

DARA 2017 Nairobi Unit1
Radioastronomy
Workshop on Lecture 3

3) A radio antenna has a diameter of 20 m and is operated at wavelength of 600 MHz. Estimate its half-power beamwidth ($\theta_{1/2}$; FWHM) expressed degrees.

4. A radio telescope has a diameter of 100m and is being operated at a frequency of 30 GHz. At approximately what distance from the telescope does the Fraunhofer (or far-field) regime start? Is this within or beyond the atmosphere?

5. The telescope in Q5 has surface with an rms roughness of 300 microns compared to a perfect paraboloid. What is its effective surface reflectivity? At what higher frequency would you estimate that the telescope has reached its useful limit?

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1) The Lovell telescope has a diameter of 76 m. Make an estimate of its maximum gain G_{\max} at 21cm wavelength expressing your answer in dB.

2) The ratio $A_e/2k$ is a convenient parameter for specifying the sensitivity of a radio telescope using units of K/Jy i.e. the antenna temperature T_A K produced by an unpolarized point source of flux density 1 Jy ($1 \text{ Jy} = 10^{-26} \text{ W m}^{-2} \text{ Hz}^{-1}$). What is the effective collecting area A_e of a radio telescope whose sensitivity is 1 K/Jy?

DARA 2016 Nairobi Radioastronomy Workshop 3 Answers

3. $d = 20 \text{ m}$ $\nu = 600 \text{ MHz} \rightarrow \lambda = 0.5 \text{ m}$

$$\theta_{\frac{1}{2}} \approx 1.15 \left(\frac{\lambda}{d} \right) \text{ rads (general guide from notes)}$$

$$\approx 1.15 \left(\frac{0.5}{20} \right) \times \frac{180}{\pi} \text{ degrees}$$

$$\approx \boxed{1.64^\circ}$$

4. Rayleigh distance $R_{\text{Ray}} \sim 2d^2/\lambda$ $d = 100 \text{ m}$

$$R_{\text{Ray}} = 2 \times 10^4 / 10^{-2}$$

$$= 2 \times 10^6 \text{ m} = \boxed{2000 \text{ km!}}$$

$$\left\{ \begin{array}{l} \lambda = 0.01 \text{ m} \\ \nu = 30 \text{ GHz} \end{array} \right.$$

This is well outside the atmosphere! This calculation will become relevant later in the course when we deal with observations through the atmosphere.

5. Ruze formula: reflectivity = $\exp - [4\pi\delta/\lambda]^2$

$$\delta = \text{rms surface error} = 300 \mu = 0.3 \text{ mm}$$

$$\delta/\lambda = 0.3/10 = 0.03 \quad (\lambda = 10 \text{ mm})$$

$$\rightarrow \text{reflectivity} = e^{- (4\pi \cdot 0.03)^2} = \boxed{0.86}$$

Useful limit (arbitrary) when reflectivity < 0.5

$$0.5 = \exp - [4\pi\delta/\lambda]^2 \rightarrow 4\pi\delta/\lambda = 0.693$$

$$\rightarrow \delta/\lambda = 0.066 \rightarrow \lambda = \left(\frac{0.066}{0.3} \right) = 4.5 \text{ mm} = \boxed{67 \text{ GHz}}$$



1. $D = 76\text{m}$ $G_{\text{ram}} = 4\pi/\Omega_A$ $A_e \Omega_A = \lambda^2$ ($\lambda = 0.21\text{m}$)

$$A_e = \left(\frac{\pi \times 76^2}{4}\right) \times 0.6 = 2722\text{m}^2$$

\uparrow A_{geom} \nwarrow typical aperture efficiency
- something to know!

$$\Omega_A = 0.21^2 / 2722 = 1.62 \times 10^{-5} \text{rad}^2 \text{ (srad)}$$

$$\rightarrow G = 4\pi / 1.62 \times 10^{-5} = \boxed{775603 \equiv 58.9 \text{ dB}}$$

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1) $A_e / 2k \equiv$ sensitivity parameter for antenna temp.

(Full equation is $T_A = S A_e / 2k$ $S =$ flux density)

• $\therefore 1 = (10^{-26} A_e) / 2.76 \times 10^{-23}$ for 1 Jy source

$$\boxed{A_e = 2760 \text{ m}^2}$$
 (lesson: need to remember the factor 10^{-26} for Jy)

