DARA 2016 Nairobi Unit1 Radioastronomy Workshop on Lecture 5

4. A lost spacecraft at a distance of 2.5 A.U. from Earth carries an *isotropic* 1.3W transmitter which produces an unmodulated (pure) cosine wave at 437 MHz. The Lovell Telescope at Jodrell Bank is used to search for the signal from this transmitter using a receiver with a system noise temperature of 90 K. Given that the Lovell Telescope produces a rise in antenna temperature of 1K for a source of flux density 1 Jy (10^{-26} W m^{-2} Hz^{-1}) calculate the spectrometer channel bandwidth which would be needed to detect the signal at the 3-sigma level within 10s of integration. Notes: i) 1 A.U. = 1.5×10^{11} m

Steps:

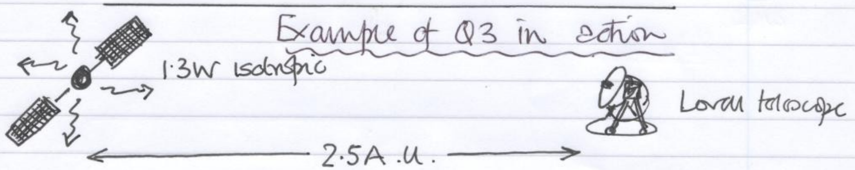
1. Calculate the signal strength (S)
   - Calculate the flux per unit area (W m^{-2}) for the distance given
   - For a spectrometer channel width of $\delta\nu$ Hz – write down an expression for the flux density (W m^{-2} Hz^{-1}) when the (unresolved) line flux is spread out across a channel.

2. Calculate the system noise (N)
   - Use the radiometer equation to obtain an expression for the rms noise in a single channel of width of $\delta\nu$ Hz given the quoted system noise temperature and integration time.
   - Express the answer in Jy given that 1 Jy = 10^{-26} W m^{-2} Hz^{-1} and that the sensitivity of the Lovell Telescope is 1K per Jy.

3. Require a signal-to-noise S/N=3 and hence calculate the maximum channel width $\delta\nu$ Hz

Ignore commentary before Q4

4. Example of Q3 in action

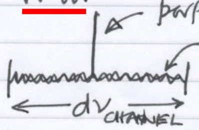


(1AU = 1.5x10[11] m)

- Flux / unit area at Earth distance = $\dfrac{1.3}{4\pi(1.5\times2.5\times10^{11})^2}$

$= 7.36\times10^{-25}$ W m^{-2}

- Flux density of line integrated across BW



Signal : $= 7.36\times10^{-25}/dv_{CHANNEL}$ W m^{-2} Hz^{-1}

- Receiver noise in 10s $= 90/dv_{CHANNEL}^{1/2}\ 10^{1/2}$

$= 28.4/dv_{CHANNEL}^{1/2}$ (K)

- Given that Lovell sensitivity ⇒ (1Jy ≡ 1K) antenna Temp

Noise: $\Delta S_{RMS} = 28.4/dv_{CHANNEL}^{1/2}$ (Jy) (system noise in Jy)

- For 3σ detection $\dfrac{7.36\times10^{-25}}{dv_{CHANNEL}} = 3\times \dfrac{28.4\times10^{-26}}{(dv_{CHANNEL})^{1/2}}$ ← 1Jy

signal = 3 x noise

$dv_{CHANNEL} = \left[\dfrac{7.36\times10^{-25}}{3\times28.4\times10^{-26}}\right]^2 = 0.75$ Hz

→ need to narrow down the channel to reduce noise power across channel & hence detect narrow band weak signal

NB This example is based on real-life search at JBO for a lost U.S. spacecraft at Mars in the 1990s!

Ignore commentary after Q4