OVLBI EARTH STATION PROJECT

A POSSIBLE OPTICS SCHEME FOR THE 45-FOOT ANTENNA IN GREEN BANK

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Introduction:

The frequency bands that are allocated to space research in the 7 to 18 GHz range, as noted in D'Addario's memo [1], are listed below:

Frequencies (GHz)	Direction
7.190-7.235	Uplink only
8.450-8.500	Downlink only
13.400-15.350	Both directions

It is necessary that the antenna has coincident beams in the sky at any combination of the above frequencies. In particular, the present funding is to support the following bands with good performance.

7.200 GHz :	Radioastron CW uplink, LCP.
8.472 GHz :	Radioastron CW downlink, RCP.
13.400 GHz[1]:	VSOP CW uplink, polarization TBD.
15.050 GHz :	VSOP data downlink, pol. TBD, 150 MHz bandwidth.
15.065 GHz :	Radioastron data downlink, RCP, 150 MHz bandwidth.

A preliminary design study was carried out to determine an optics scheme to support the above frequency bands that is viable within the mechanical constraints on the antenna which are as follows:

1. Central blockage at prime focus should be less than 88.5" diameter.

2. The receivers, if at secondary focus, should be located so that access to them is from below the panel surface.

3. Clear access that is available at the vertex of the antenna because of the backup structure is a circular area of 32" diameter.

Optics Scheme:

The scheme calls for an asymmetric cassegrain subreflector, two secondary focus feeds covering the 7.19-8.50 GHz (X) and 13.4-15.35 GHz (K_u)

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[1]For political reasons, the VSOP project may change this link to another frequency in this general region. Possibilities being considered range from 13.25 to 17.1 GHz. The main conclusions of this report would not be affected.

bands respectively, an ellipsoidal tertiary over the K_u-band feed and a dichroic (frequency selective surface) reflector over the X-band feed. The layout of the optics is shown in Figure 1. The asymmetric subreflector with a focal length of 185" and diameter of 79.470" places the secondary focal point in a plane 15" above the vertex of the antenna and at a distance of 13.2" off of the main reflector axis. When the subreflector is rotated about the main reflector axis, the secondary focus describes a circle of radius 13.2" about the main reflector axis. The subreflector subtends a half angle of 13.23° from the secondary focus. The X-band feed is located with its aperture in the focal plane and centered at the secondary focus, while the K_u-band feed is located diametrically across with its axis passing through the 13.2" radius circle and its aperture 5.43" above the focal plane. The axes of the two feeds are inclined at 4.08° to the antenna axis.

The ellipsoidal reflector is placed at a distance of 15.92" above the aperture of the K_u-band feed along its axis. The parameters of the ellipsoid and its location have been chosen to fulfill the following conditions:

(i) The beam reflected off the ellipsoidal reflector maintains nearly the same shape as that of the K_u-band feed.

(ii) The spillover loss past the ellipsoidal reflector is minimum.

(iii) Maximum efficiency at 15.065 GHz.

(iv) The beam from the X-band feed is not blocked by the ellipsoidal reflector.

(v) Coincident phase centers at the two frequency bands, or at least minimum separation of the two phase centers.

The beam from the ellipsoidal reflector is bounced off the dichroic reflector placed over the aperture of the X-band feed, towards the subreflector. The dichroic reflector has an array of Jerusalem crosses which are resonant at 15.065 GHz and, hence, would reflect most of the energy at K_u-band (loss < 0.2 dB). The X-band energy transmits through the dichroic reflector into the feed with minimum loss (< 0.2 dB).

Feeds:

The K_u-band feed is a wideband corrugated horn and covers the frequency band of 13.4 to 15.35 GHz. The feed has an aperture of 7.082" and the semi-flare angle is 14.8°. The phase center of the feed at 15.35 GHz is 11.4" below the aperture. The feed pattern at the edge of the subreflector is down -12 dB from the peak at 13.4 GHz and -12.9 dB at 15.35 GHz. The phase center at 15.35 GHz gets translated to a point 2.5" below the focal plane after the two reflections. For the X-band (7.19-8.5 GHz), a narrow band corrugated horn has been chosen in order to keep its phase center close to the aperture. The aperture diameter is 8.449" with a semi-flare angle of 9.11°. The feed pattern is -10 dB at 7.19 GHz and -13.5 dB at 8.50 GHz at the edge of the subreflector. The phase centers are at distances 7.67" and 8.63" below the aperture at 7.19 GHz and 8.5 GHz, respectively.

The layout of the optics including the focal length of the subreflector has been chosen so that the X-band dewar is below the interfering truss, while the K_u-band dewar is above it as seen in Figure 2. A VLBA-type dewar with minor modifications could be used. The efficiency of the system going through various optics is shown in Table I.

Conclusion:

An optics scheme at the secondary focus of the telescope seems viable with the following conditions and assumptions:

(i) Needs an asymmetric cassegrain subreflector of 79.47" diameter.

(ii) A VLBA-type dewar with modifications to accommodate the transmitter could be used.

(iii) Needs a 21.6" ellipsoidal reflector.

(iv) Needs a dichroic reflector to reflect at 15 GHz and transmit 7.19 to 8.50 GHz band. The ratio of the reflection/transmission frequencies has a minimum value of 1.75 to 1. Dichroic reflectors with ratios as low as 1.5 to 1 have been demonstrated with Jerusalem cross-type arrays [2].

(v) For VSOP frequencies, the K_u-band feed can be used without the ellipsoidal reflector, with the subreflector aimed at the K_u-band feed.

References:

[1] "Requirements for Feeds and Optics on the 45-foot Antenna in Green Bank," L. R. D'Addario, OVLBI-ES Memo No. 4, September 7, 1990.

[2] "Resonant-Grid, Quasi-Optical Diplexers," J. A. Arnaud and F. A. Pelow, *The Bell System Technical Journal*, pp. 263-283, February 1975.

TABLE I. Efficiency (η) of Optics.

		ELLIPSOIDAL REFL.	DICHROIC REFLECTOR		CASSEGRAIN OPTICS				
Freq. (GHz)	Pattern Taper at 13.2° (dB)	Spillover η	Reflection η	Transmission η	Spillover η	Taper η	Phase η	Total η	Comments
7.19	-9.98			0.977[1]	0.880	0.903	0.988	0.767	Feed with dichroic
8.50	-13.56			0.977[1]	0.924	0.834	0.980	0.738	Feed with dichroic
13.40	-12.04				0.882	0.850	1.000	0.750	Feed only
15.35	-11.49[2]	1.000	0.977[1]		0.898	0.888	0.993	0.774	Feed with ellipsoid and dichroic

[1] Assumes 0.2 dB transmission and reflection loss at dichroic reflector.

[2] The feed taper at 13.2° is -12.9 dB. After reflection off the ellipsoidal reflector, the taper is -11.49 dB.

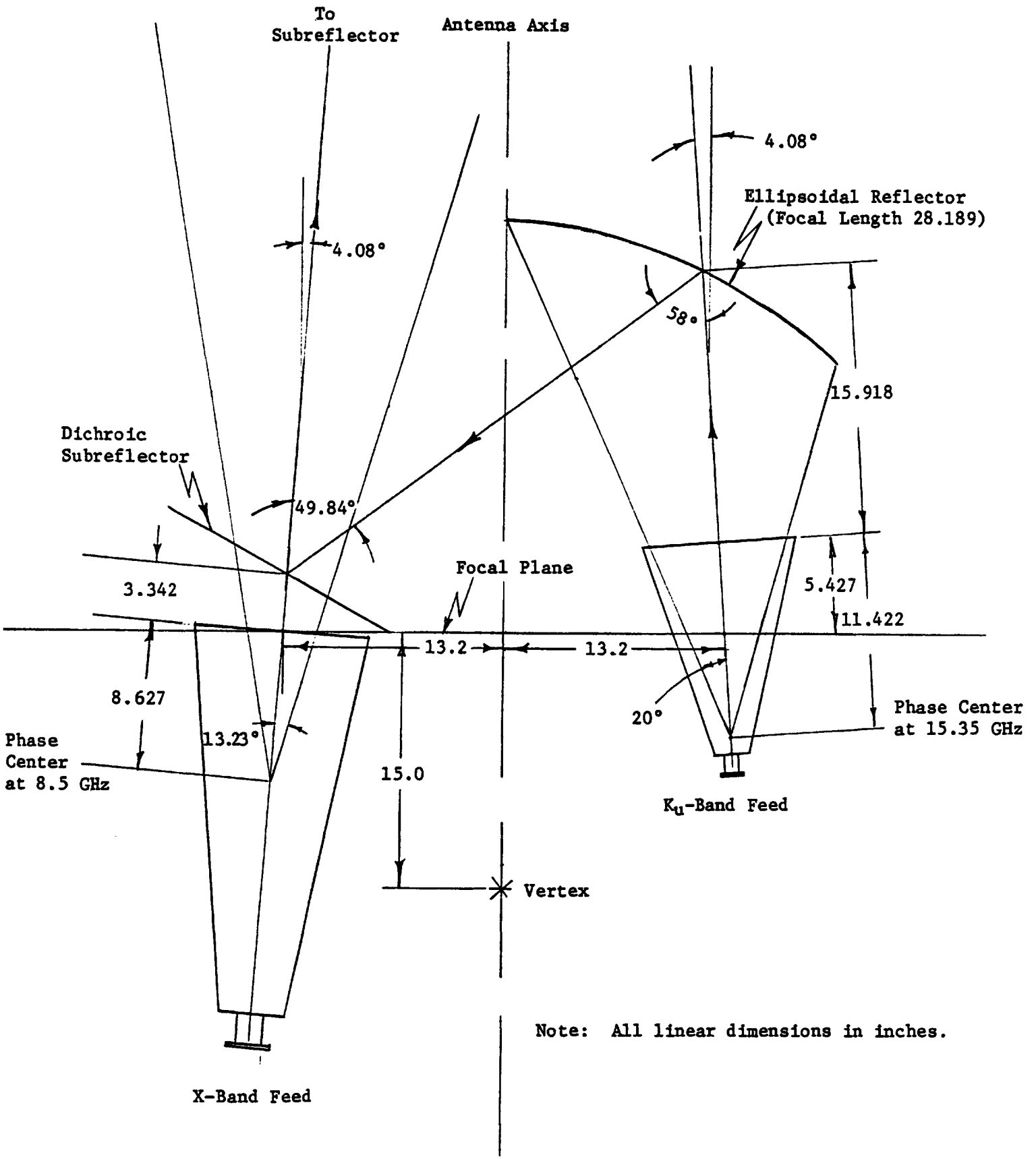
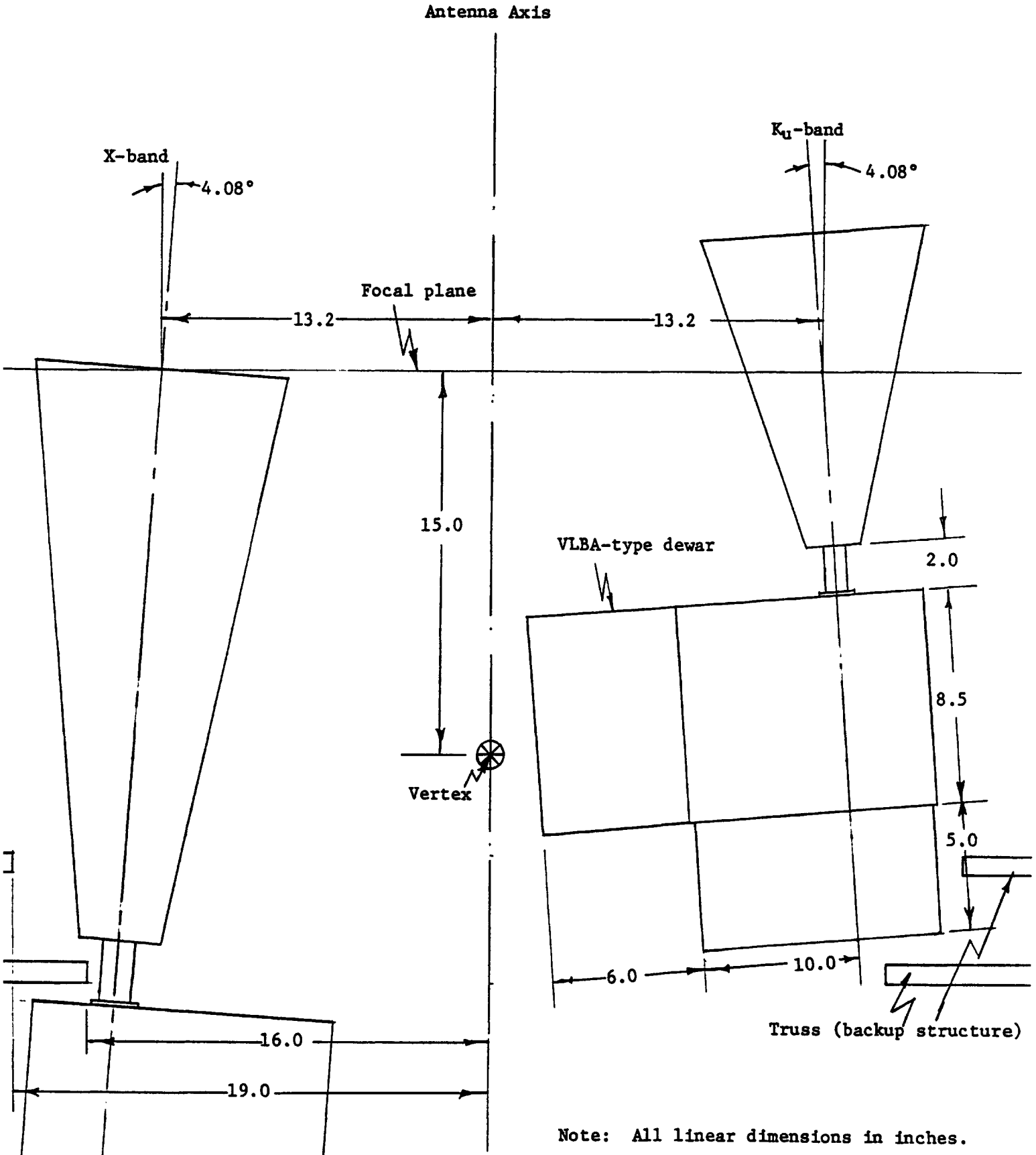


Fig. 1. Layout of optics on the 45-foot antenna.



Note: All linear dimensions in inches.

Fig. 2. Layout of front-ends.