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# A DUAL-POLARIZATION CROSSED-DIPOLE FEED FOR RECEPTION AT 488 AND 944 MC/S

BY

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## ABSTRACT

The design and construction is described of a dual-polarization crossed-dipole feed, to receive signals simultaneously at frequencies of 488 and 944 mc/s. Each output is matched to 50-ohm coaxial cable. The radiation patterns, measured in the two principal planes of each dipole, at each frequency, are illustrated. In addition, representative values of the variation in output impedance of each section of the feed over bands of frequencies about 488 and 944 mc/s are shown. The bandwidth between the limits of which the voltage standing-wave ratio is less than 2 to 1 is about 45 mc/s, or 4.7% at 944 mc/s, and 18 mc/s, or 3.7%, at 488 mc/s. Isolation between the dipoles is better than 40 db at both design frequencies.

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## FIGURES



## PLATES

# A DUAL-POLARIZATION CROSSED-DIPOLE FEED FOR RECEPTION AT 488 AND 944 MC/S

- R.F. Millar -

## INTRODUCTION

Frequencies of 488 and 944 mc/s have been assigned to the Radio Physics Laboratory of the Defence Research Board for use in auroral studies. In this connection, several feeds for paraboloidal reflectors operating at a single frequency have been designed in this Division.

It was recently found desirable to receive simultaneously, at the two frequencies, signals having mutually perpendicular polarizations. For reasons of economy, it was decided to design a single crossed-dipole feed to satisfy this requirement, rather than to employ two independent single-frequency installations. The paraboloid to be used with the feed had an aperture 28 feet in diameter, and a focal length of 12 feet; hence the angle subtended by the reflector at the focus was about 111°.

## DESIGN SPECIFICATIONS

The feed was required to satisfy the following conditions.

1) To provide a means for mounting the assembly at the focus of the paraboloid, and to aid in the suppression of the back lobe from the feed, the dipoles should be situated in front of, and parallel to, a circular aluminum plate 2 feet in diameter.
2) The primary radiation patterns in a given plane, for each frequency, should be as similar as possible.
3) The side lobe level in the secondary radiation pattern should be 20 db below the level of the main beam.
4) The output from each section of the feed should be matched (VSWR less than 2 to 1) to RG-8/U (50-ohm) cable.

## LIMITATIONS ON DESIGN IMPOSED BY SPECIFICATIONS

Several E- and H-plane patterns were calculated for a dipole mounted over an image plane. It was found that condition (3) could be satisfied in the H-plane (where the pattern is independent of dipole length), and the patterns at both frequencies be kept reasonably similar if the spacing from the plate to the axis of the dipole was less than about $\frac{3}{16}\lambda$ at the higher frequency. Here $\lambda$ denotes the wavelength of the signal. Since the dipole impedance becomes more sensitive to changes in plate

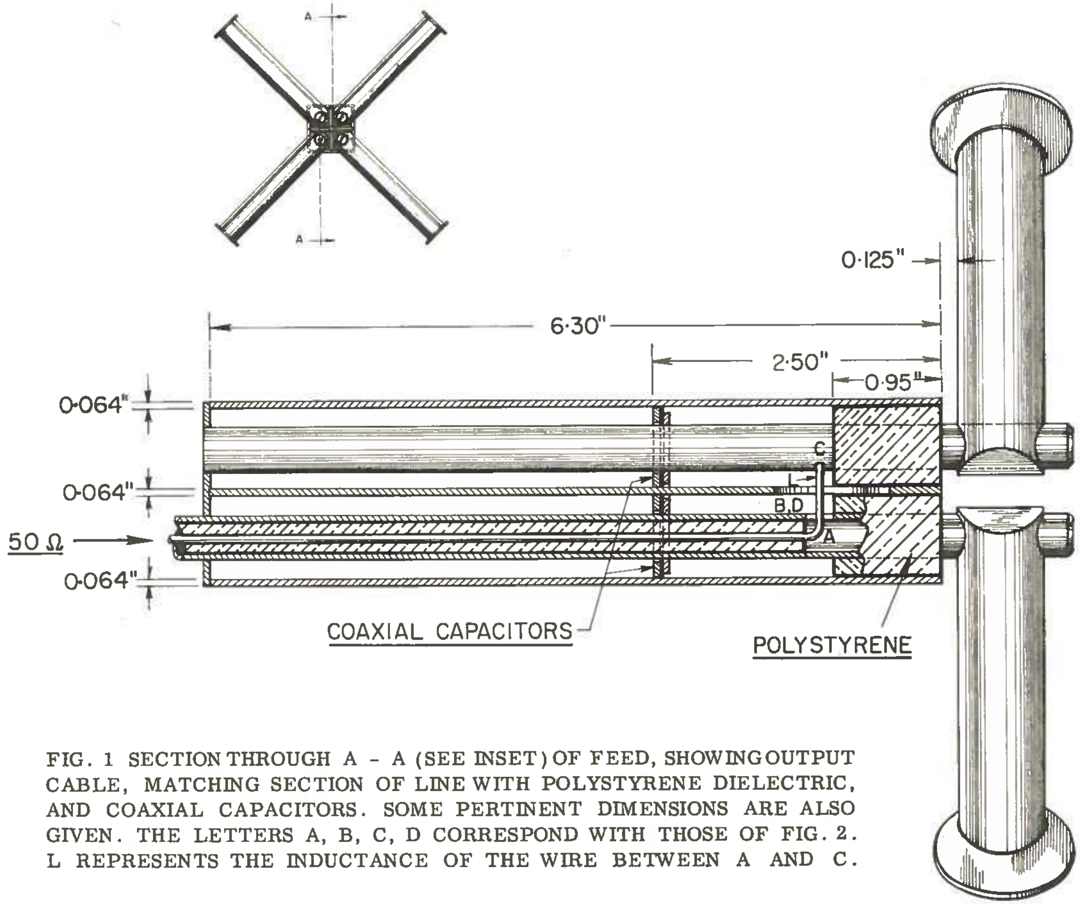


FIG. 1 SECTION THROUGH A - A (SEE INSET) OF FEED, SHOWING OUTPUT CABLE, MATCHING SECTION OF LINE WITH POLYSTYRENE DIELECTRIC, AND COAXIAL CAPACITORS. SOME PERTINENT DIMENSIONS ARE ALSO GIVEN. THE LETTERS A, B, C, D CORRESPOND WITH THOSE OF FIG. 2. L REPRESENTS THE INDUCTANCE OF THE WIRE BETWEEN A AND C.

spacing as the spacing decreases, the separation was taken to be $\frac{3}{32}\lambda$ at 488 mc/s, or 2.27 inches.

On the other hand, for the above choice of plate spacing, condition (3) was satisfied in the E-plane over a considerable range of dipole lengths, although the dipole length was restricted to somewhat less than a wavelength at the higher frequency by condition (2).

## METHOD OF DESIGN

Since it was necessary to connect an (unbalanced) coaxial line to a balanced dipole, the use of some form of balun was essential. The type chosen was that described in Section 4-10 of Reference 1, with the addition of a length of matching line in the balanced section and lumped shunt susceptances in the form of coaxial capacitors in the stub lines to permit operation at the two frequencies (see Figs. 1 and 2).

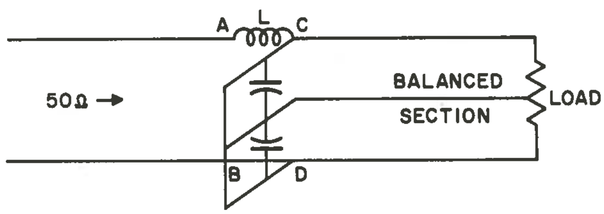


FIG. 2 EQUIVALENT CIRCUIT OF FEED. THE LETTERS A, B, C, D DENOTE THE POINTS SHOWN IN FIG. 1. L REPRESENTS THE INDUCTANCE OF THE WIRE BETWEEN A AND C.

The balun itself was employed in the impedance transformation. The length of matching line was chosen to transform the dipole conductances to the correct values and the susceptance at each frequency was then tuned out by proper choice of the stub length and position and magnitude of the shunt capacity. (If both the length and characteristic impedance of the stubs were at the disposal of the designer, this latter operation could be performed without the introduction of lumped elements. In the present case, however, the characteristic impedance was fixed in advance.)

In order to obtain some idea of the impedances to be encountered at the terminals of the dipole, measurements were performed using image-plane techniques and monopoles of several lengths and diameters mounted to give a $\frac{1}{2}$" gap between the image plane and end of the antenna. This latter dimension (which essentially fixed the characteristic impedance of the stubs in the balun) was chosen to coincide with the gap in previously constructed feeds for single frequency operation. Monopole lengths ranged from about $\frac{1}{8}\lambda$ at 488 mc/s to $\frac{3}{8}\lambda$ at 944 mc/s, with diameters between $\frac{1}{4}$" and $\frac{3}{4}$". Not unexpectedly, it was found that the monopole impedance at the lower frequency was much less than 50 ohms, and considerably greater than this value at the higher frequency. In all cases, the mismatch became progressively less as the diameter was increased, and this led to the choice of $\frac{3}{4}$" for the design value.

In an attempt to raise the impedance level at the lower frequency, the effect of end-loading the monopole by circular discs was determined. It was found that for the lengths employed, little change in impedance was produced at 944 mc/s for a considerable variation in disc size, while impedance at the lower frequency increased with disc diameter, and was quite sensitive to variations in end-loading. This latter feature was employed to provide an impedance adjustment at 488 mc/s which had little effect on the impedance at the higher frequency.

On the basis of the above measurements, a model of the feed was constructed. The balanced line, center conductors of the stubs, and outer conductor of the output coaxial cable, consisted of $\frac{3}{8}$" O.D. brass tubing with a $\frac{1}{32}$" wall. The center conductor and Teflon dielectric for the output cable were obtained from solid-copper-sheathed equivalent of RG-8/U, and the characteristic impedance of this combination was approximately 50 ohms. The balun was made sufficiently long to permit a $\frac{1}{2}\lambda$ variation in stub length at 488 mc/s and the stub lengths were made adjustable by means of shorting plungers. Polystyrene was chosen for the dielectric in the matching line which, in addition to transforming the impedance, provided support for the dipole assembly.

The reactance of the exposed portion of the center conductor of the coaxial cable is not negligible at these frequencies, and its determination was necessary before the required length of matching line could be finally selected. This measurement was carried out in the following manner. From Fig. 2, it is evident that, if all other parameters are held constant, a change in stub length will cause the admittance at CD to traverse a constant conductance circle on the Smith chart. It follows that, if a series of measurements is taken of the impedance at AB when the stub length is varied, a circle is thereby determined on the chart which touches the circle of zero resistance at the point whose reactance is equal to $X_L = \omega L$ ($\omega = 2\pi \times$ frequency).

Knowledge of $X_L$ at each frequency made it possible to determine on which constant conductance circles the admittances at CD must lie in order that a match might be obtained at AB solely by susceptance changes at CD*. These correct

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*Because the susceptances to be supplied by the stubs and capacitors were of comparable magnitudes at each frequency, to ensure the possibility of a match it was necessary to transform the high-frequency admittance to the positive susceptance side of the desired circle, while the low-frequency admittance was transferred to the negative-susceptance portion of the circle.

values were then obtained by a suitable choice of length of matching line, dipole length, and disc size. Since a variation in end-loading essentially affected the admittance only at the lower frequency, the lengths of dipole and transmission line were chosen to transform the admittance at 944 mc/s to the desired position on the Smith chart. The end-loading was then varied to transform the low-frequency admittance to the correct value.

Measurements were next made to determine the values of susceptance at CD necessary to produce a match at each frequency. Since the addition of a negative susceptance was required to give a match at the higher frequency, while a positive susceptance was needed at the lower, the stub length was of necessity somewhat greater than $\frac{1}{2}\lambda$ at 944 mc/s, and $\frac{1}{4}\lambda$ at 488 mc/s. Most of the positive susceptance was to be provided by the lumped capacity in the stub lines. It was calculated that a capacity of approximately 14 $\mu\mu f$ located properly in each stub would lead to the desired results. This capacity was obtained by means of a coaxial capacitor, the two parallel-plates being separated by 0.005" Teflon dielectric. The precise location in the stub lines was found by trial-and-error, after which the permanent short circuit was placed across the stubs.

## DETAILS OF CONSTRUCTION AND PERFORMANCE

The final form of the feed is illustrated in Fig. 3. The dipole length (including the disc thicknesses) is 10.3". The length of polystyrene-dielectric transmission line is 0.95", while the disc diameter is 1.25". Because of slight differences between the two dipoles, the position of the coaxial capacitors and length of stub, differ by small amounts in the two cases.

Plates I and II show the feed with, and without its accompanying ground plane.

In Fig. 4 are shown E- and H-plane patterns of the feed at the design frequencies. Corresponding patterns at the two frequencies appear reasonably similar. The broadest of the patterns is in the H-plane at 944 mc/s. In this plane the illumination at the edge of the paraboloid is such that, in the secondary pattern, the side lobes should be at least 20 db below the level of the main beam; the side-lobe level will be correspondingly lower in the other cases.

Representative values of the output impedances (at the connectors) over bands of frequencies about the design values are shown in Fig. 5. The degree of match originally obtained was somewhat better than indicated, but replacing of the output connectors in their final positions shifted the associated discontinuities by amounts which were sufficient to increase the voltage standing-wave ratio at the design frequencies by up to about 0.2. Nevertheless, the VSWR is less than 2 to 1 over 45 mc/s in the region of 944 mc/s, and 18 mc/s about 488 mc/s.

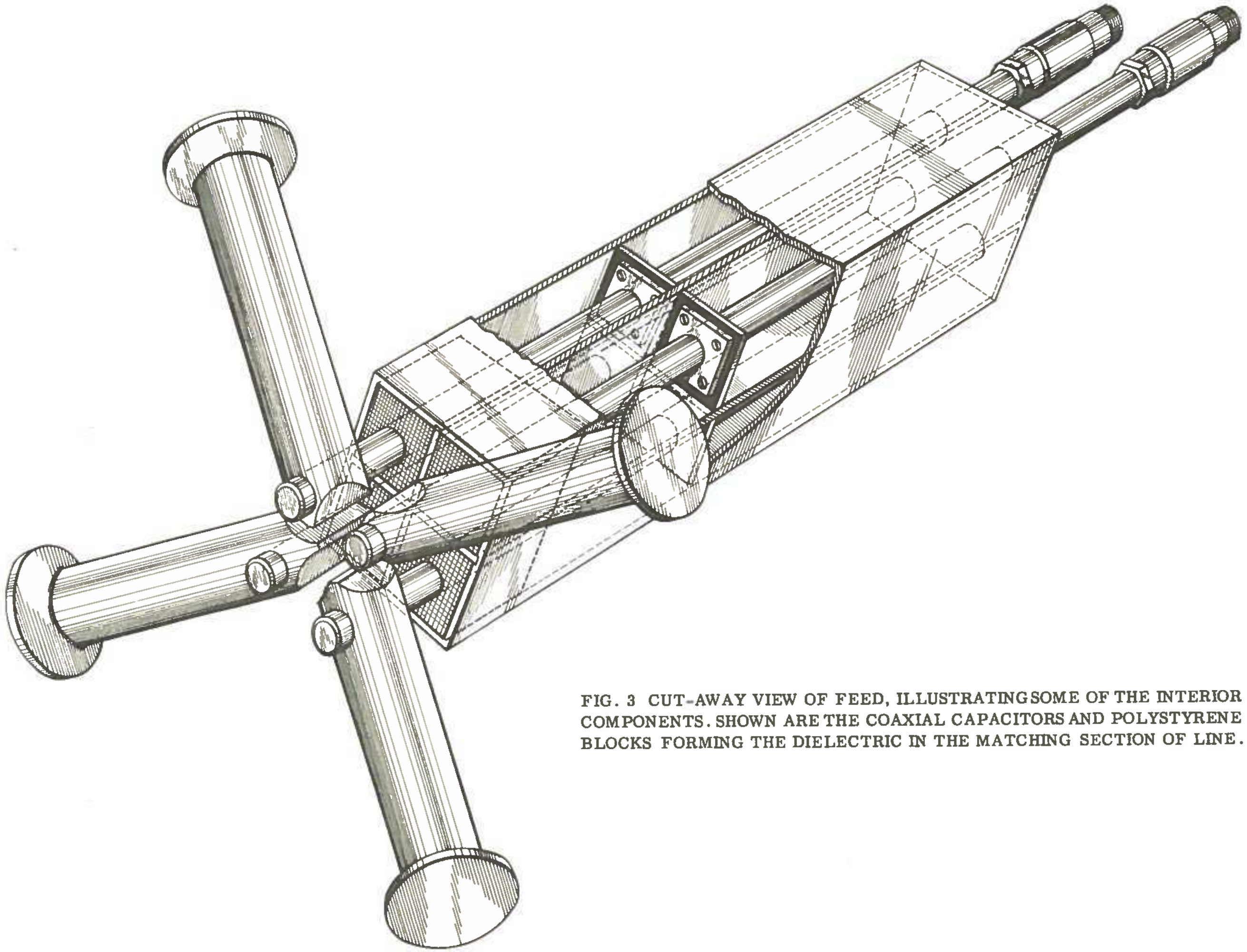

FIG. 3 CUT-AWAY VIEW OF FEED, ILLUSTRATING SOME OF THE INTERIOR COMPONENTS. SHOWN ARE THE COAXIAL CAPACITORS AND POLYSTYRENE BLOCKS FORMING THE DIELECTRIC IN THE MATCHING SECTION OF LINE.

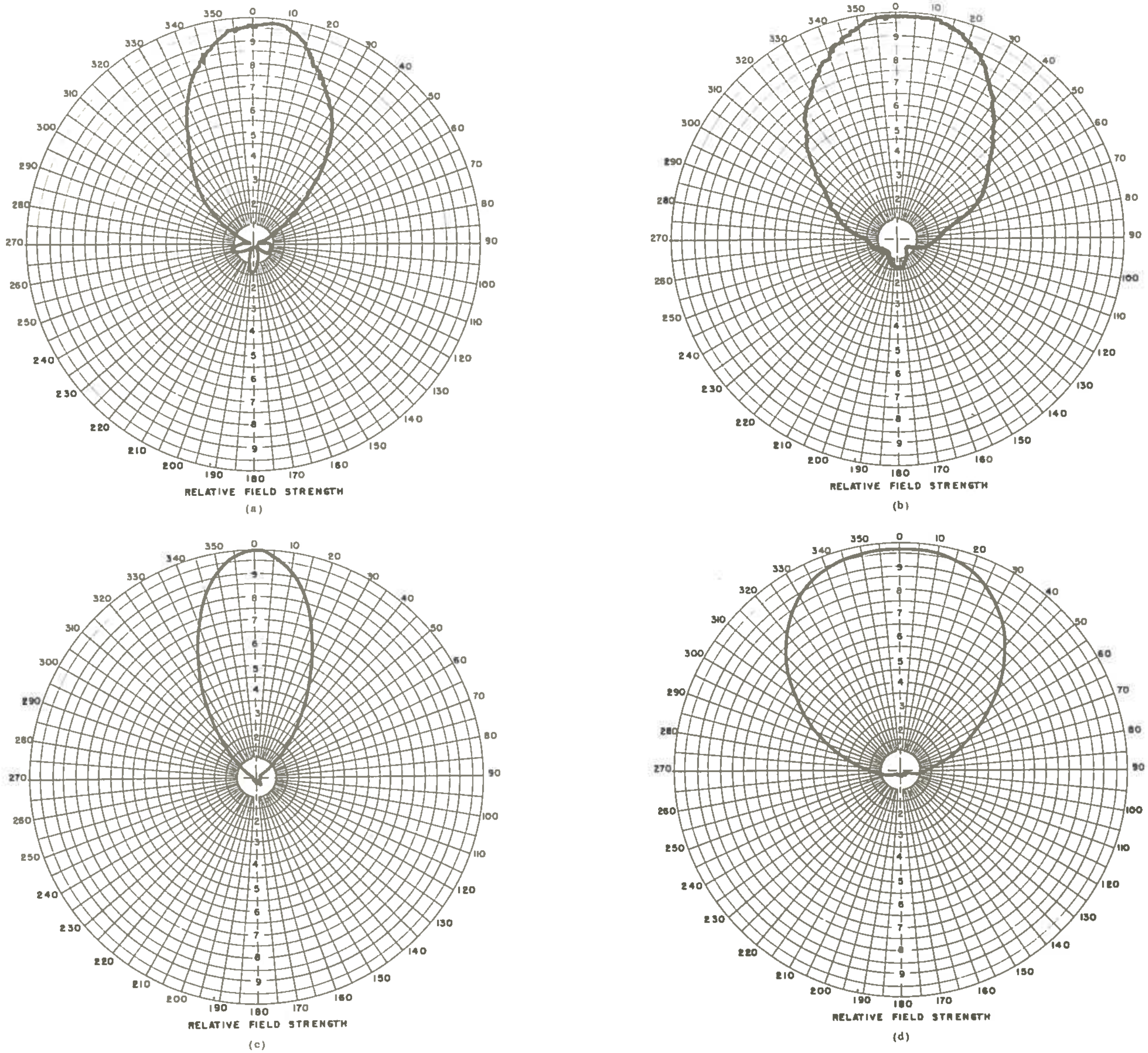


FIG. 4 E- AND H-PLANE PATTERNS OF ONE SECTION OF THE FEED AT THE DESIGN FREQUENCIES, WITH GROUND PLANE 2.27 INCHES FROM CENTER-LINE OF DIPOLES.

(a) E-plane, 488 mc/s
(b) H-plane, 488 mc/s
(c) E-plane, 944 mc/s
(d) H-plane, 944 mc/s

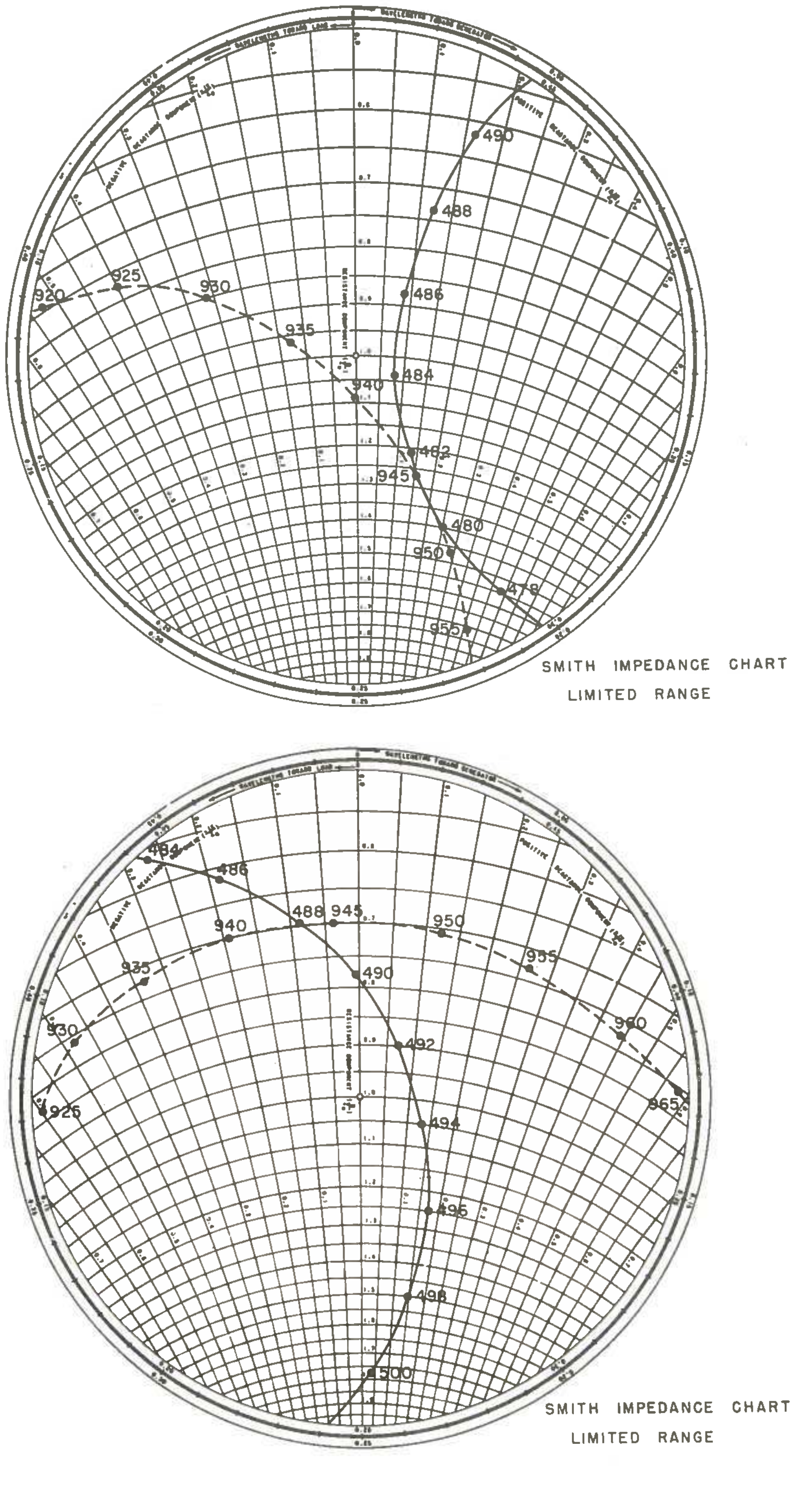


FIG. 5(a, b) REPRESENTATIVE VALUES OF THE IMPEDANCES AT THE TWO OUTPUT CONNECTORS MEASURED OVER BANDS OF FREQUENCIES ABOUT THE DESIGN VALUES. THE NUMBERS REPRESENT FREQUENCIES IN MEGACYCLES PER SECOND.

Isolation between the dipoles was found to be 43 db at 488 mc/s, and 47 db at 944 mc/s.

## CONCLUDING REMARKS

It is possibly worth while to discuss a few points which arose during construction of the feed.

As mentioned above, the discontinuity between the $\frac{3}{8}$" O.D. brass tube and output connector is sufficient to increase the VSWR by about 0.2, if the position of the connector is sufficiently changed. Although this is not serious in the present application, it would be desirable in future models either to eliminate this discontinuity to the greatest possible extent, or to place the connector in its final position while it is still a relatively simple matter to compensate for the change in position of the discontinuity.

Another point which gave some trouble concerns the construction of the coaxial capacitors in a manner such as to withstand the heat of soldering into the stub lines without change of plate separation. The method here employed was to fasten the plates and dielectric together with four 2-56 bolts. These were insulated from one plate by Bakelite washers under the bolt head, and Teflon bushings over the threaded portion, but this solution was not entirely satisfactory.

## ACKNOWLEDGMENT

The author would like to thank Mr. W.A. Cumming and several members of the technical staff for much assistance in the design, construction, and testing of this device.

## REFERENCE

1. Reich, H.J. et al., "Microwave Theory and Techniques" (D. Van Nostrand, 1953)

PLATE I VIEW OF FEED MOUNTED OVER GROUND PLANE

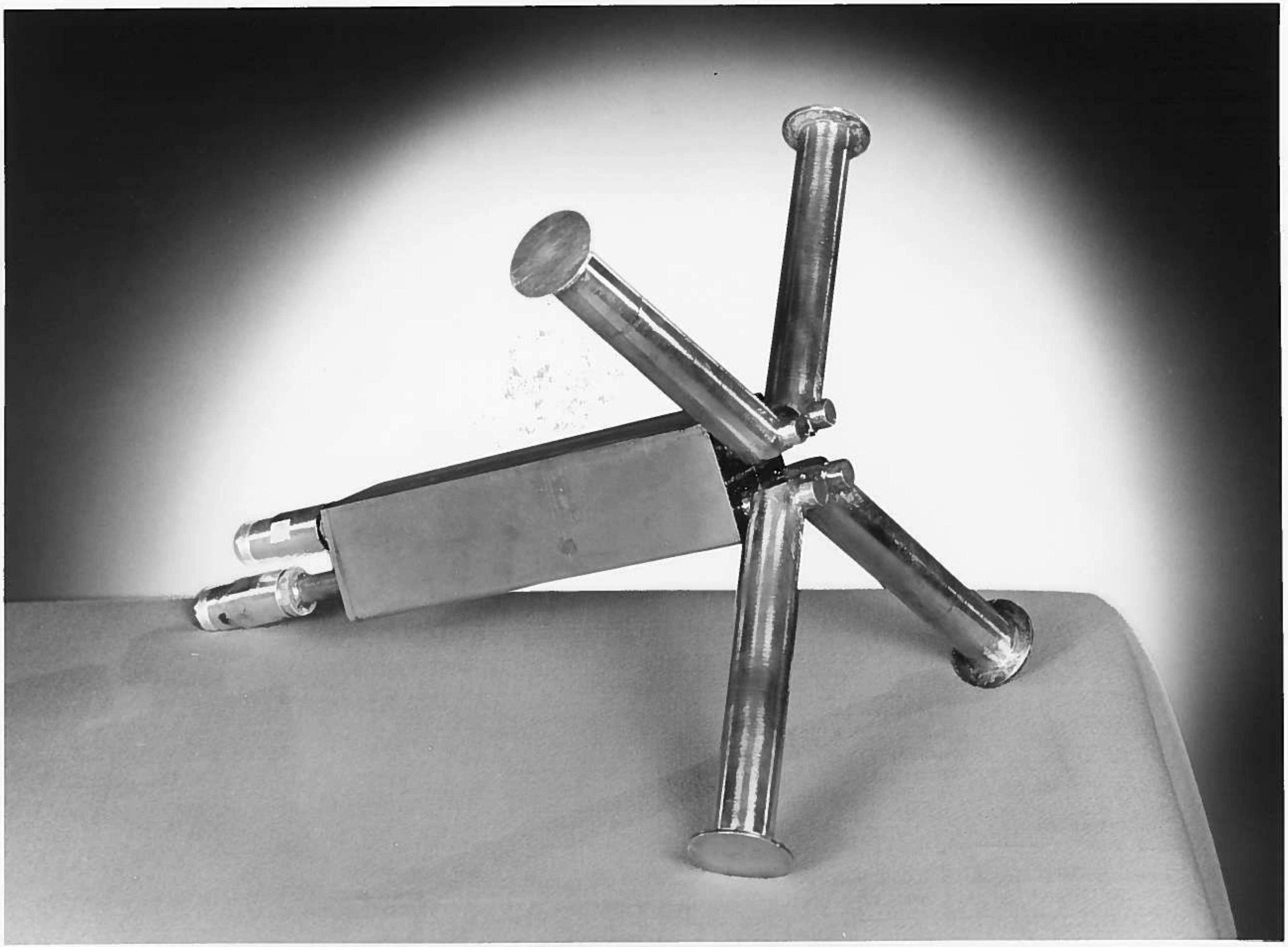

PLATE II VIEW OF FEED WITHOUT GROUND PLANE AND ASSOCIATED MOUNTING FLANGE