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Lecture Notes 1970

Filled-aperture Radio Telescopes

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1. Deal only with filled-aperture instruments; i.e., those where the gain and beamwidth are both directly determined by the size of the illuminated aperture. Best example--the parabolic reflector antenna.

2. Main Characteristics:

(a) Gain $\propto \dfrac{\text{Aperture area}}{\lambda^2}$

(b) HPBW $\propto \dfrac{\lambda}{\text{Aperture size}}$

Describe the need for high gain and small beamwidth.

Note that these factors are closely connected for filled aperture antennas and their disconnection in aperture synthesis, for example, is an important advantage.

High Gain = High collecting area = larger signals from small diameter sources.

Define A_{eff} = Effective collecting area = area of uniformly illuminated aperture which collects the same energy. $\eta = A_{eff}/A \approx 60\%$.

What determines gain and A_{eff}? Size and illumination or, for short wavelengths, the surface accuracy. Minor factors such as aperture blocking.

Size

A_{eff} for NRAO dishes:

	A	A_{eff}
140-foot	1430 sq. m.	855 sq. m.
300-foot	6550 sq. m.	3930 sq. m.

Illumination

Describe typical primary feed patterns--show edge taper--refer to spill-over and unwanted radiation. Brief comments on the attempts to increase η and the side effects on beam-shape and spill-over.

The Antenna Pattern

Describe what it is and how it may be measured.

Main beam shape - described by HPBW - for a practical dish:

$$HPBW = 1.20\ \lambda/D\ \text{(radians)}$$

For a uniformly illuminated dish

$$HPBW = 1.02\ \lambda/D$$

For 140'

λ	21 cm	10 cm	3 cm
HPBW	20.3'	9.7'	2.9'

Actual main beam shape is closely Gaussian.

Side-lobes. Near-in sidelobes are similar to aperture diffraction pattern. Far-out sidelobes are confused - describe effects. Mention difficulties which result from the more distant sidelobes - interference, T_A rises due to ground - errors in maps - H for example.

Effects of surface irregularities

$$G/G_o \simeq 1 - \overline{\delta^2}$$

where $\overline{\delta^2}$ is the mean square phase error in radians. For a dish with an RMS surface accuracy of $\lambda/16$, the RMS phase error is $4\pi/16$ (twice the surface error), so

$$G/G_o = 1 - \frac{\pi}{4}^2 \simeq 0.4$$

Thus RMS surface accuracy should be better than $\lambda/16$.

Effects also on sidelobes can be important.

Example 300-foot (with original surface)

λ	RMS	Measured η_{eff}
40 cm	$\sim$1 cm	0.59
21.4 cm	$\sim$1 cm	0.40

Slides 1 and 2 show the beam distortion due to the surface irregularities.

3. Illustrate some of the further points in radio telescopes by describing examples.

(a) Jodrell Bank 250-foot. ($\sim$1954-59)

Alt-az mounting. Wheel and track.

Focal plane - f/D = 0.25.

Solid surface - but λ_{min} > 21 cm

(b) CSIRO 210-foot. ($\sim$1956-61)

Alt-az mounting - tower - limited elevation coverage

f/D = 0.41

Mesh surface $\lambda_{min} \sim 6$ cm

Pointing precision by a "master equatorial" telescope.

Briefly discuss coordinate conversion systems.

(c) NRAO 300-foot. (1961-62)

Transit telescope - limited elevation coverage

f/D = 0.427 (true for all Green Bank telescopes)

Limitations due to transit system - weighed against low telescope cost.

Partially offset by use of traveling feed.

Feed support and cabin replaced - new surface now being installed.

Original λ_{min} = 21 cm

New λ_{min} = 10 or even 6 cm

(d) NRAO 140-foot. (1957-63)

Largest ever equatorially mounted telescope.

Solid surface. λ_{min} (design) 3 cm

λ_{min} (used) to 1.9 cm.

If time permits describe some of the design and erection difficulties encountered.

(e) Haystack, MIT Lincoln Lab. (1958-62)

Alt-az in a space-frame radome.

Discuss briefly the pros and cons of use of radome:

For	Against
Telescope lighter	Absorption
Drive and control easier	Scattering
Thermal effects more predictable	Long wave limit

The cost is still being discussed.

One of the first examples of computer-controlled telescope.

(f) NRAO 36-foot on Kitt Peak. (1965-67)

Alt-az in an astrodome.

λ_{min} certainly 3.5 mm, has been used at 1 mm.

Computer control.

(g) U. of Illinois - cylindrical paraboloid

First hole-in-ground telescope.

Transit only - fixed frequency.

(h) Arecibo - Cornell University.

First large spherical reflector.

Brief description of the feed difficulties and advantages.

Results of recent 300 MHz feed.

(j) Kraus type reflectors.

Transit - elliptical beam - but cheap and quite good tracking by moving the feed.

(k) Horn antennas.

The Horn paraboloid (Bell Labs)

The NRAO Calibration Horn.

4. What of the future?

The MPIfR 100-meter

Lovell's 400-foot

NEROC 440-foot

NRAO 65-meter (213-foot).