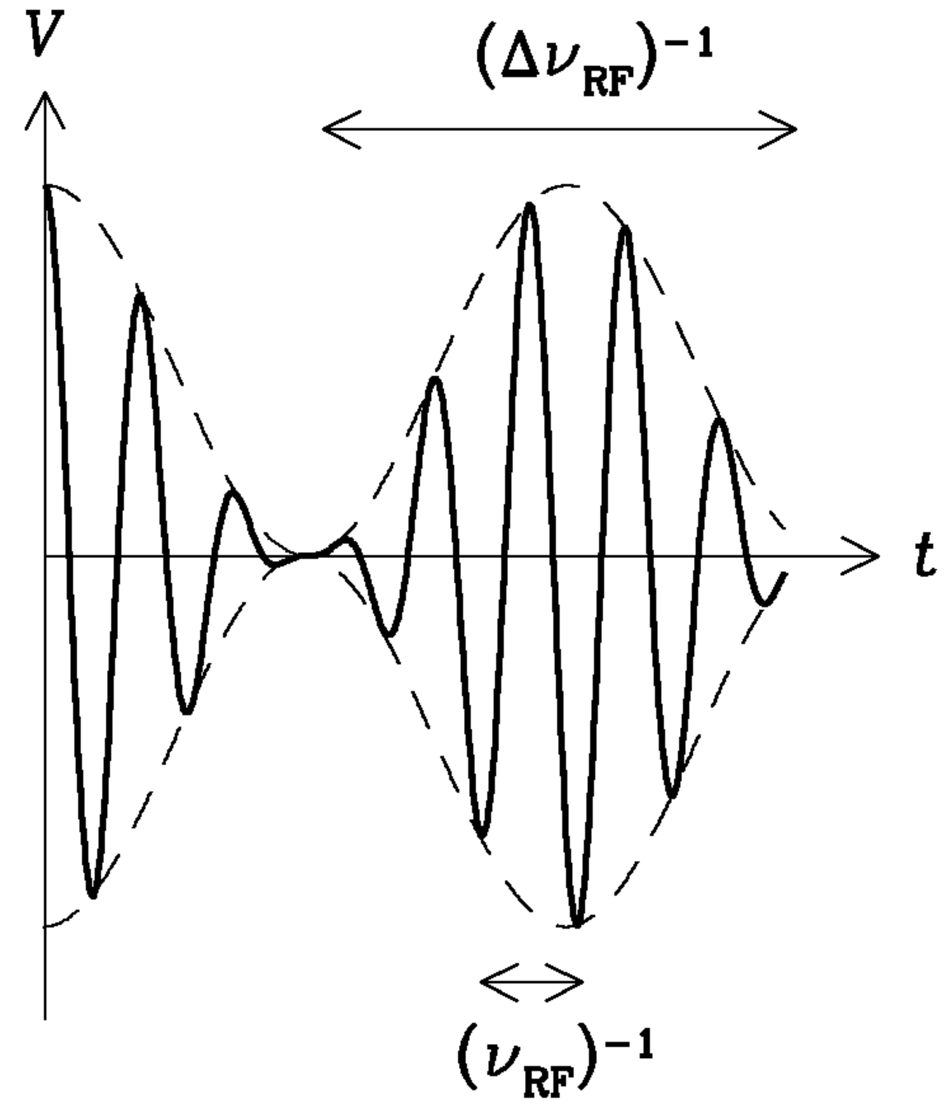
- For a good receiver bandwidth might be 10% to 50% of frequency
- More absolute bandwidth means better electronics
- More relative bandwidth means harder RF design
- The simplest systems use square-law power detection

Model



Power and voltage





Noise uncertainty

$$\sigma_T \sim \frac{T_{sys}}{\sqrt{(\tau \ \Delta\nu)}}$$

- Depends on
  - how much bandwidth we can use
  - how long we can integrate for
  - how low we can get the system temperature

Problems

- Gain variations
- Atmospheric variations

- SO?
  - Calibrate faster than the variations!
  - with a **noise diode**

Mixing

Super heterodyne receivers

- It used to be difficult to handle high frequency signals (>1GHz) (*now easier*) so it was very convenient to reduce the frequency of the signal for handling in a **mixer** with a **Local Oscillator (LO)** to make an **Intermediate Frequency (IF)**
- This allowed different receivers to share a common **Back-end**
- This is unnecessary at low frequency

Other terms

- The bit where the signal enters is the **feed**
- Receiver electronics is the **front-end**
- Noise is injected via a **coupler**

Gain, SEFD

- If the telescope has an effective area A_e (always less than the geometrical area – typically 50-60%)

$$Gain = \frac{4\pi A_e}{\lambda^2}$$

- Sensitivity in K/Jy is

$$\frac{10^{-26} A_e}{2k}$$

- Another measure is **System Equivalent Flux Density**

$$SEFD = \frac{2kT_{sys}}{10^{-26} A_e}$$

Back of envelope

- If we have a 25m dish and 60% efficiency with a system temperature of 30K at 21cm
  - gain about 140000 (51dB)
  - sensitivity about 0.1 K/Jy
  - SEFD about 300Jy (low = good)
  - A_e /Tsys about 10 (high = good)