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TITLE: Reflectors for the 140-foot Telescope Polarization Splitter

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REFLECTORS FOR THE 140-FT TELESCOPE
POLARIZATION SPLITTERS

R. Fisher

Before long, Chuck Brockway will have the second 4.7 to 26 GHz maser/upconverter receiver on the 140-foot mounted on the opposite side of the offset feed circle from its twin which has been in operation for a number of years. The second receiver will have its own set of feeds, and the two receivers are intended to be used simultaneously on orthogonal linear polarizations by splitting the telescope focal cone in two directions with polarization selective mirrors and placing the new focii on the phase centers of the separate feeds. A schematic diagram of the two-feed system is shown in Figures 1a and b.

My original concept was to use a flat reflector above each feed which would have required the wire grids to be about 8 feet across. Holding a surface tolerance of better than 300 μm (0.012") over this area would be difficult at best, so I have gone to a curved reflector refocussing geometry to reduce the required splitter size. Also, for somewhat the same size and tolerance reasons, I have elected to build two reflector/splitter systems, one above 7.5 GHz and one below. The size of the C-band feed relative to the others is shown in Figure 1c. Using two systems will require reflector changes when switching from C-band to any other band, and the hardware on top of the Cassegrain house will be more complex to provide mounts for the two sizes of reflectors and splitters. In exchange for this complexity, I think we can produce a more efficient and slightly more compact system. So far, I have worked only on the system for above 7.5 GHz.

The geometry of half of the 7.5 to 26 GHz reflector system is shown in Figure 2. This drawing is in the plane which contains the central rays for the splitter and the feed. These central rays are inclined at an angle of 6.62° to one another and at an angle of 4.69° to the telescope axis. Partly for convenience and partly to keep the effective splitter focus near the optimum position for the current subreflector the splitter is located in the plane of the original Cassegrain design phase center. The curved reflector is placed high enough above the feeds to keep the reflected convergent beam well clear of the edge of the tallest (X-band) feed.

Like a lens, the curved reflector can change the effective beamwidth of the feed. The positions of the far-field phase centers of the three feeds are a function of frequency so the potential exists for introducing an unwanted beamwidth, hence, subreflector illumination, dependence on frequency. Since the curved reflector is very much in the near field of the feed, proper near-field diffraction calculations are required, the results of which are shown in Figure 3. These calculations all assumed an ellipsoidal reflector at a fixed position above the Cassegrain house roof, and reflected far-field beamwidths were computed at each end of the frequency range of each feed using the curvature of the reflector as a variable parameter.

Figure 3 shows the field strength relative to beam center at a point 7° from the center of the beam (near the subreflector edge of 7.14°). The field strength at 7° on all of the original feed beams were within ± 0.6 dB of 10.6 dB. If we choose a constant reflector curvature in Figure 3, say the light dotted line, we see that the reflected patterns vary from 9.4 to 12.4 dB at 7° over the full band. This is a spread of ± 1.5 dB which is somewhat worse than the original design. However, if we compute the telescope aperture efficiency for these illumination extremes we find that it varies by only about 2% (relative to 100%) because of the counterbalancing effects of spillover and taper efficiency. Spillover plus scatter temperature changes by 0.5 K. The dashed lines show the ellipsoid focal lengths that would be required to keep the illumination constant, but changing the focal length is impractical. The focal length is defined as the semimajor axis of the ellipsoid.

The reflected beamwidth is not as strong a function of frequency as one would expect from the movement of the far-field phase centers because the center of curvature of the near-field phase front stays fairly close to the feed cone apex.

An unsymmetric curved reflector such as this one will cause some cross polarization in the reflected beam. A quick calculation on a reflector similar to the one proposed here shows that the level of crosspolarized power is about 31 dB below the copolar power averaged over the beam. Since the crosspolarized power is improperly reflected by the grid it will be scattered in an unwanted direction, but even if all of this spurious response lands on a 300 K absorber it will add only 0.25 K to the system temperature.

The size of the ellipsoidal reflector is determined by the fraction of power which can be allowed to spill over its edge and by the tolerable distortion of the reflected beam from edge diffraction. The former is relatively independent of frequency in this case, while the latter tends to be strongest at low frequencies so beam patterns were computed for a series of reflector sizes at 7.5 and 12.0 GHz. The reflector edge was defined by a cone whose apex was at the far-field phase center of the feed, and the reflector size was specified by the opening angle of this cone. Beam distortions are insignificant at 7.5 GHz for cone half angles equal to or greater than 17°. The spillover for this size reflector is about 0.6% at 7.5 GHz and 0.8% at 12 GHz. The cone angle is smaller (14.8°) at 12 GHz for this reflector because the phase center is deeper in the feed. The relative size of the reflector is shown in Figure 2. With 0.8% spillover we will have to be careful about leaving a relatively unobstructed path behind the ellipsoidal reflector in the forward direction so that ground radiation does not get scattered into the feed. It might be a good idea to make the reflector slightly larger than the minimum.

The effective phase centers for the reflected beams after the second reflection off the splitter are between 30 cm (7.5 GHz) and 65 cm (26 GHz) below the center of the splitter. The phase centers of the feeds are between 40 and 105 cm below the same plane, so the splitter system actually appears to have a tighter distribution of phase centers.

JRF/cjd

Attachments
Figs. 1-3

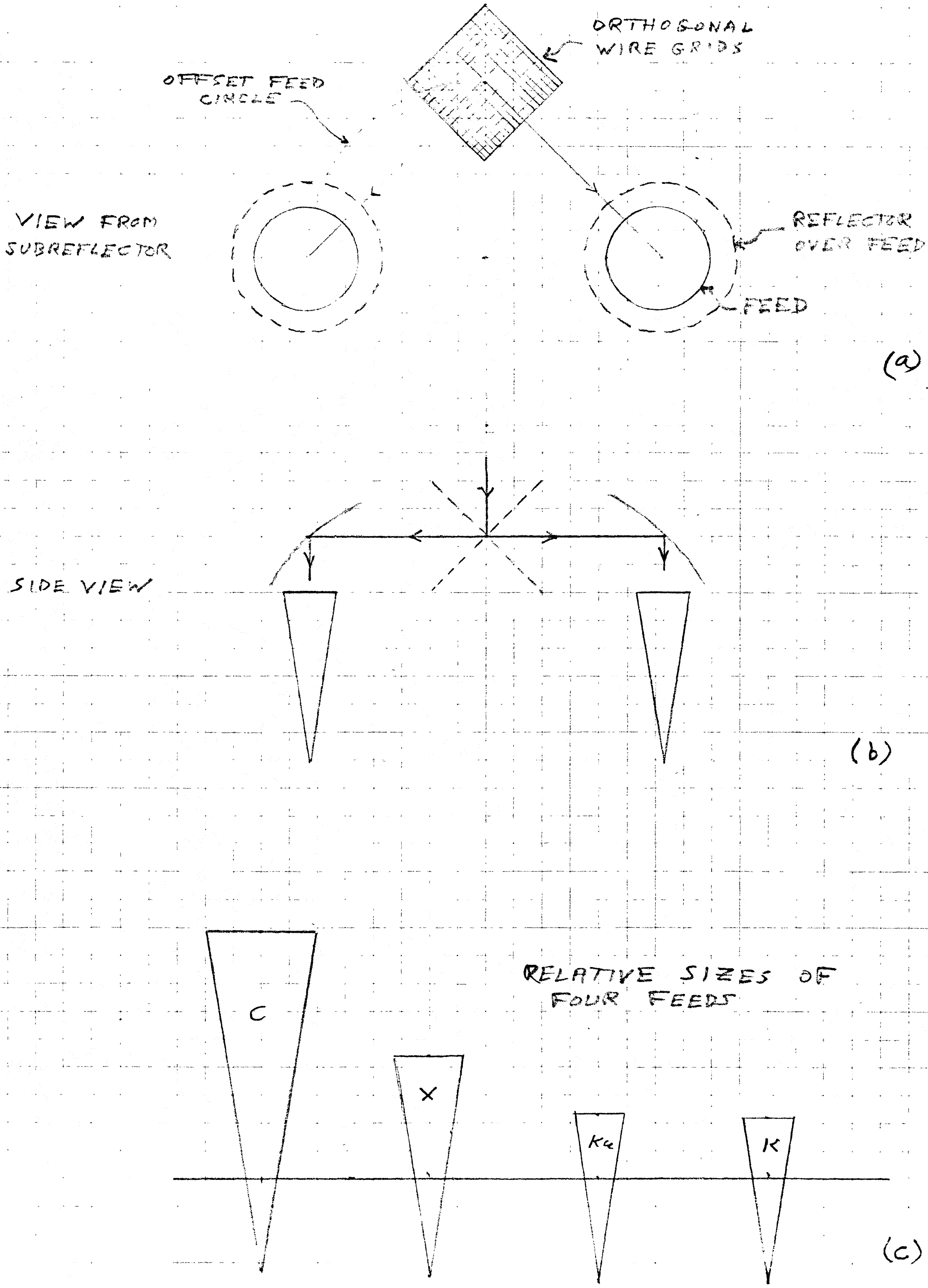
ORTHOGONAL
WIRE GRIDS
OFFSET FEED
CIRCLE
VIEW FROM
SUBREFLECTOR
REFLECTOR
OVER FEED
FEED
(a)
SIDE VIEW
(b)
RELATIVE SIZES OF
FOUR FEEDS
C
X
Ka
K
(c)

Fig. 1.

Paper in plane common to feed and splitter axes
Scale 20:1

If b = great circle angular displacement from the ellipsoid-splitter axis ⊥ the plane of paper and Φ is the azimuthal rotation around feed axis ($\Phi = 180°$ toward splitter) Then

$$\Phi = \tan^{-1}\left(\frac{\tan b}{\sin 46°}\right) + 180°$$

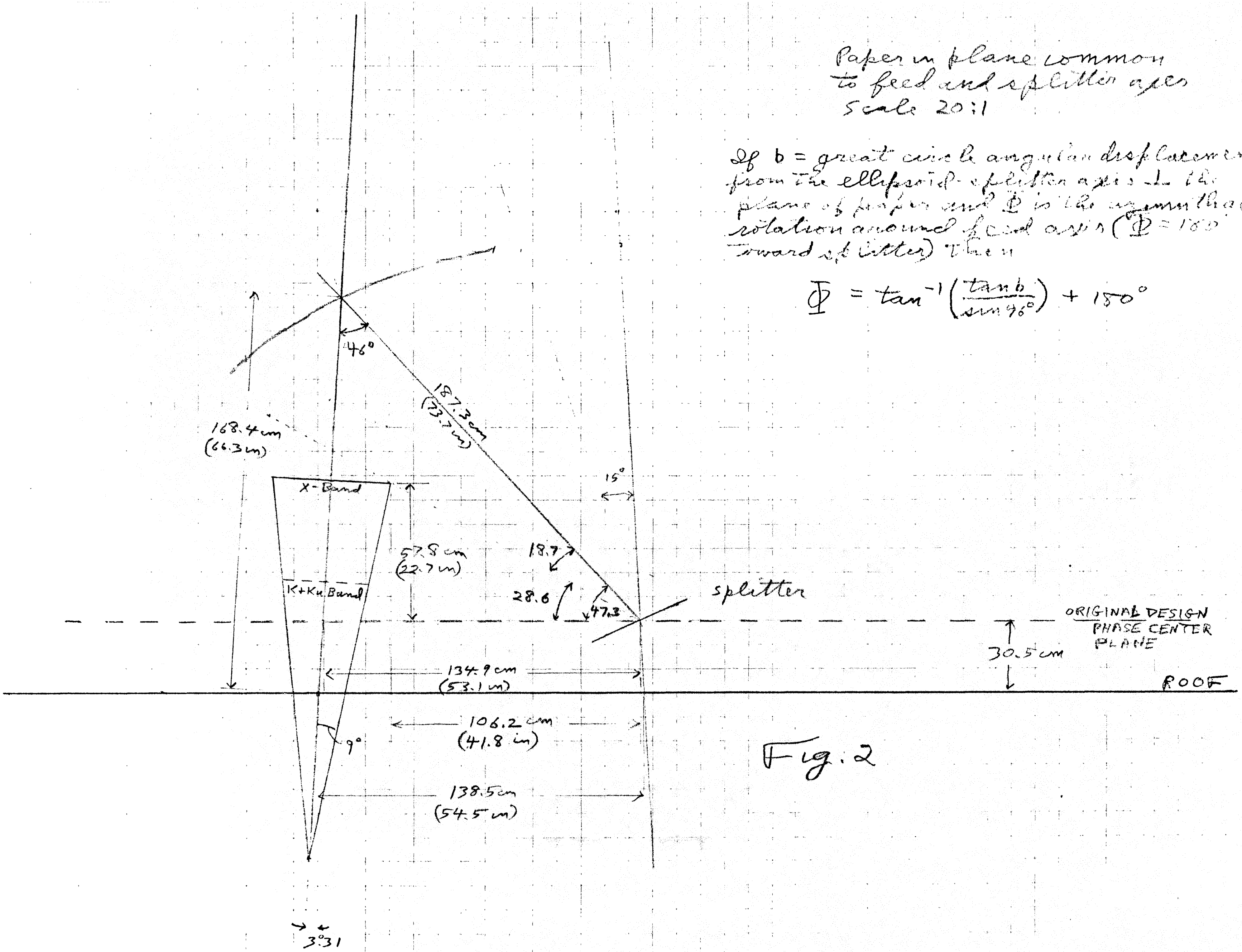

Fig. 2

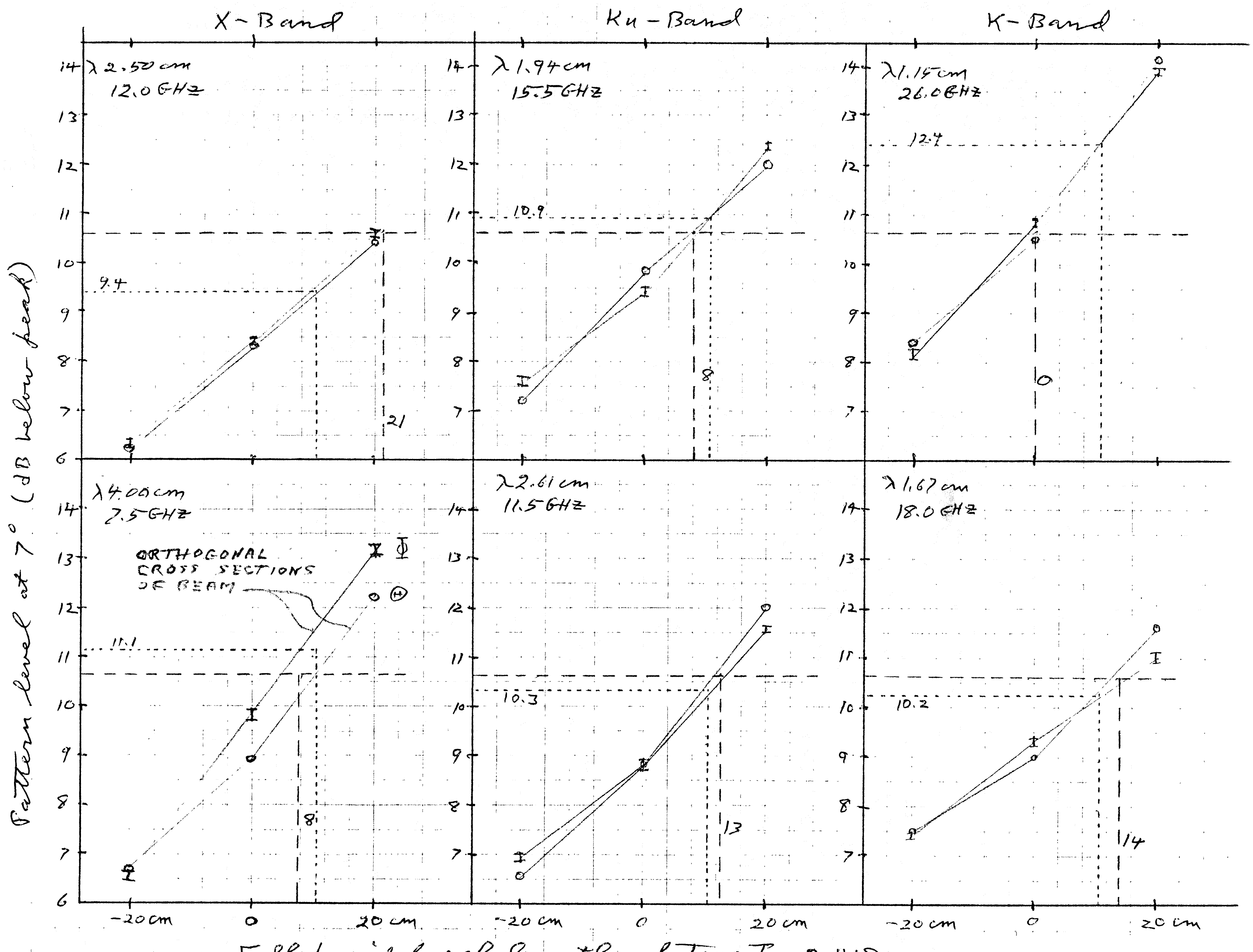
X - Band
Ku - Band
K - Band
λ 2.50 cm
12.0 GHz
λ 1.94 cm
15.5 GHz
λ 1.15 cm
26.0 GHz
λ 4.00 cm
7.5 GHz
λ 2.61 cm
11.5 GHz
λ 1.67 cm
18.0 GHz
ORTHOGONAL CROSS SECTIONS OF BEAM
9.4
21
10.9
8
12.4
0
11.1
8
10.3
13
10.2
14
Pattern level at 7° (dB below peak)
-20 cm
0
20 cm
Ellipsoid focal length relative to 2.418 m

Fig. 3.