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Aubrey, H.; Breithaupt, R.; Clarke, B.; Hazell, J.; Woods, L.

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4.97 CM AND 9.4 CM VARIABLE POLARIZATION FEEDS FOR MASER RECEIVERS AT THE ALGONQUIN RADIO OBSERVATORY

- H. AUBREY, R. BREITHAUPT, B. CLARKE, J. HAZELL, AND L. WOODS -

OTTAWA

MARCH 1970

ABSTRACT

This report describes two narrow-band low-loss feeds, built for use with maser receivers and the 150-foot antenna at the Algonquin Radio Observatory in the gregorian configuration. A choice of rotating linear or LH/RH circular polarization is provided.

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DRAWINGS

Copies of drawing Nos. DF-4-48D, -27E, -54C, -1E are available on request from The Editor, Radio and Electrical Engineering Division, National Research Council, Building M-50, Montreal Road, Ottawa 2, Ontario.

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Introduction

Both variable polarization feeds described in this report are low-loss, narrow-band components to be used with maser receivers, and consequently have the same fundamental design. They are both used at the vertex with the gregorian antenna configuration, and can be operated in either a right hand circular, a left hand circular, or a rotatable linear polarization mode.

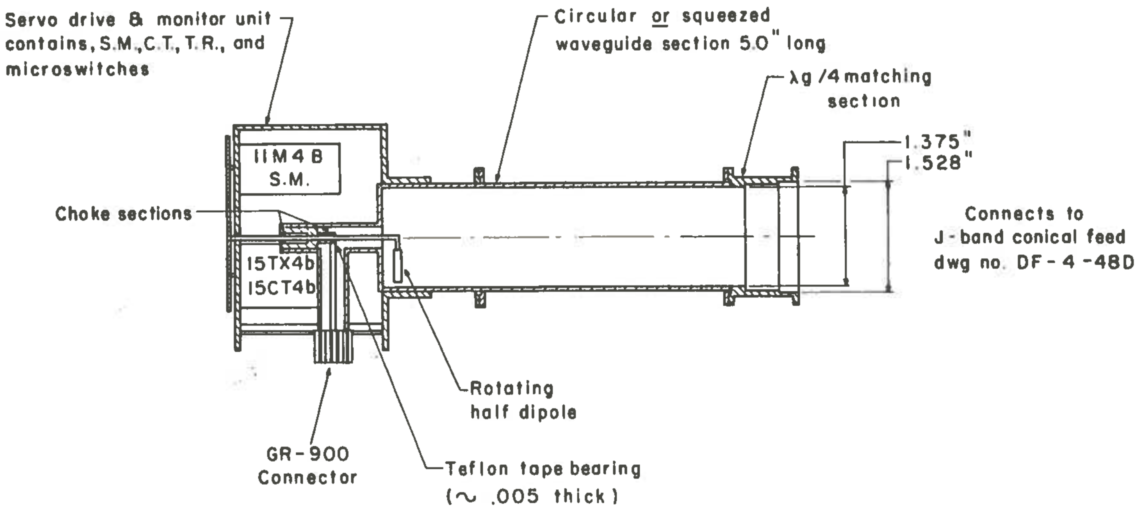

Figure 1 4.97-cm maser feed schematic diagram

Each unit contains a coaxial feed into the rear of a circular waveguide section, where the coaxial center conductor is terminated as a rotatable half-dipole as shown in the schematic of Fig. 1. The circular TE°_{11} mode thus excited then either continues as rotatable linear polarization, or is transformed into LH or RH circular polarization by the insertion of $\pi/2$ differential phase shift oriented correctly with respect to the linear polarization. The correct differential phase shift is provided by a slightly elliptical waveguide section. Differential phase shift provided in this manner has the advantage of negligible mismatch and low loss, but the bandwidth is inherently narrow, as demonstrated previously [1].

A servo unit rotates the half-dipole to provide linear polarization whose orientation is controlled from the main telescope console. A schematic diagram of the servo connections is given in Fig. 2. If the circular waveguide section is replaced by the slightly elliptical section provided, and this is oriented as marked, then either RH or LH circularly polarized energy is received by rotating the polarizer shaft to the correct

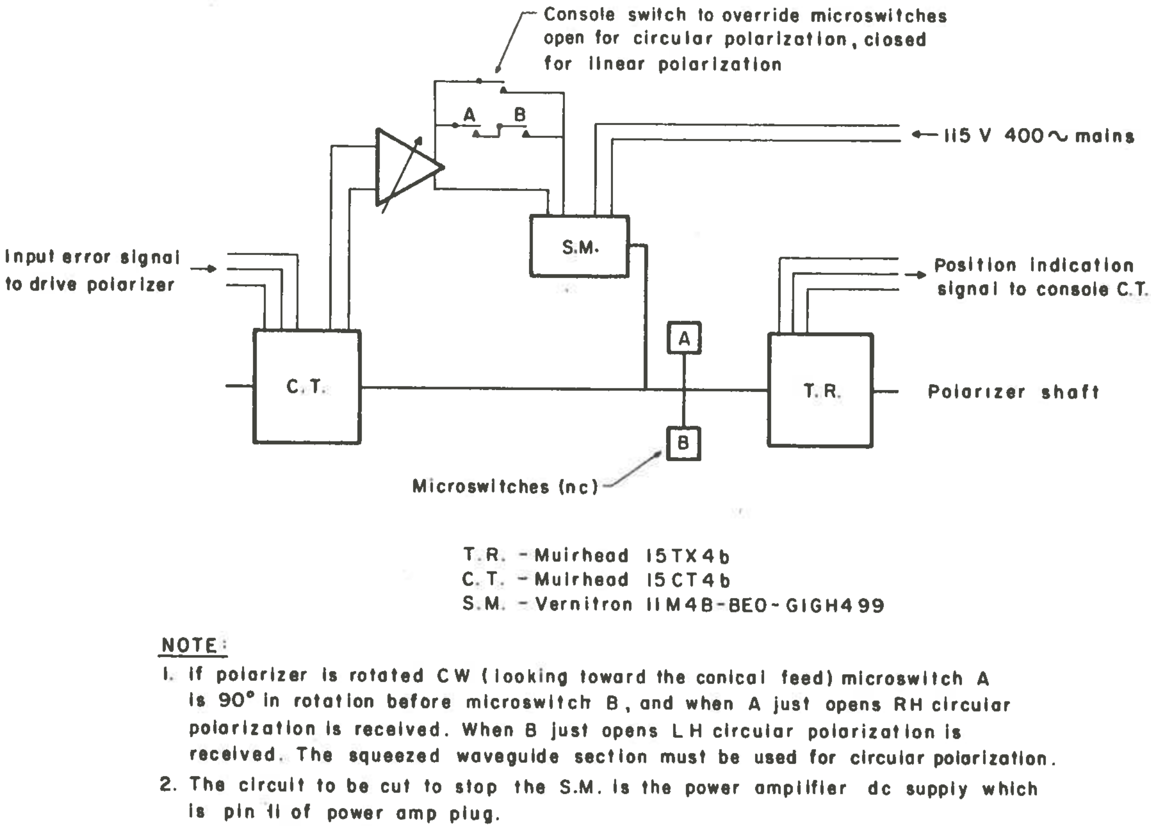

Figure 2 Servo schematic diagram

location. This is done at the telescope console by opening the switch (manual) shown in Fig. 2, and then having the polarizer shaft rotate CW until the polarizer microswitch stops the rotation. See Fig. 2 for choice between LH and RH circular polarization.

The single design difference between the 4.97-cm and 9.4-cm feeds is that the latter contains a step prior to the conical horn to provide dual-mode aperture illumination. This is intended to effectively cancel sidelobes produced by a TE_{11}^{o} circular mode horn [2].

4.97-cm Variable Polarization Feed

A schematic view of this device is given in Fig. 1 and its general properties are given in Table I. These were achieved after modification of the teflon bearings to reduce a considerable resonant loss in the desired frequency band.

TABLE I

Polarizer Characteristics

Polarizations provided	LH circular RH circular Rotatable linear	not simultaneous
Center frequency	6.035 GHz	
Bandwidth	0.050 GHz	
Transmission loss	0.055 db	
For circular polarization		
– average VSWR across frequency band specified, terminated by a circular waveguide flat load	1.07 (<1.3*)	
– average axial ratio (field strength) across frequency band	0.973 (>0.91*)	
– axial ratio at center frequency	>0.992	
For rotatable linear polarization		
– maximum change of VSWR as polarization is rotated at center frequency**	0.035	
– average VSWR across frequency band specified, terminated by a circular waveguide flat load, for arbitrary linear polarization setting	1.07	

* bracketed values are specifications requested

** the maximum change of average VSWR across frequency band when polarization is rotated is much less.

A parameter of importance is the isolation between LH and RH circular polarization in this device when the polarization is nominally LH or RH circular. This is easily obtained by writing the elliptically polarized signal as the sum of LH and RH circular components [3], and defining the isolation as

$$I = 20 \log \left| \frac{\text{amplitude of LH component}}{\text{amplitude of RH component}} \right|$$

$$= 20 \log \frac{1 + E}{1 - E} \qquad (1)$$

where E is measured ellipticity (field strength).

Thus for a measured $E = 0.973$, $I = 37.3$ db.

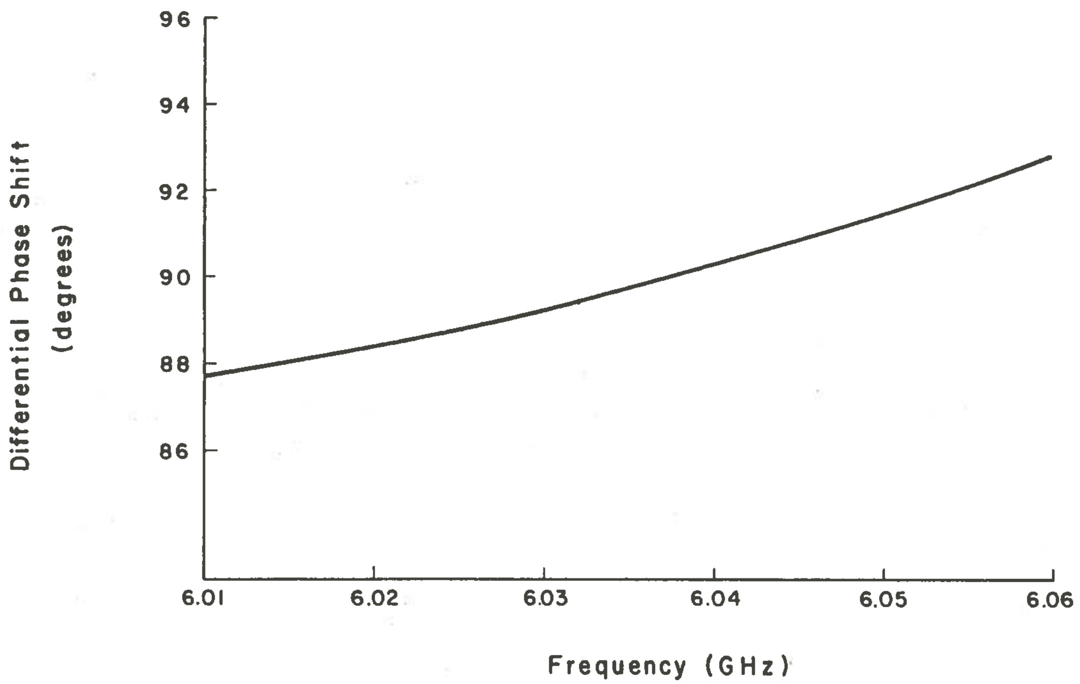

Figure 3 Differential phase shift vs frequency for 4.97-cm feed

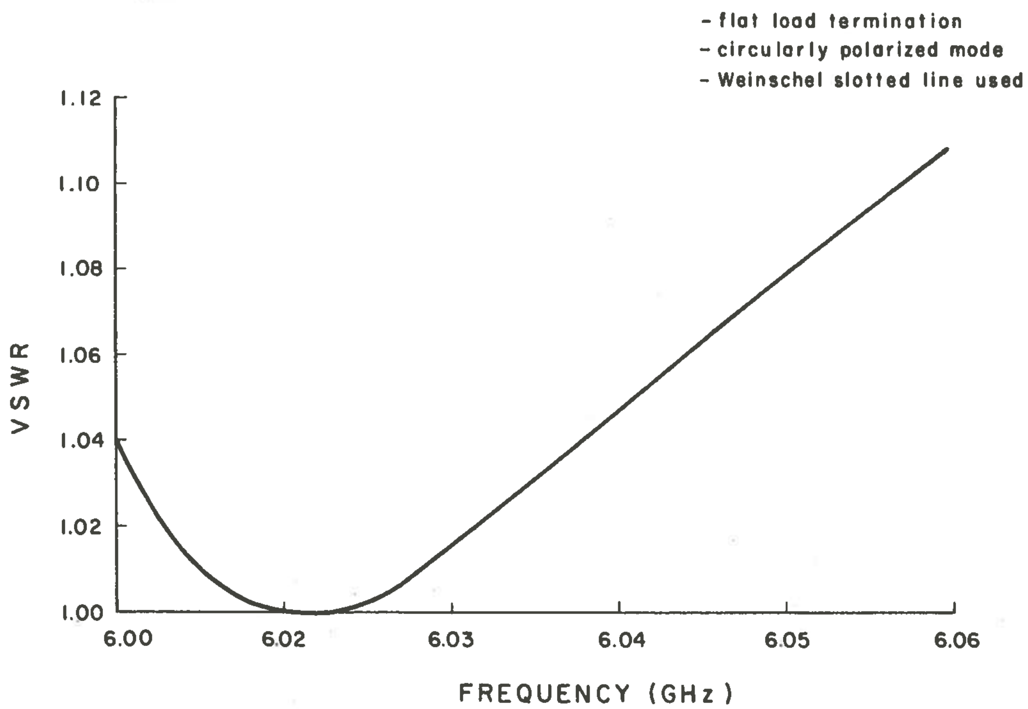

Figure 4 VSWR vs frequency for 4.97-cm feed

The measured variation of differential phase shift with frequency for this device is plotted in Fig. 3. The rapid change of differential phase shift with frequency is inherent in a circular waveguide deformed over a short length.

Figure 4 gives the VSWR—frequency characteristic with the polarizer terminated by a flat load. Variation of VSWR with probe rotation, at center frequency, is shown in Fig. 5.

The completed unit is shown in Plates 1 and 2.

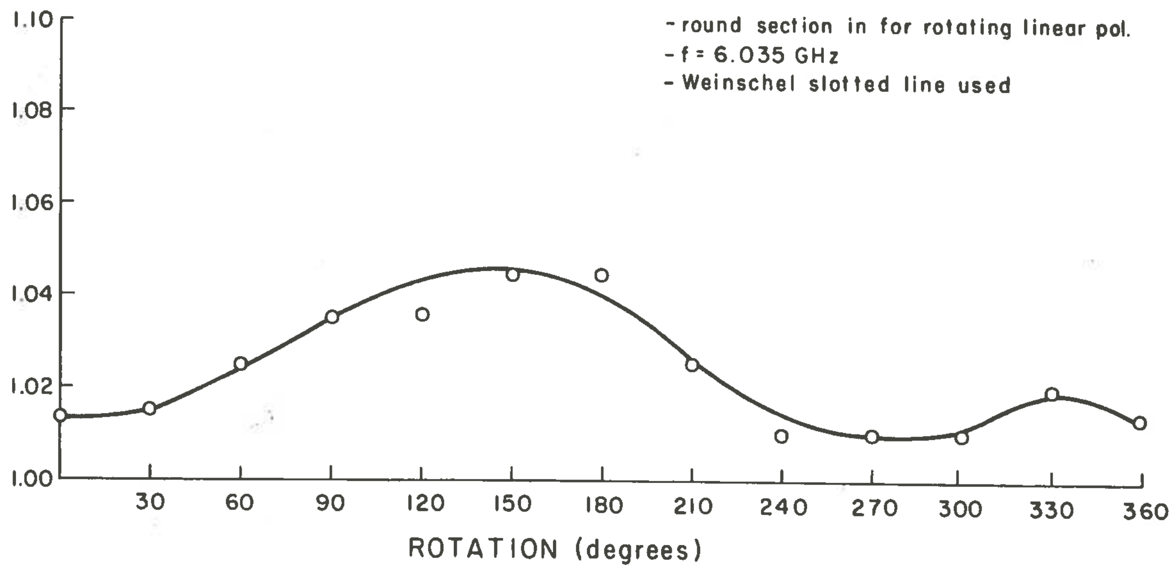

Figure 5 VSWR vs probe rotation for 4.97-cm feed

Installation

This device connects to the J-band conical section described on drawing No. DF-4-48D. The J-band horn extension (see drawing DF-4-27E) must be used for the cone aperture.

The 5-inch circular waveguide section must be used when rotatable linear polarization is desired. The squeezed 5-inch waveguide section must be used for circular polarization, and the servo system, operated from the main console, must be used to rotate the half-dipole to its appropriate LH or RH circular polarized location. Operators of the system must keep this device in its box when not in use. This feed was constructed of brass and was not plated, so the loss might be expected to vary with time.

9.4 cm Maser Feed Schematic

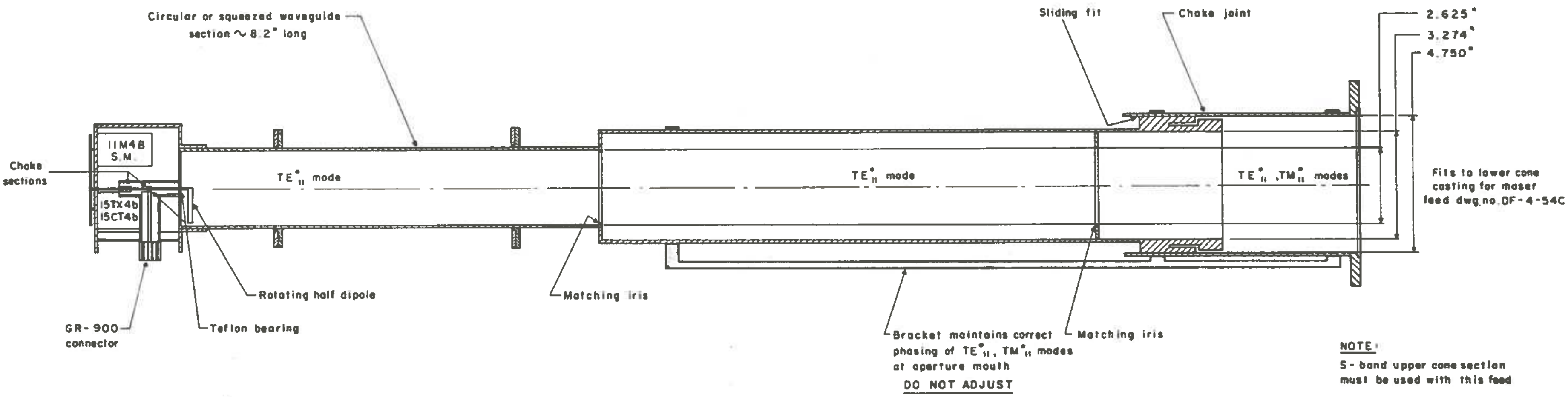

Figure 6 9.4-cm maser feed schematic diagram

9.4-cm Variable Polarization Feed

The schematic diagram for this feed is shown in Fig. 6, with the general properties being listed in Table II.

TABLE II

Feed Characteristics

Polarizations provided	LH circular RH circular Rotatable linear	not simultaneous
Center frequency	3.200 GHz	
Bandwidth	0.040 GHz	
Transmission loss from coaxial input to end of 8.2-inch section	≤0.04 db	
For circular polarization		
– average VSWR* across frequency band specified, terminated by a circular waveguide flat load		1.089
– average axial ratio (field strength) across frequency band		0.958
– axial ratio at center frequency		0.997
For rotatable linear polarization		
– maximum change of VSWR as polarization is rotated at center frequency**		0.02
– average VSWR across frequency band specified, terminated by a circular waveguide flat load, for abitrary linear polarization setting		1.087

*All VSWR figures are valid for entire unit shown in Fig. 6.

**The maximum change of average VSWR across frequency band when polarization is rotated is much less.

It was found necessary to maintain very good concentricity between the half-dipole shaft and the 2.625-inch I.D. waveguide adjacent to the half-dipole, because of the small clearance between the rotating element and waveguide.

Both 8.2-inch squeezed and circular waveguide sections were silver plated and coated with 1B12 Humi-Seal (Columbia Tech. Corp.) to give a constant low loss. The larger brass waveguide sections beyond this are gold plated.

Isolation for a measured $E = 0.958$, is $I = 33.4$ db (see Equation 1). The measured variation of differential phase shift with frequency when using the 8.2-inch squeezed section is given in Fig. 7.

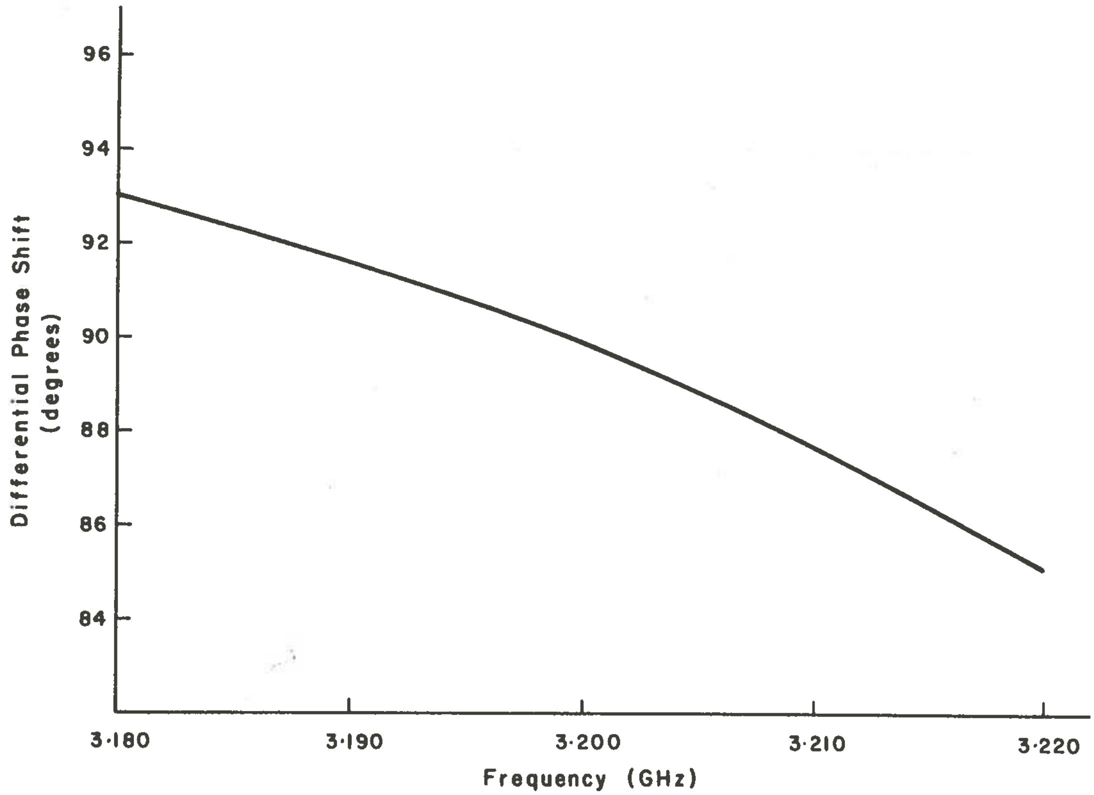

Figure 7 Differential phase shift vs frequency for 9.4-cm feed

The technique of using a dual-mode aperture distribution in order to suppress E-plane sidelobes from horn antennas [2] is by now well known. The slightly broadened main beam and resultant reduced sidelobes are very useful in illuminating reflector antennas for minimum spillover. The TM°_{11} mode must be excited in the correct amplitude and arrive at the aperture in phase with the dominant TE°_{11} mode on the horn axis. Waveguide diameters on either side of the step producing the TM°_{11} mode have to satisfy four conditions listed by Potter [2, pp. 75–76]. In this case, these diameters were found and verified through modeling at ∿18 GHz, by W.A. Cumming.

An approximate evaluation of the mode conversion coefficient

$$C_{\text{discontinuity}} = \left| \frac{E_\rho^{\text{TM}}}{E_\rho^{\text{TE}}} \right|_{\text{on waveguide wall}}$$

is given by Nagelberg *et al* [4] for a step change in radius. Cole *et al* [5] have given an exact treatment of this problem, but this result is in a complicated form. Potter shows the most useful value of $C_{aperture}$ to be $\sim$0.6. For the parameters chosen for this problem, Nagelberg's approximate expression gives a value of $\sim$0.96 for $C_{aperture}$. The exact theoretical treatment presumably gives a value nearer 0.6.

It was not possible to take E-plane radiation patterns in order to set the correct relative phasing of the TE°_{11} and TM°_{11} modes at the aperture, because of the large feed length of $\sim$21 feet (aperture diameter = 37 inches and half-cone angle is 4°24′). The correct aperture phasing was set by adjusting the aperture–step discontinuity distance, by means of the sliding joint (see Fig. 6), and then clamping this permanently. An E_{ρ} probe was inserted into a small hole in the first conical feed section (lower cone casting in DF-4-54C) at a radius $\alpha = 3.474$ inches. The required phase of the standing wave due to the TE°_{11} and TM°_{11} modes was then calculated for this radius. The rear section of the feed was then moved at the sliding joint until the correct differential phase shift between modes (596.5° from the aperture) was observed.

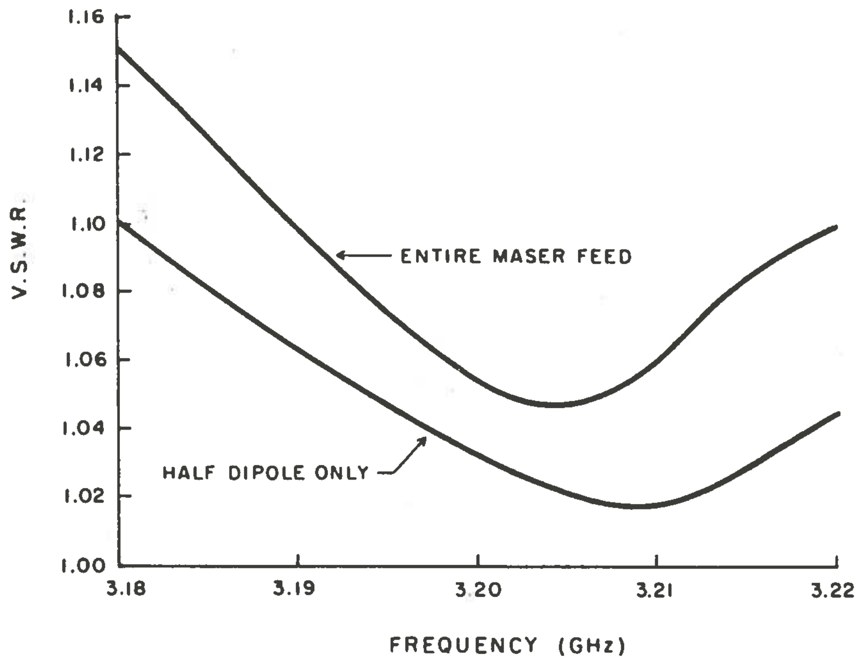

Figure 8 VSWR vs frequency for 9.4-cm feed

The step discontinuities seen in Fig. 7 are individually matched with irises as shown. This feed has a VSWR–frequency characteristic looking away from the receiver as given by Fig. 8. Variation of VSWR with probe rotation is given in Fig. 9.

The completed feed up to and including the lower cone casting (drawing DF-4-54C) is shown in Plates 3 and 4.

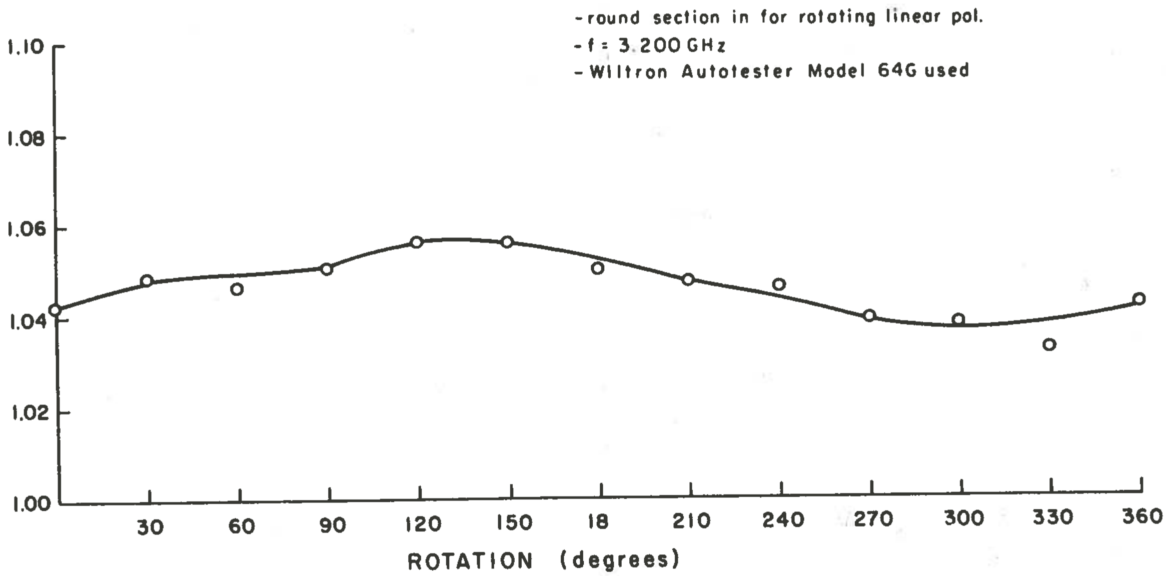

Figure 9 VSWR vs probe rotation for 9.4-cm feed

Installation

The alternate lower cone casting (drawing DF-4-54C) connects to the next conical section (see assembly drawing DF-4-1E and Fig. 6) and is used in conjunction with the S-band aperture section. The squeezed or circular 8.2-inch waveguide sections are used according to the polarization desired (see Fig. 2).

Acknowledgment

The conception of and early work on the 9.4-cm feed was done by W.A. Cumming. Some work on the coax–circular waveguide transition was also done by W. Lavrench.

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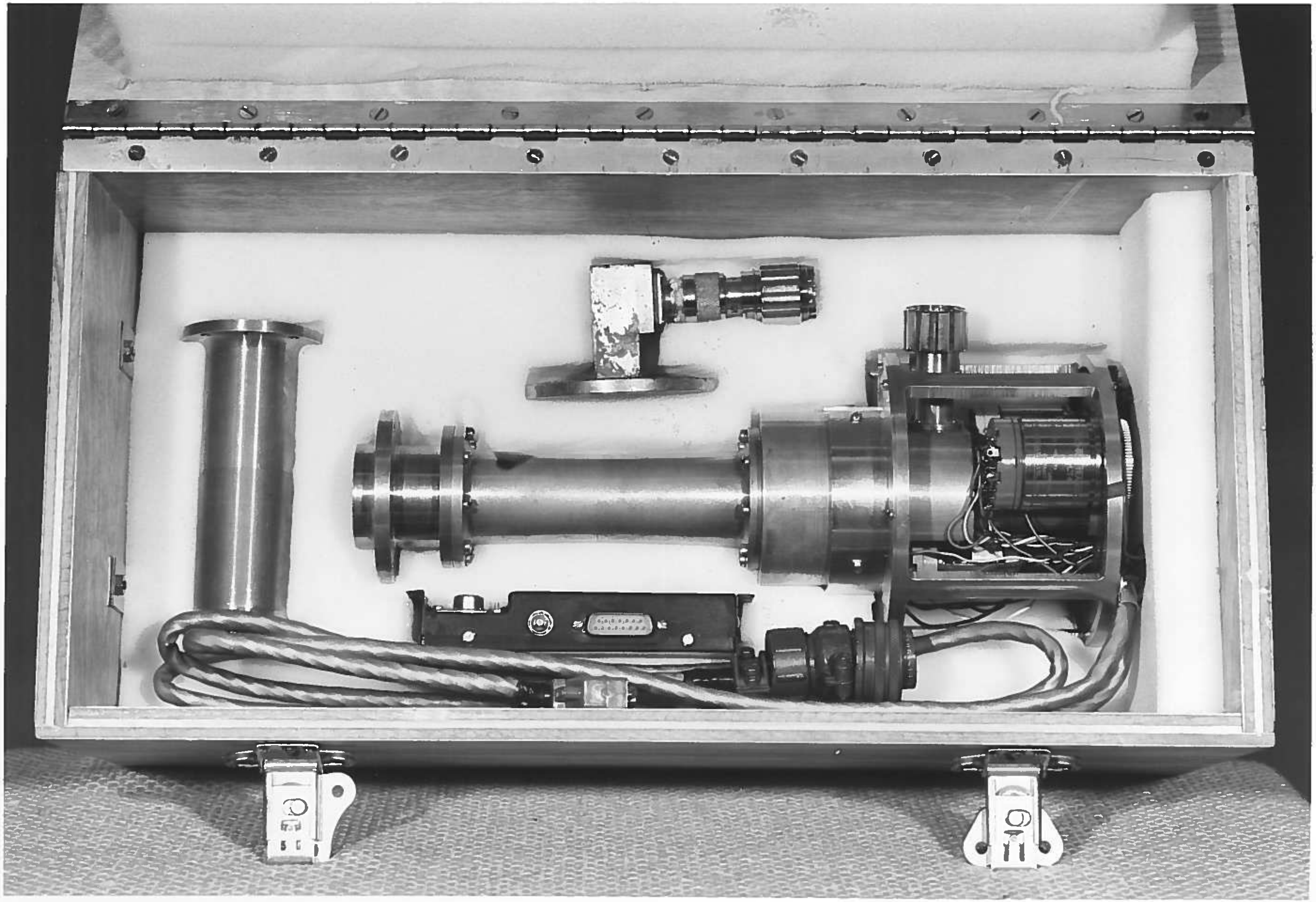

Plate I Complete 4.97-cm feed, with matched transition and servo amplifier

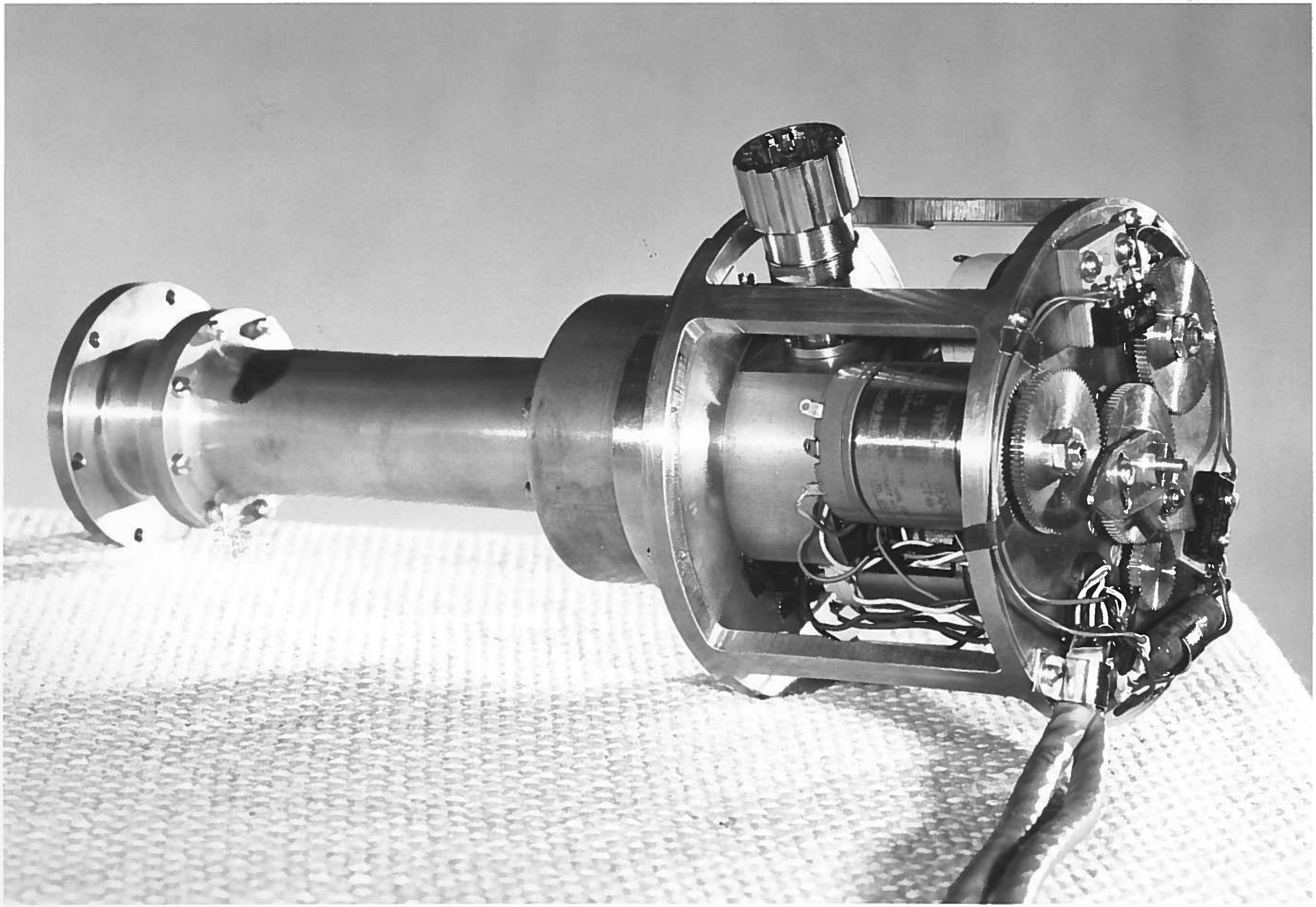

Plate II Servo unit detail for 4.97-cm feed

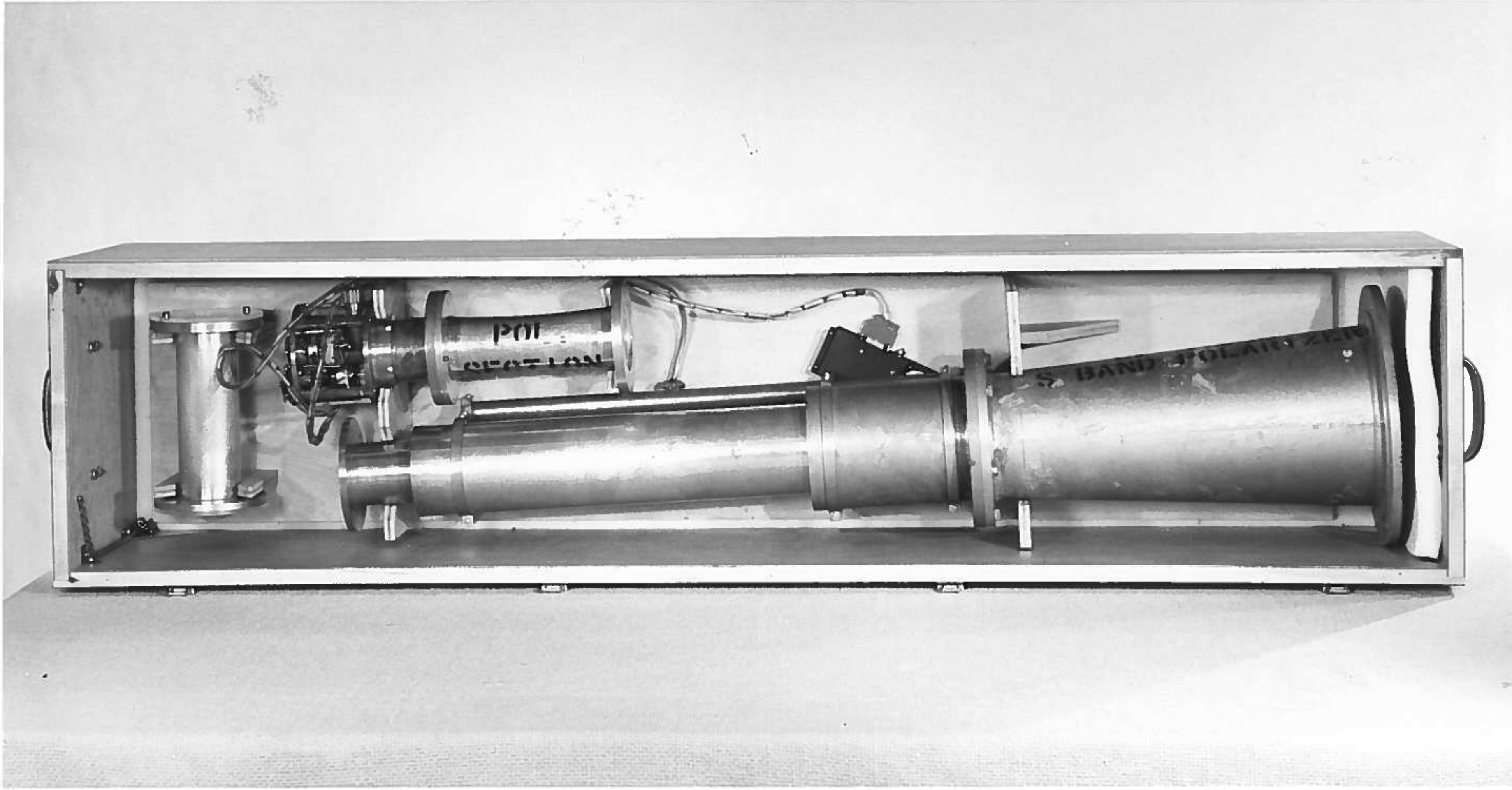

Plate III Complete 9.4-cm feed with servo amplifier

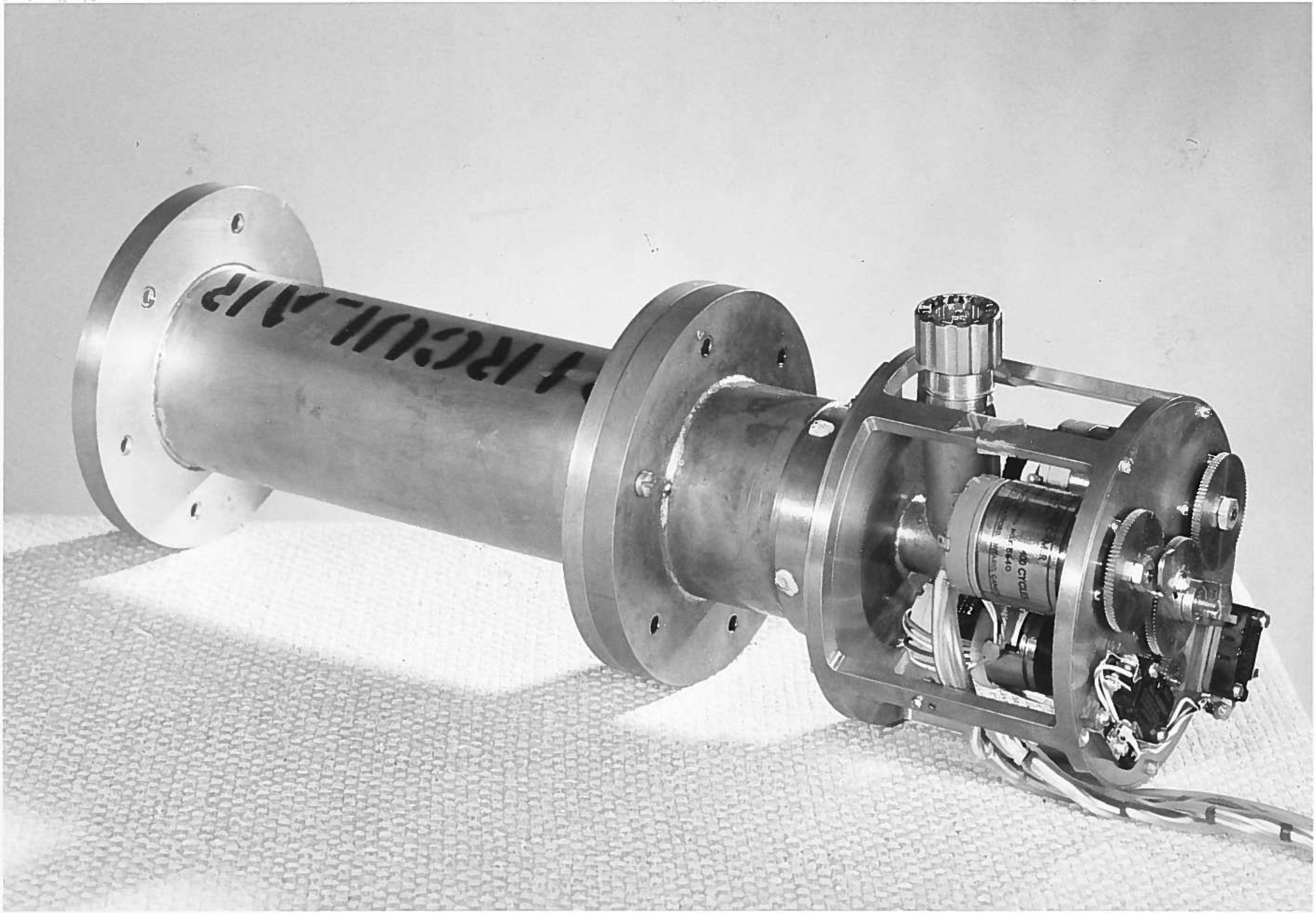

Plate IV Detail of 9.4-cm feed