1983 LECTURE NOTES

MILLIMETER WAVELENGTH RADIO TELESCOPES

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1. Deal only with single reflector antennas*. There are some interferometers working at wavelengths of a few millimeters, but these have not yet contributed much to the science.

2. Main Characteristics of a Reflector Antenna

(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 beam width.

Note that these factors are directly 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. $\eta = A_{eff}/A \simeq 60\%$ in practice.

What determines gain and A_{eff}? Size, illumination, and the reflector surface accuracy. Lesser factors are aperture blocking and, in dual reflector antennas, the reflector shapes.

* A very good (but detailed) review article, "High Efficiency Microwave Reflector Antennas," by Clarricoats & Poulton has appeared in Proc. IEEE, 65, 1470-1504, 1977.

3. Some Existing Millimeter-Wavelength Telescopes

[This is an incomplete list.]

Telescope	Location	Size	Built	λ_{min}
Aerospace	El Segundo	4.6 m	1963	1.2 mm
Univ. Texas	Mt. Locke	4.9 m	1963	1.6 mm
NRAO	Kitt Peak	12.0 m*	1965/1983	1.2 mm
CRAAM	Itapetinga	13.7 m	1971	6.0 mm
5-Colleges	Amherst	13.7 m	1976	2.5 mm
Chalmers	Rao, Sweden	20.0 m	1976	3.0 mm
Bell Labs	Crawford Hill	7.0 m	1977	1.6 mm

* The original telescope has been rebuilt.

References: Chalmers. Sky and Telescope, 52, 240-242, Oct. 1976.
BTL. Bell Syst. Tech. J., 57, 1257-1288, 1978.

4. Illumination

Describe typical primary feed patterns--show edge taper--refer to spillover and unwanted radiation. Brief comments on the attempts to increase η and the side effects on beam shape and spillover. Advantages of two-reflector systems. Use of shaped reflector systems.

5. The Antenna Pattern

Describe what it is and how it may be measured.

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

$$\text{HPBW} = 1.4\ \lambda/D\ \text{(radians)}$$

For example, the HPBW of the 12 meter antenna at 1.2 mm wavelength is 29 arcseconds.

6. Effects of Surface Irregularities

$$G/G_o = \exp - \left(\frac{4\pi\sigma}{\lambda}\right)^2 ,$$

where σ is the RMS surface accuracy and λ the wavelength. For a dish with an RMS surface accuracy of $\lambda/16$,

$$G/G_o = 0.54 ,$$

and this loss of gain by a factor of about 2 is significant. Note that the above expression is true for random irregularities. If the irregularities have a pattern, no simple theory describes the effect on the gain.

7. The Importance of Pointing Accuracy

Not only must a good millimeter-wavelength telescope have a precise reflector surface, it must also be capable of being pointed to the correct place in the sky and either tracked to follow that place or scanned and tracked in a precisely controlled way around the required point in the sky.

Pointing accuracy should be at least as good as 1/10 x HPBW, i.e., the 12 meter at 1.2 mm should point to 3 arcseconds or better. This sort of accuracy requires calibration and a good antenna design.

The main detriments to good pointing are the effects of wind and temperature. Discuss briefly the pros and cons of radomes, astrodomes, and open-air operation.

<u>A radome is good because</u>: Telescope lighter.

Drive and control easier.

Thermal effects more predictable, but not eliminated.

<u>But bad because</u>: Absorption--leads to a shortwave limit.

Scattering.

Long wave limit.

An astrodome is better than a radome but can be much more expensive to build.

8. The Reflector Surface

Describe briefly ways of making and measuring precise reflector surfaces.

The homology principle.

Machined surfaces.

Measuring methods.

9. New Telescopes Now in Construction or Operation

The IRAM 30 meter telescope.

The UK 15 meter telescope.

The Japanese 45 meter telescope and array.

The French array.