Astro731 - Radio Astronomy

8 Lecture 8: Antennas II

8.1 In previous lectures, we discussed

1. power received: $P_r = S_\nu \Delta\nu A_0$ (where A_0 is the "collecting area" of the telescope)

8.2 Antenna Illumination and Aperture Efficiency .

8.2.1 Antenna Illumination and Optics

- Goal: maintain plane parallel E-wave.

  (Examples of optics are shown by a slide show)

- **aperture efficiency** η_A: a radio telescope is lossy so that $A_0 \leq A_G$, where $A_G = \frac{4\pi D^2}{4}$ is the geometric area of a telescope. Then, the aperture efficiency is defined as

$$\eta_A = \frac{A_0}{A_G} = \frac{|\int E dS|^2}{A_G \int E^2 dS} \tag{8-1}$$

Aperture efficiency depends on several different terms:

$$\eta_A = \eta_{sf} \times \eta_{bl} \times \eta_{sp} \times \eta_{tap} \tag{8-2}$$

where

$$\begin{aligned} \eta_{sf} &= \text{surface efficiency} \\ \eta_{bl} &= \text{blockage efficiency} \\ \eta_{sp} &= \text{spillover efficiency} \\ \eta_{tap} &= \text{illumination taper efficiency} \end{aligned}$$

8.2.2 Surface Efficiency η_{sf} .

Surface deviation (tolerance) ϵ leads to a phase error

$$\delta = 4\pi \frac{\epsilon}{\lambda}$$

Given the illumination function $g(x) = g_o(x) e^{i\delta(x)}$, the gain is

$$G = \frac{4\pi}{\lambda^2} \frac{|\int\int g_o(x) e^{i(kx - \delta(x))} dS|^2}{\int\int g_0^2(x) dS}$$

Taylor expand: $e^{i\delta} = 1 + i\delta - \frac{1}{2}\delta^2 + ...$

Then, $\frac{G}{G_0} = 1 + \frac{\int\int g_0(x)\delta(x)dS}{\int\int g_0^2(x)dS} - \frac{1}{2}\frac{\int\int g_0(x)\delta^2(x)dS}{\int\int g_0^2(x)dS} \simeq 1 - \bar{\delta}^2$

A more sophisticated calculation by Ruze (1952) shows that $\eta_{sf} \simeq e^{-\bar{\delta}^2}$ ("Ruze formula").

Example: the target $\epsilon = 70$ micron for the LMT. At 1100 micron,

$$\eta_{sf} = exp(-(4\pi(70)/(1100))^2) \simeq 0.53$$

8.2.3 Blockage Efficiency η_{bl} .

- central blockage by the secondary
- plane wave blockage by the quad pods or struts
- spherical wave blockage by the quad pods and struts

$$\eta_{bl} = [1 - \frac{effective\ area\ blocked}{total\ area}]^2 \tag{8-3}$$

- typically, η_{bl} = 0.8-0.9
- blockage also changes the total power pattern

8.2.4 Spillover Efficiency η_{sp} .

- fraction of power radiated by the feed that is intercepted by the subreflector

$$\eta_{sp} = \frac{\int_0^{2\pi}\int_0^{\theta_R} P(\theta,\phi) sin\theta d\theta d\phi}{\int_0^{2\pi}\int_0^{\pi} P(\theta,\phi) sin\theta d\theta d\phi} \tag{8-4}$$

- typically, $\eta_{sp} \sim 0.9$

8.2.5 Illumination Taper Efficiency η_{tap} .

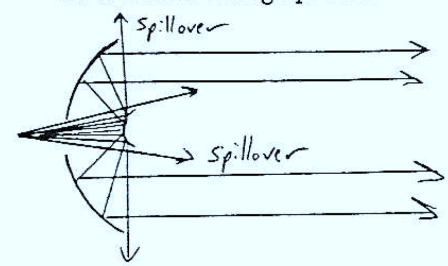
- loss in collecting area due to under illumination of the outer parts of the primary reflector

- $\eta_{tap} = 1$ if uniformly illuminated, but also a large spillover loss!

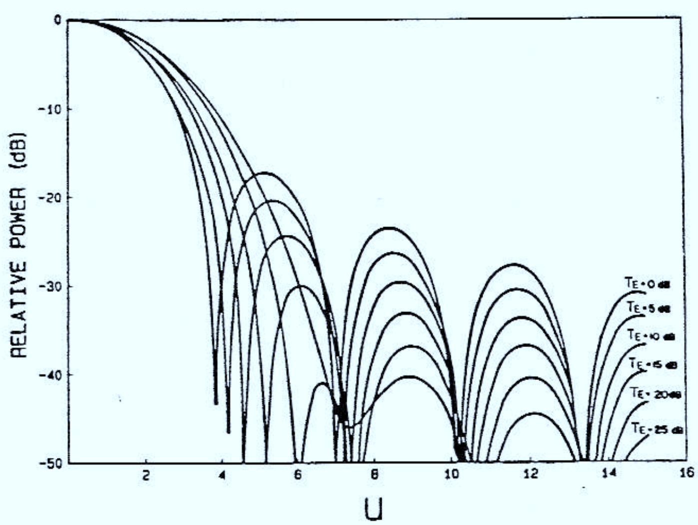
  → Shape the secondary to improve illumination and optimize spillover

- typically, $\eta_{sp} \sim 0.9$

Schematic Showing Spillover



Far–Field Pattern as a Function of Edge Taper



The Taper and Spillover Efficiencies as a Function of Edge Taper