GBT Memo No. 1

NATIONAL RADIO ASTRONOMY OBSERVATORY
GREEN BANK, WV

To: P. Vanden Bout
J. Condon
L. D'Addario
D. Emerson
R. Fisher
D. Heeschen
D. Hogg
R. Brown
L. King
P. Napier
R. Norrod
J. Payne
G. Seielstad
A. Thompson

Following are view-graphs that will be discussed by R. Norrod in GBT Specification Working Group Meeting of 7/13/89.

R. Norrod
July 13, 1989

HANDBOOK OF ANTENNA DESIGN, VOL. I, Rudge, et al.

1

- amplitude and phase control of the aperture illumination by subreflector shaping
- spillover past the subreflector is directed toward a cold sky
- low spillover past the paraboloid toward the ground for high elevation angles
- large depth of focus and field of view.

Some disadvantages are also apparent:

- greater blockage, particularly in small antennas (less than 100 wavelength apertures)
- higher sidelobes near the main beam
- not readily adaptable to use of poorly directional, frequency independent feeds feeds

Given D =
F/D =
Freq. =

(1) Hyperboloid Diameter

For Minimum Blockage

$d = \sqrt{k \lambda F} \approx$

* k =

use d =

(2) Hyperboloid Focal Length

$f = \frac{d}{2} (\text{ctn}\ a + \text{ctn}\ \phi_o)$

$\phi_o = 2 \tan^{-1} \frac{D}{4F} =$

$a =$ ° (From Feed Design)

f =

(3) Cassegrain Magnification

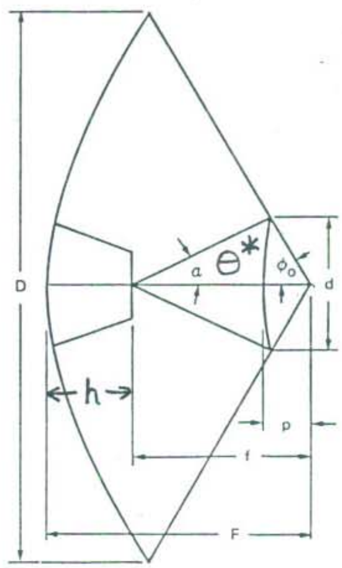
$M = \frac{D}{4F}\ \text{ctn}\ \frac{a}{2} =$

(4) Hyperboloid Eccentricity

$e = \frac{M+1}{M-1} =$

(5) Hyperboloid Location

$p = \frac{f}{2} \left(\frac{e-1}{e}\right) =$



D = Paraboloid Diameter
F = Paraboloid Focal Length
ϕ_o = Paraboloid Half Angle

d = Hyperboloid Diameter
f = Hyperboloid Focal Length
a = Hyperboloid Half Angle

M = Hyperboloid Magnification
e = Hyperboloid Eccentricity
p = Hyperboloid Location

λ = Free space wavelength
k = Feed beamwidth constant

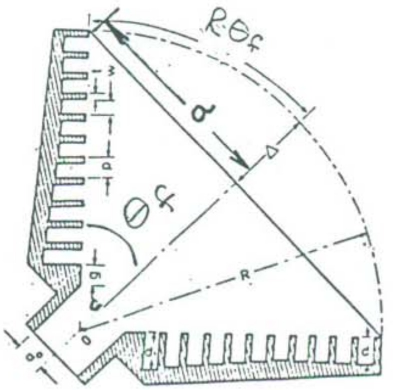
Fig. 3.33 *Determination of Cassegrain geometry*

* "k = 2 for average feed with 10 dB taper."

FIGURE 1

Cassegrain Optics Design

Figures taken from Thomas, AP-26, p. 367f.



$$k \equiv \frac{2\pi}{\lambda}$$

θ^* = Subtended half angle of reflector.
Narrowband ($\Delta \leq 0.4$)
Wideband ($\Delta \geq 0.75$)

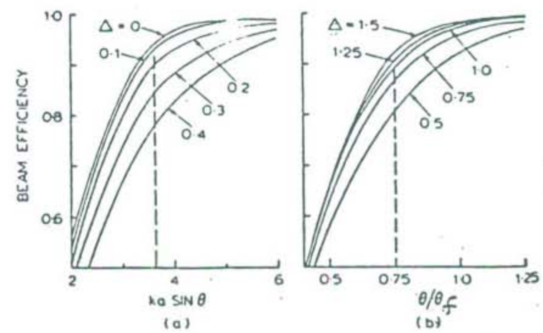


Fig. 4. Beam efficiencies for (a) narrow-band and (b) wide-band horns. Dashed line in both cases indicates horn parameters and beam efficiencies at −10-dB level of radiation patterns.

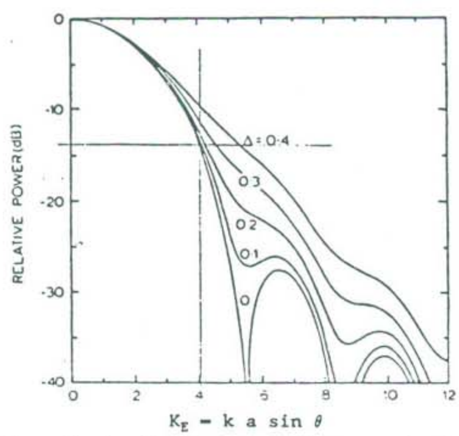


Fig. 2. Normalized radiation patterns for narrow-band corrugated horns where θ is radiation angle relative to axial direction.

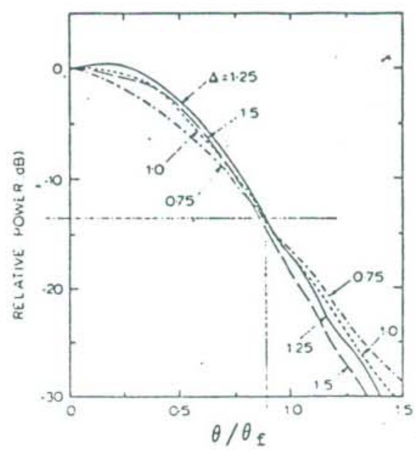


Fig. 6. Normalized radiation patterns for wide-band corrugated horns with $\theta_0 < 70°$.

"Narrowband"

1) Select $\Delta \leq 0.4$
2) Select K_E from Fig. 2 for desired edge taper--
   e.g., $K_E = 4$ for ~ 13 dB.
   Calculate:

$$a/\lambda = \frac{K_E}{2\pi \sin \theta^*}$$

3) From geometry,

$$\theta_f = 2 \tan^{-1} \left(\frac{\Delta\lambda}{a}\right)$$

and

$$\frac{R}{\lambda} = \frac{a}{\lambda \sin \theta_f}$$

"Wideband"

1) Select $\Delta \geq 0.75$
2) Select θ^*/θ_f from Fig. 6 for desired edge taper. From this calculate θ_f.

3) Then

$$a/\lambda = \frac{\Delta}{\tan\left(\frac{\theta_f}{2}\right)}$$

and

$$R/\lambda = \frac{a}{\lambda \sin \theta_f}$$

FIGURE 2
Corrugated Horns

Chronology of Proposed Designs

July 12, 1989

Design 1: Technical Study Group Report (NLSRT #51) 4/18/89

F/D = 0.35 d = 7 m h = 3.8 m (12.6')

Theta * = 6.66

Wide-Band Feed : Dia/Lambda = 21; Length/Lambda = 71
Narrow-Band Feed: Dia/Lambda = 11; Length/Lambda = 64

Implications: Prime focus may be difficult; Fairly large feeds.

Design 2: Draft GBT Proposal (ca 5/15/89, unpublished)

F/D = 0.30 d = 10 m h = 5 m (16.4')

Theta * = 11.73

Wide-Band Feed : Dia/Lambda = 12; Length/Lambda = 23
Narrow-Band Feed: Dia/Lambda = 6; Length/Lambda = 21

Implications: Prime focus difficult; Fairly small feeds.

Design 3: GBT Proposal 6/15/89

F/D = 0.42 d = 8 m h = 0 m

Theta * = 5.74

Wide-Band Feed : Dia/Lambda = 24; Length/Lambda = 96
Narrow-Band Feed: Dia/Lambda = 13; Length/Lambda = 86

Implications: Cassegrain pushed to 3 - 5 GHz. Feeds large.

Design 4: Fisher-Napier-Thompson Small Sub-reflector

F/D = 0.42 d = 4 m h = 5 m

Theta * = 3.19

Wide-Band Feed : Dia/Lambda = 43; Length/Lambda = 310
Narrow-Band Feed: Dia/Lambda = 23; Length/Lambda = 278

Implications: Cassegrain difficult. Many feeds required.

Other examples in R. Norrod report of 7/12/89 to be released as NLSRT memo.

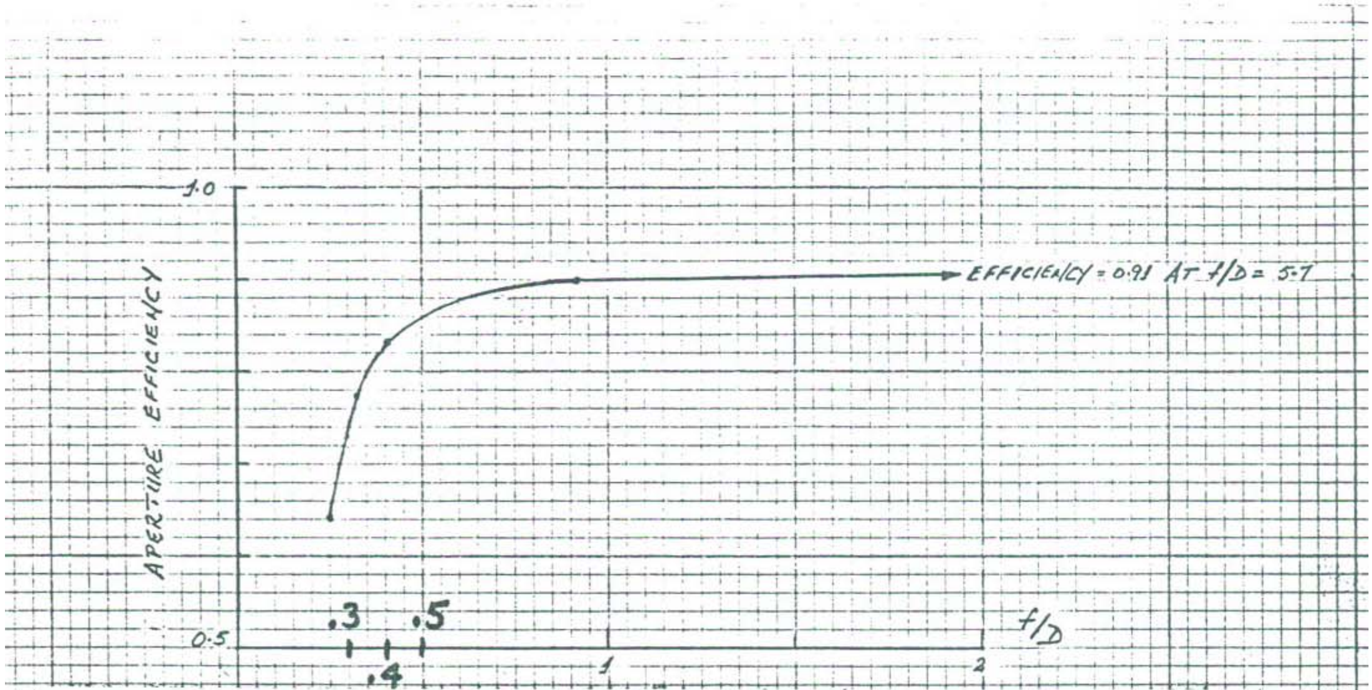
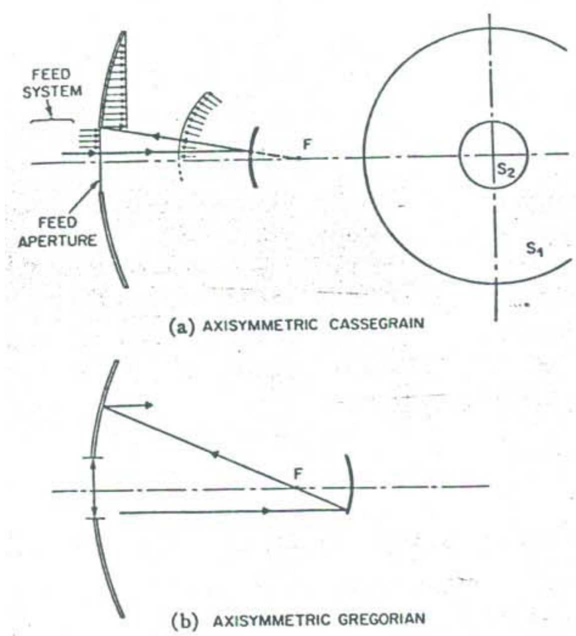


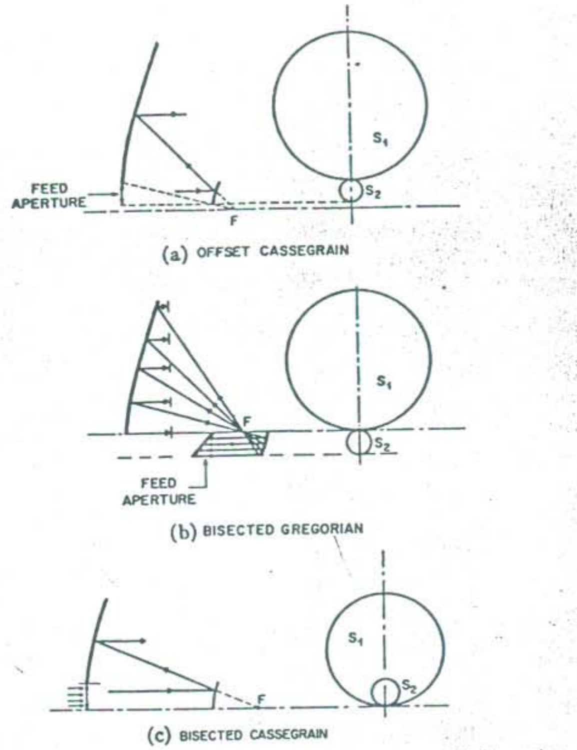
Fig. 1. Theoretical aperture efficiency of a paraboloid reflector antenna with a dual hybrid-mode feed at the prime focus. Data are taken from Fig. 13 of Minnett and Thomas (1968).

See NLSRT Memos #59 (Fisher) and #62 (Thompson) for discussion



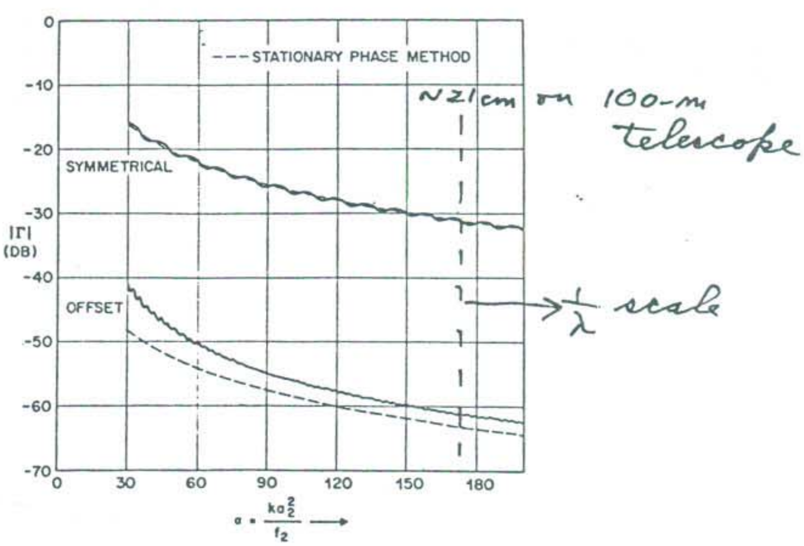
Conventional axially symmetrical antennas of Cassegrainian and Gregorian type.

Figure 4-1



(a) Cassegrainian configuration without blockage. (b) Gregorian configuration without blockage. (c) Bisected Cassegrainian configuration with some blockage.

Figure 4-2



Reflection coefficients for cases of Figs. 1 and 2(c), assuming an illumination taper of 13 dB at edge of subreflector.

Figure 4-3

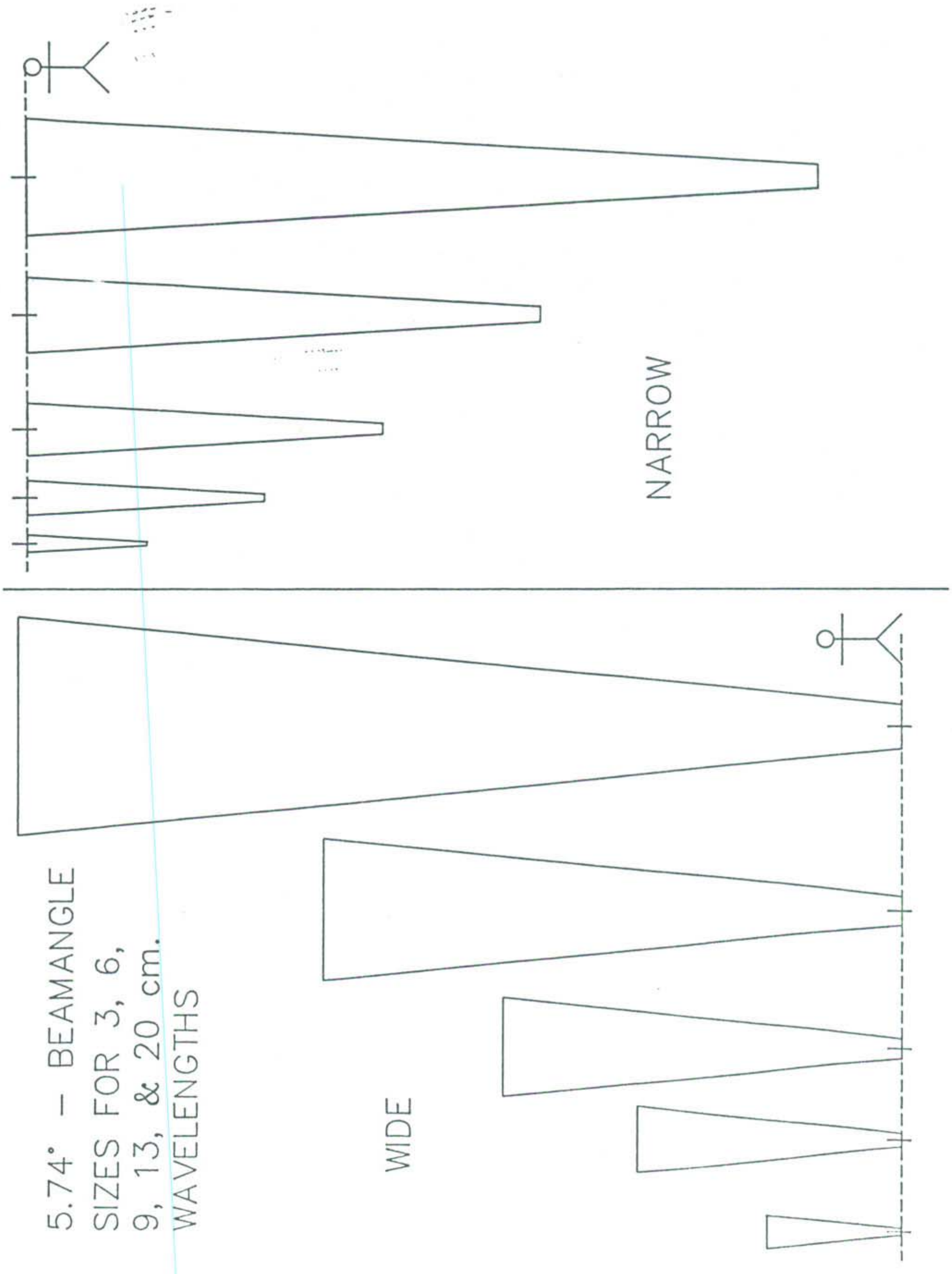

5.74° – BEAMANGLE
SIZES FOR 3, 6,
9, 13, & 20 cm.
WAVELENGTHS
NARROW
WIDE

FIGURE 6

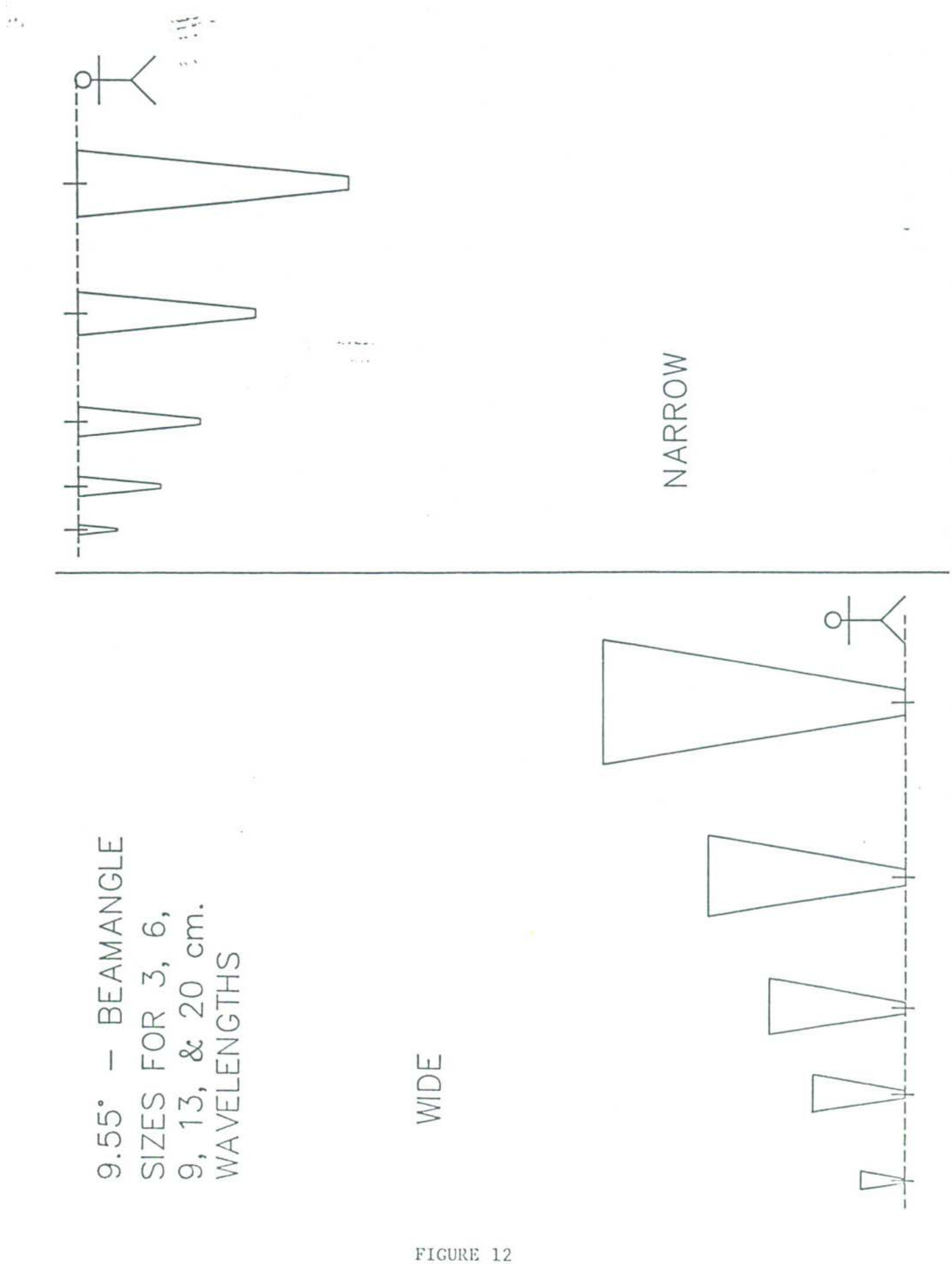

9.55° – BEAMANGLE
SIZES FOR 3, 6,
9, 13, & 20 cm.
WAVELENGTHS
WIDE
NARROW

FIGURE 12

7

MEMBERS
Optics Engineering Group

M. Balister

C. Brockway

J. Coe

L. D'Addario

R. Fisher

L. King

J. Lamb

P. Napier

J. Payne

S. Srikanth

A. Thompson

R. Norrod (chair)

GBT OPTICS DESIGN

July 12, 1989

Working Assumptions:

1) Attempt to maximize sensitivity over entire frequency range of antenna.

2) Design for nearly continuous frequency coverage from about 100 MHz to at least 45 GHz.

3) Must have capability to have multiple receivers on-line and "rapid" (automated if possible) switchover. Must include a "high use" weather independent frequency.

4) Must support VLBA observing to extent possible.

DRAFT AGENDA
Optics Engineering Group
Meeting 7/14/89

1) Goals
   - Short-term : Generate report with recommended optics configuration(s) for symmetrical antenna. Finish by Aug 10.

   - Long-term : ??

2) Fundamental Questions
   - F/D ?
   - Subreflector Diameter?
   - Location of secondary focus relative to vertex?
   - Receiver locations? How do we switch between receivers?
   - How do we cancel atmosphere?

3) Design Questions
   - How can we set physical limits on some of these parameters?
     - Strut blockage vs. F/D
     - Efficiency vs. F/D
     - Nutation of subreflector
     - Hiding or removal of subreflector
     - Feed diameter & length
     - Size of vertex cabin
   - Can we arrange optics to allow simultaneous observations at multiple frequencies?

4) Select a few cases to examine in detail
   - F/D = 0.3, d > 8 m
   - F/D = 0.42, d > 8 m
   - F/D = 0.42, d < 5 m
   - Design similar to 12 meter antenna optics?
   - Beam waveguides?
   - Other exotic cases?

5) Miscellaneous
   - NRAO analysis software
   - Outside expertise
   - Communications within group