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
Quasi-optical antenna design

- 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

Given

\[
\frac{D}{F_0} = \text{Freq.}
\]

(1) Hyperboloid Diameter

For Minimum Blockage
\[
d = \sqrt{k \lambda F} \approx k
\]

Use \(d = k\)

(2) Hyperboloid Focal Length

\[
f = \frac{d}{2} \left(c + \cot \alpha + \cot \phi_0\right)
\]

\[
\phi_0 = 2 \tan^{-1} \frac{D}{4F} = \alpha = 0 \text{ (From Feed Design)}
\]

(3) Cassegrain Magnification

\[
M = \frac{D}{2F} \cot \frac{\alpha}{2}
\]

(4) Hyperboloid Eccentricity

\[
e = \frac{M + 1}{M - 1}
\]

(5) Hyperboloid Location

\[
p = \frac{f}{2} \left(\frac{M - 1}{e}\right)
\]

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.

\[ k = \frac{2\pi}{\lambda} \]

**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 \( \theta^*/\theta_f \) from Fig. 6 for desired edge taper.

From this calculate \( \theta_f \).

3) Then

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

and

\[ \frac{R}{\lambda} = \frac{a}{\lambda \sin \theta_f} \]

**Fig. 2.** Normalized radiation patterns for narrow-band corrugated horns where \( \theta \) is radiation angle relative to axial direction.

**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.

\( \theta^* = \) Subtended half angle of reflector.

Narrowband \( (\Delta \leq 0.4) \)

Wideband \( (\Delta \geq 0.75) \)
Chronology of Proposed Designs

July 12, 1989

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

F/D = 0.35  \( d = 7 \text{ m} \)  \( h = 3.8 \text{ m (12.6')} \)

\( \Theta^* = 6.66 \)

Wide-Band Feed:  \( \text{Dia}/\text{Lambda} = 21; \)  \( \text{Length}/\text{Lambda} = 71 \)

Narrow-Band Feed:  \( \text{Dia}/\text{Lambda} = 11; \)  \( \text{Length}/\text{Lambda} = 64 \)

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

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**Design 2:** Draft GBT Proposal (ca 5/15/89, unpublished)

F/D = 0.30  \( d = 10 \text{ m} \)  \( h = 5 \text{ m (16.4')} \)

\( \Theta^* = 11.73 \)

Wide-Band Feed:  \( \text{Dia}/\text{Lambda} = 12; \)  \( \text{Length}/\text{Lambda} = 23 \)

Narrow-Band Feed:  \( \text{Dia}/\text{Lambda} = 6; \)  \( \text{Length}/\text{Lambda} = 21 \)

Implications:  Prime focus difficult;  Fairly small feeds.

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**Design 3:** GBT Proposal 6/15/89

F/D = 0.42  \( d = 8 \text{ m} \)  \( h = 0 \text{ m} \)

\( \Theta^* = 5.74 \)

Wide-Band Feed:  \( \text{Dia}/\text{Lambda} = 24; \)  \( \text{Length}/\text{Lambda} = 96 \)

Narrow-Band Feed:  \( \text{Dia}/\text{Lambda} = 13; \)  \( \text{Length}/\text{Lambda} = 86 \)

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

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

F/D = 0.42  \( d = 4 \text{ m} \)  \( h = 5 \text{ m} \)

\( \Theta^* = 3.19 \)

Wide-Band Feed:  \( \text{Dia}/\text{Lambda} = 43; \)  \( \text{Length}/\text{Lambda} = 310 \)

Narrow-Band Feed:  \( \text{Dia}/\text{Lambda} = 23; \)  \( \text{Length}/\text{Lambda} = 278 \)

Implications:  Cassegrain difficult.  Many feeds required.

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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) AXISYMMETRIC CASSEGRAIN

(b) AXISYMMETRIC GREGORIAN

Conventional axially symmetrical antennas of Cassegrainian and Gregorian type.

Figure 4-2

(a) OFFSET CASSEGRAIN

(b) BISECTED GREGORIAN

(c) BISECTED CASSEGRAIN

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

Figure 4-3

Reflection coefficients for cases of Figs. 1 and 2(c), assuming an illumination taper of 13 dB at edge of subreflector.
5.74° - BEAM ANGLE

SIZES FOR 3, 6, 9, 13, & 20 cm. WAVELENGTHS

FIGURE 6

WIDE

NARROW
9.55° - BEAM ANGLE
SIZES FOR 3, 6, 9, 13, & 20 cm.
WAVELENGTHS

FIGURE 12
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 online 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