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PRISMATIC EFFECT COMPENSATION TECHNIQUE

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Techniques Branch
Rome Air Development Center
Research and Technology Division
Air Force Systems Command
Griffiss Air Force Base, New York

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PRISMATIC EFFECT COMPENSATION TECHNIQUE

May 1965 through July 1965

By

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PUBLICATION REVIEW

This report has been reviewed and is approved. For further technical information on this project, contact EMATA, Mr. Carmen S. Malagisi, 330-2443

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ABSTRACT

The first project report covered the design analysis demonstrating the realizability of components necessary to correct dispersion in cyclic arrays. The second report covers the design and development of the microwave components required to build an actual system which demonstrates the theory of prismatic correction of dispersion. This report shows that prototypes of all the individual components have been designed and developed which meet the necessary specifications with little or no compromise.

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1. INTRODUCTION

The prismatic correction of dispersion in phased arrays will be made by the use of a Huygens source array as the primary feed for a reflecting array. The theory and analysis of this type correction was given in the first report of this project and will not be repeated here. This second report will cover the design and development of the individual microwave components required to produce a system that demonstrates the theory of prismatic correction.

The system is naturally divided into two parts:

a) a secondary reflecting array.

b) a distributed Huygens source array as the primary feed.

Each part divides further into subassemblies of basic microwave components. A discussion of each type follows:

2. REFLECTING ARRAY

The design of the reflecting array requires an aperture 7 feet wide (E-plane) by 28 inches high (H-plane) by 7 inches deep, made up of sections of rectangular waveguide 1.5 inches by 3/4 inches. Each guide element contains a mechanically variable short circuit phase shifter, and a matching element. The short circuit is a simple metal block almost filling the guide in cross section, with an electrical length of $\lambda g/4$ at the center frequency. A sufficient gap is left between the block and guide to allow free motion. A spring loaded ball bearing is built into the block to lock it at any desired position in the guide. The shorting block is made of brass to prevent binding in the aluminum waveguide. Measured reflections of the short circuit showed values to be greater than 40 db, i.e., VSWR > 100:1. This is four times better than the minimum acceptable VSWR of 25:1.

A second design problem of the reflecting array is the matching of the rectangular guide to free space. Since the true impedance at the guide aperture includes coupling effects to adjacent guides, the matching was done using a section of the array, i.e., a center element ringed by one layer of adjacent guides. Using a post across the narrow dimension of the guide, a maximum VSWR of 1.30 was obtained across the band of 5870 to 6405 MC. To achieve a better match would require double posts with more critical dimensions;

however, because of the large number of elements in the array the added expense and construction difficulties would not be justified when compared to the small VSWR improvement.

The mechanical structure to house all the array elements is a standard mechanical structure typical of phased array supports, and no new problems are posed. (See Fig. 1)

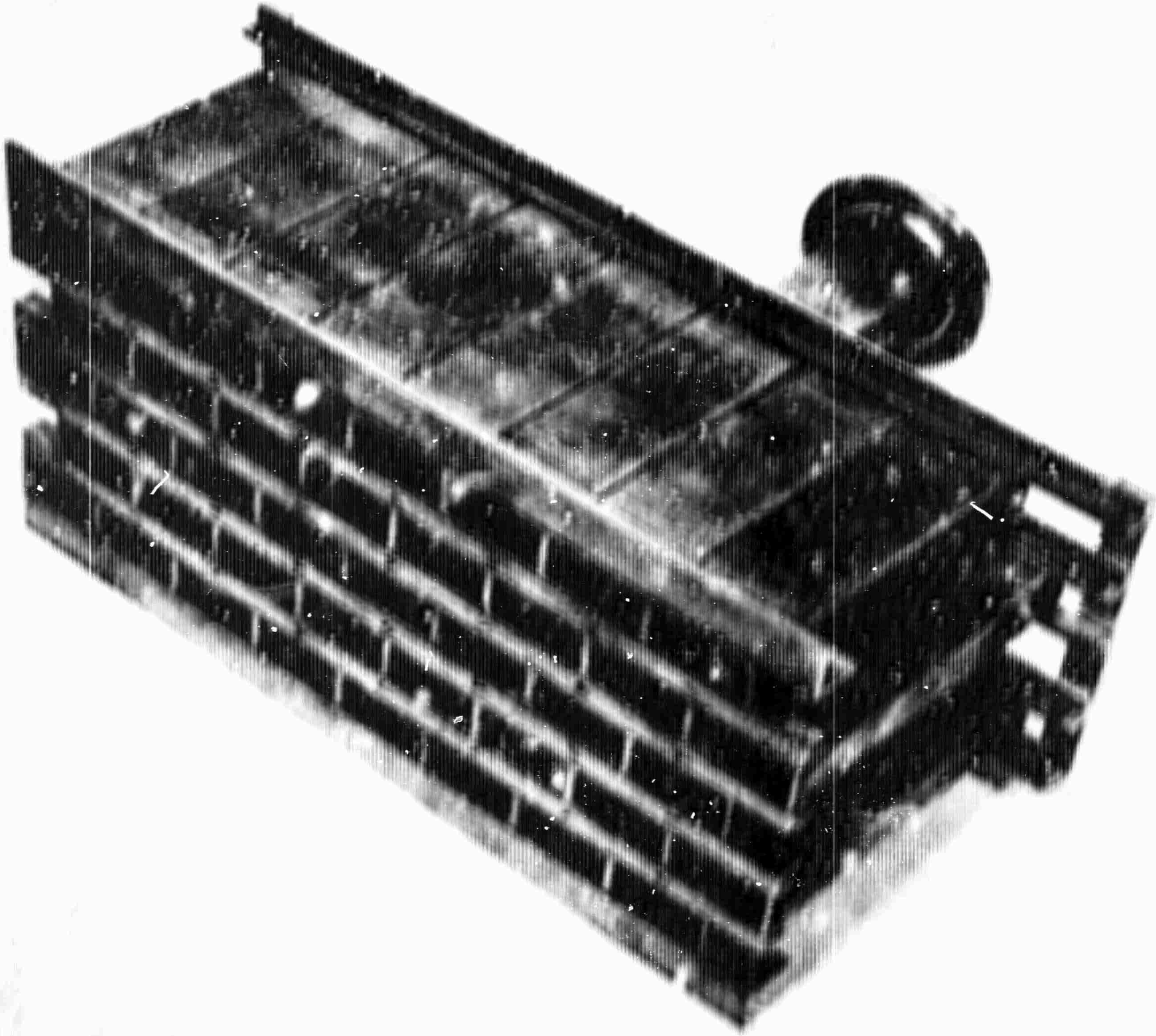
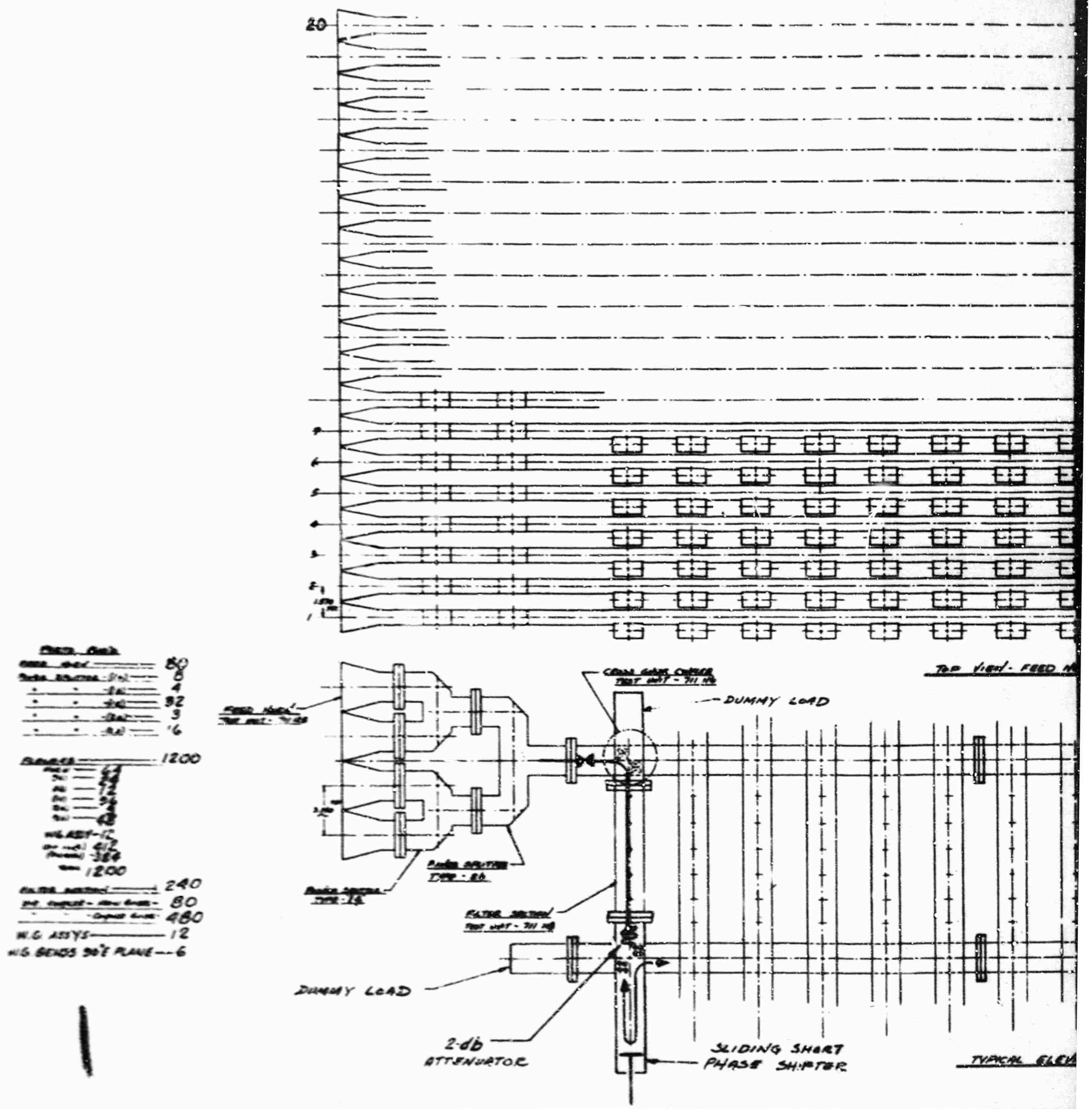


FIGURE 1 - Prototype Section of the Reflecting Array

3. MATRIX AND CORPORATE FEED (DISTRIBUTED HUYGENS SOURCE)

The Huygens source consists of a matrix of horns in 20 rows in four columns. Each row consists of four horns fed by a ladder network composed of 12 filters, 12 phase shifters, and 24 directional couplers. The twenty rows are connected to a corporate feed which transmits equal power to all the rows. This feed is composed of power splitters of various types. (See Fig.2) for the complete layout of the matrix and feed, and designations for the components.) The microwave components that make up this system and associated design problems are discussed below.

a) Feed Horn - A rectangular guide flared in both dimensions to give an aperture of 3 X 1.5 inches is used to give the required beam patterns. The resulting match to free space produces a maximum VSWR over a 522 MC band of 1.25. This VSWR, is a relatively good match. To reduce it further requires either an excessively long taper or a complicated resonant-iris matching structure; both methods were discarded as being not justified on the basis of cost and space requirements required versus the small VSWR improvement realized. Because of the configuration and the large number of horns, fabrication by casting was designated.


20
7
6
5
4
3
2
1
FEED HORN — 80
1200
1200
240
80
480
W.G. ASSYS — 12
W.G. BENDS 90° E PLANE — 6
FEED HORN/ TEST UNIT - 711 HB
CROSS GUIDE COUPLER TEST UNIT - 711 HB
DUMMY LOAD
PHASE SPLITTER TYPE - 2b
PHASE SPLITTER TYPE - 1b
FILTER SECTION/ TEST UNIT - 711 HB
DUMMY LOAD
2-db ATTENUATOR
SLIDING SHORT PHASE SHIFTER
TOP VIEW - FEED H
TYPICAL ELEV

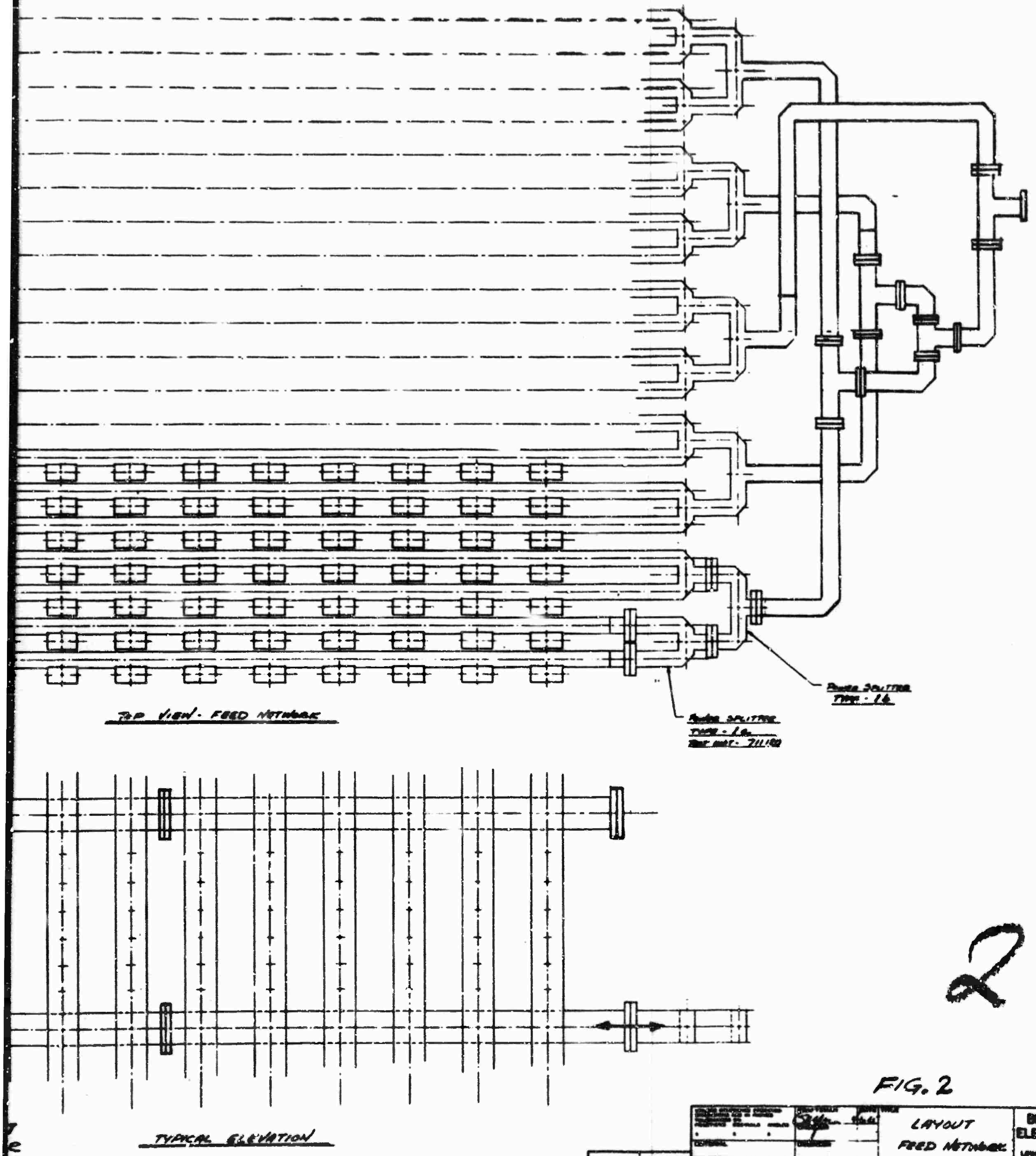


FIG. 2

LAYOUT FEED NETWORK

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Samples of these cast horns have been tested and found to have identical characteristics to the breadboard units. (See Fig. 3)

b) Power Splitters for Horn Matrix (Types IC, 2B Fig.2)
It is required that the four horns of one row operate from a single port, consequently, the power must be split into four equal lines. This is done with an assembly of three power dividers, each of which divides the power into two equal parts. The fundamental design problem for the dividers is their inherent mismatch when all of the terminating lines are of the same impedance. This is apparent if an equivalent circuit is imagined where the two output impedances add in series at the input port resulting in an impedance mismatch of 2:1. A further design problem was the narrow spacing between output arms which was fixed by the horn positions required, i.e., four adjacent horns. Instead of the conventional solution of $\lambda/4$ impedance transformers in each output arm, a novel design solution was devised that offered important advantages in construction. This approach is based on an analysis which shows that a reactive iris added at each junction results in a matched input at any desired power division; the reactive elements together are a "π" or "T" section. This structure reduced, for H-plane equal power dividers, to a single reactance in the junction area.

Figure 3 - Final Feed Horn Configuration

It was realized physically by a single post across the narrow guide dimension in the junction region of the three guides. The final VSWR and power division were 1.08 maximum VSWR with a 3 ± 0.1 db division over 5885 - 6407 MC band for the Type 2B divider and 1.17 maximum VSWR with 3 ± 0.1 db division for the Type 1C divider. This performance exceeded the original design goals of 1.35 maximum VSWR with 3 ± 0.25 db division. (See Figures 4 and 5)

c) Couplers

The couplers are used in conjunction with the filters to divide the system bandwidth into 12 sub-bands each one separately phase shifted. The allowable system loss requires a maximum coupling factor of 16 db, consequently the design objectives are: coupling 16 ± 0.5 db, directivity 23 db minimum over the band 5885 MC to 6407 MC. The design solution was a cross guide coupler with cross type coupling irises; however, a modification is required because the directivity of this type coupler decreases as the coupling is made tighter. Thus, a third iris in the form of a round hole was added to compensate for the decreased directivity. The modified coupler is a hybrid of a "Moreno" and a "Round Hole" cross guide coupler.* The completed design showed 16.15 ± 0.37 db coupling and minimum directivity of 28 db. This exceeded the design goals for both coupling variation and minimum directivity.

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*Microwave Engineers Handbook, 1965, Pages 106, 114.
Horizon House

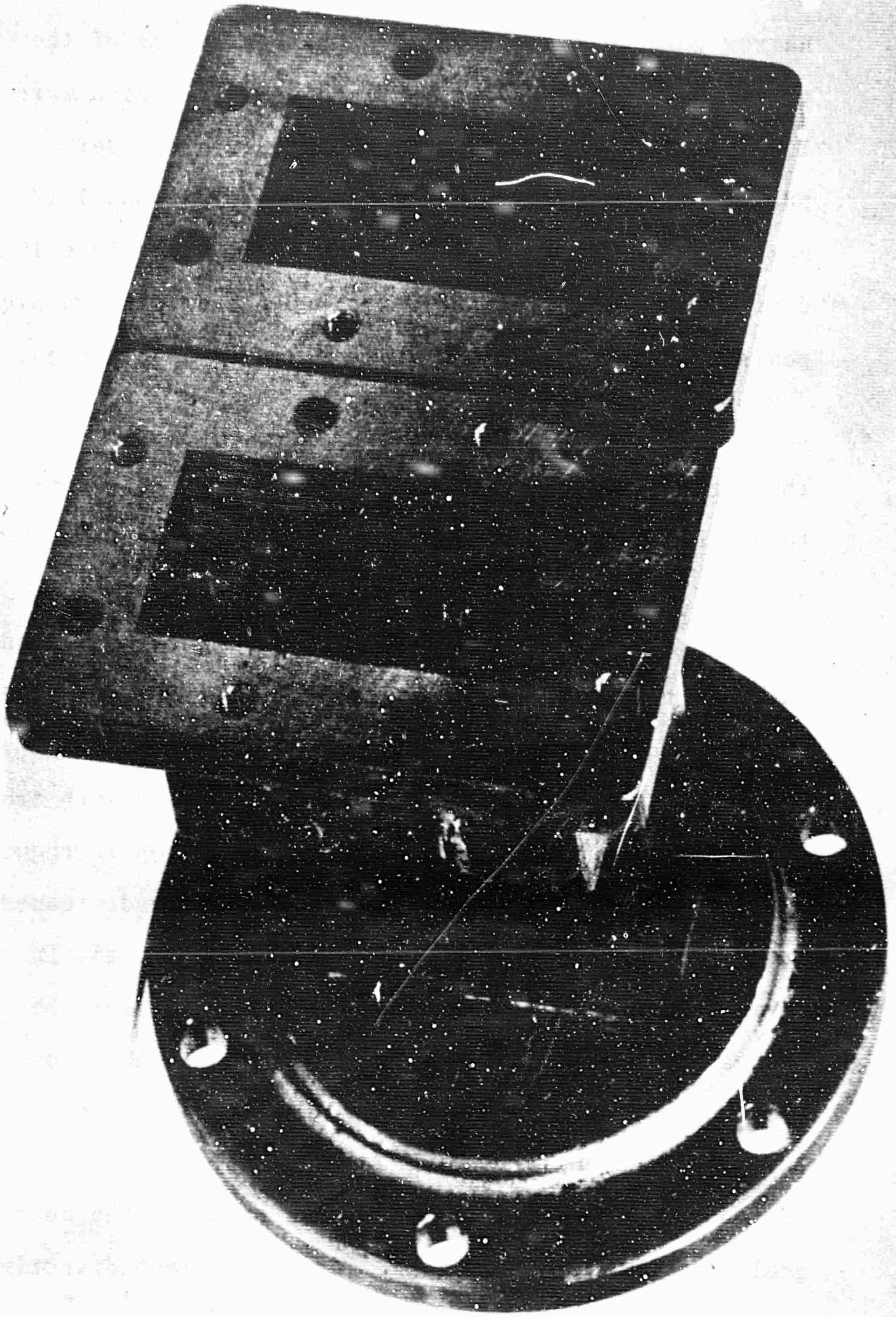

Figure 4 - E Plane In-Line 1:1 Power Splitter

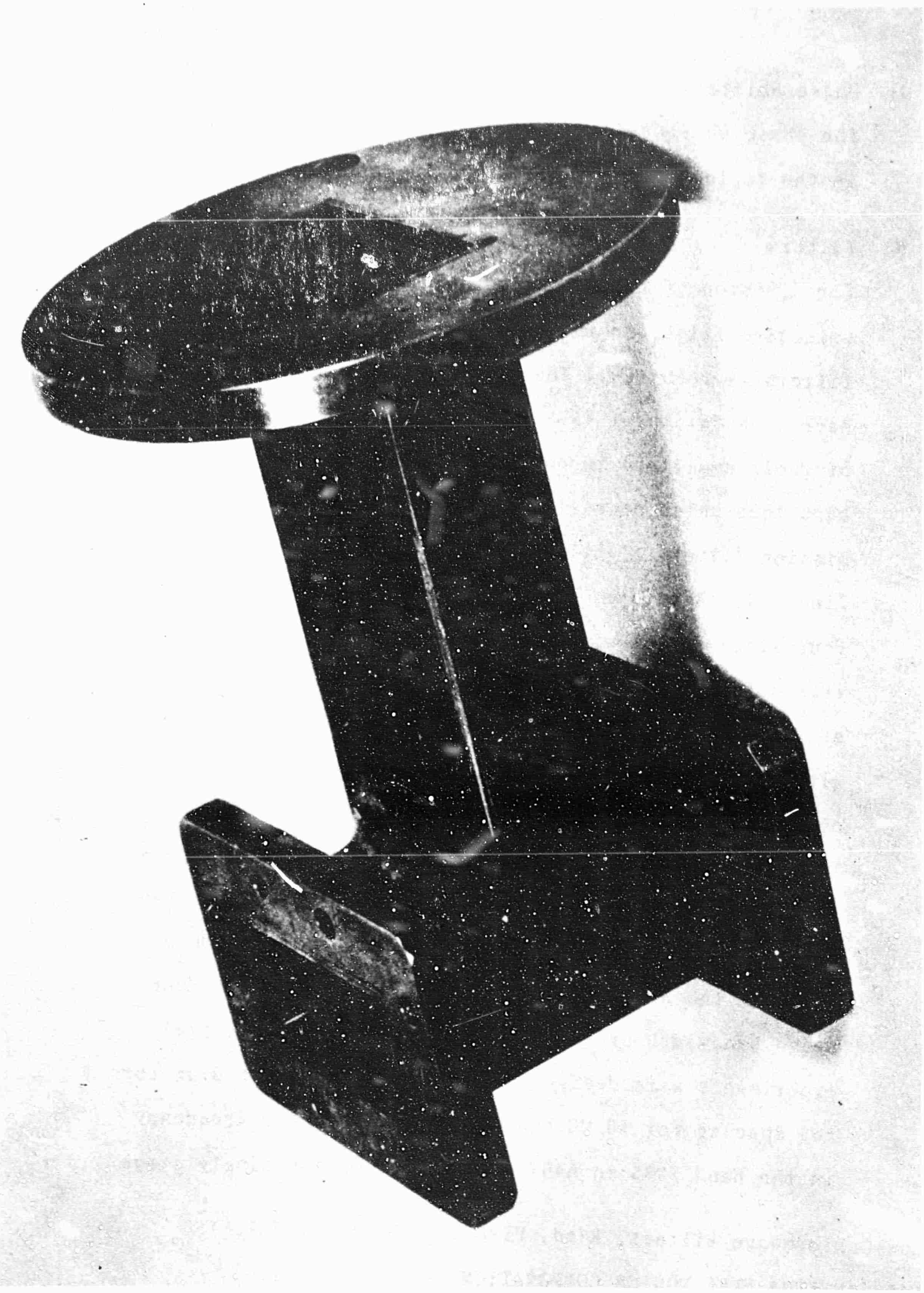

Figure 5 - E Plane 90° Power Splitter

d) Phase Shifters

The phase shifters are essentially the same type used in the reflector array described in Part II. (See Fig.6)

e) Filters

For division of the system bandwidth into 12 channels, selective filtering in the form of 12 band pass filters is required. The individual filters must have a bandwidth of 43.5 MC at the 5.5 db points of their amplitude response with a minimum of pass band loss which necessitates an in-line, or transmission filter, tightly coupled to the transmission line and, therefore, of low Q. The design chosen is a four stage filter with each stage formed of two inductive irises (posts) spaced to give a match (100% transmission) at the resonant frequency*. Four stages are required to give a rectangular response curve having a wider bandpass of high transmission efficiency. See Fig. 7 and 8 . The design goals are 43.5 MC Bandwidth at 5.5 db points, 1 db maximum ripple in pass band, 2 db maximum insertion loss at center frequency. A single stage bandwidth of 50 MC at the 3 db points is required to achieve a four stage bandwidth of 43.5 MC. Consequently the initial experiments were designed to determine the post diameters and spacing for 50 MC bandwidth at any center frequency in the band 5885 to 6407 MC. Based on the single stage

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*Low Q Microwave Filters, Reed, PIRE Vol. 38 No. 7 Jul. '50

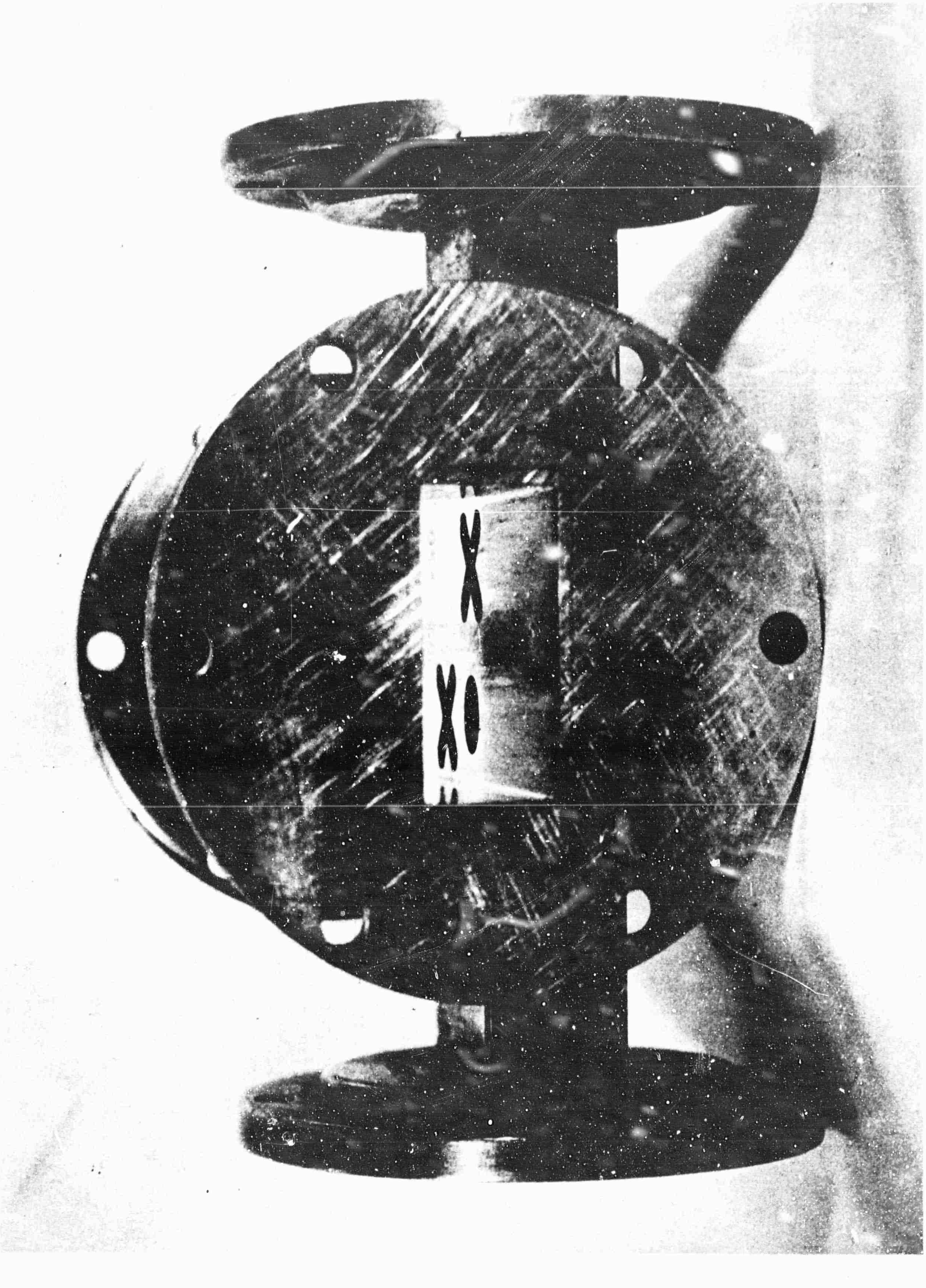

Figure 6 - Crossguide Coupler

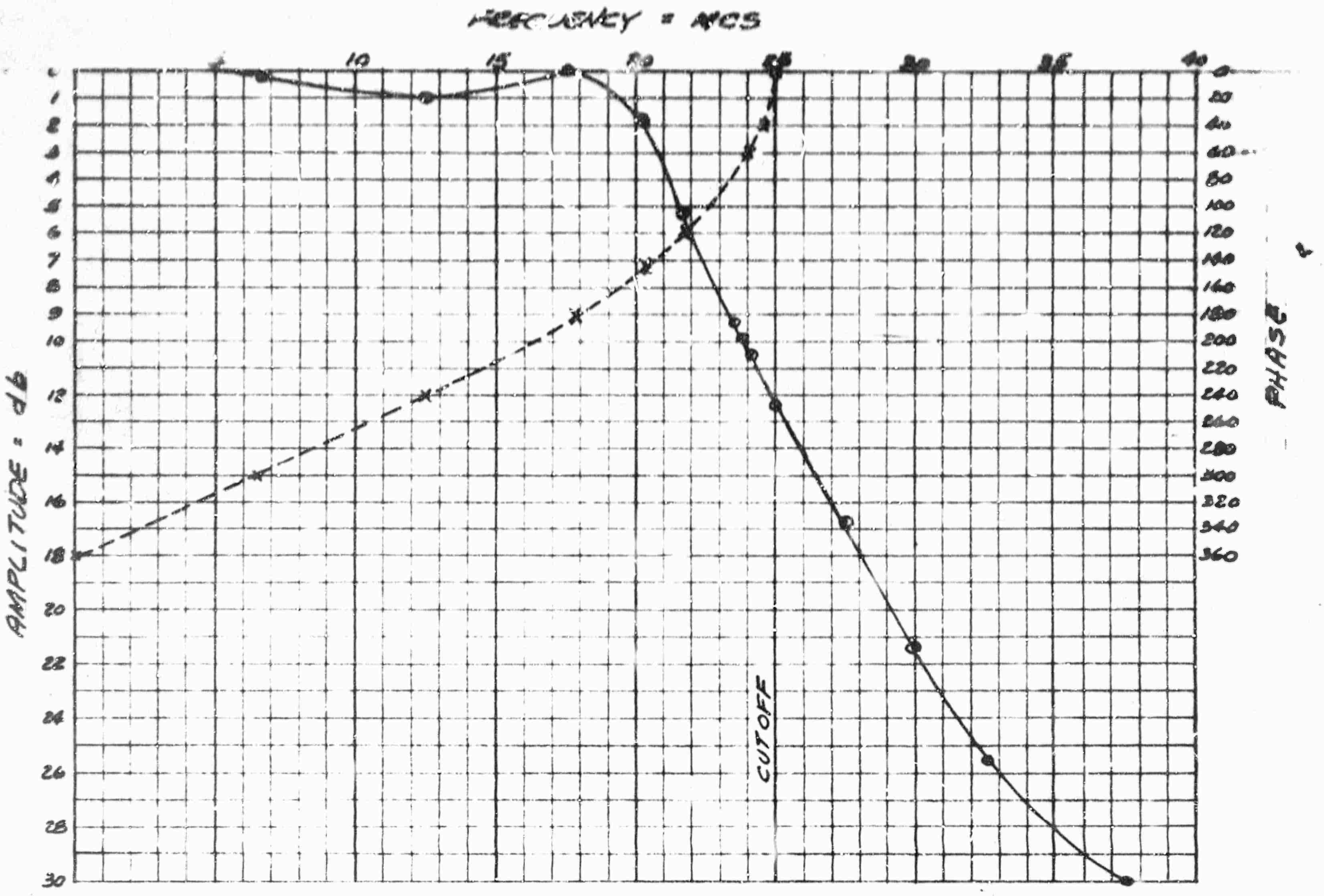

FIG. 7 FOUR STAGE FILTER
AMPLITUDE & PHASE CHARACTERISTICS

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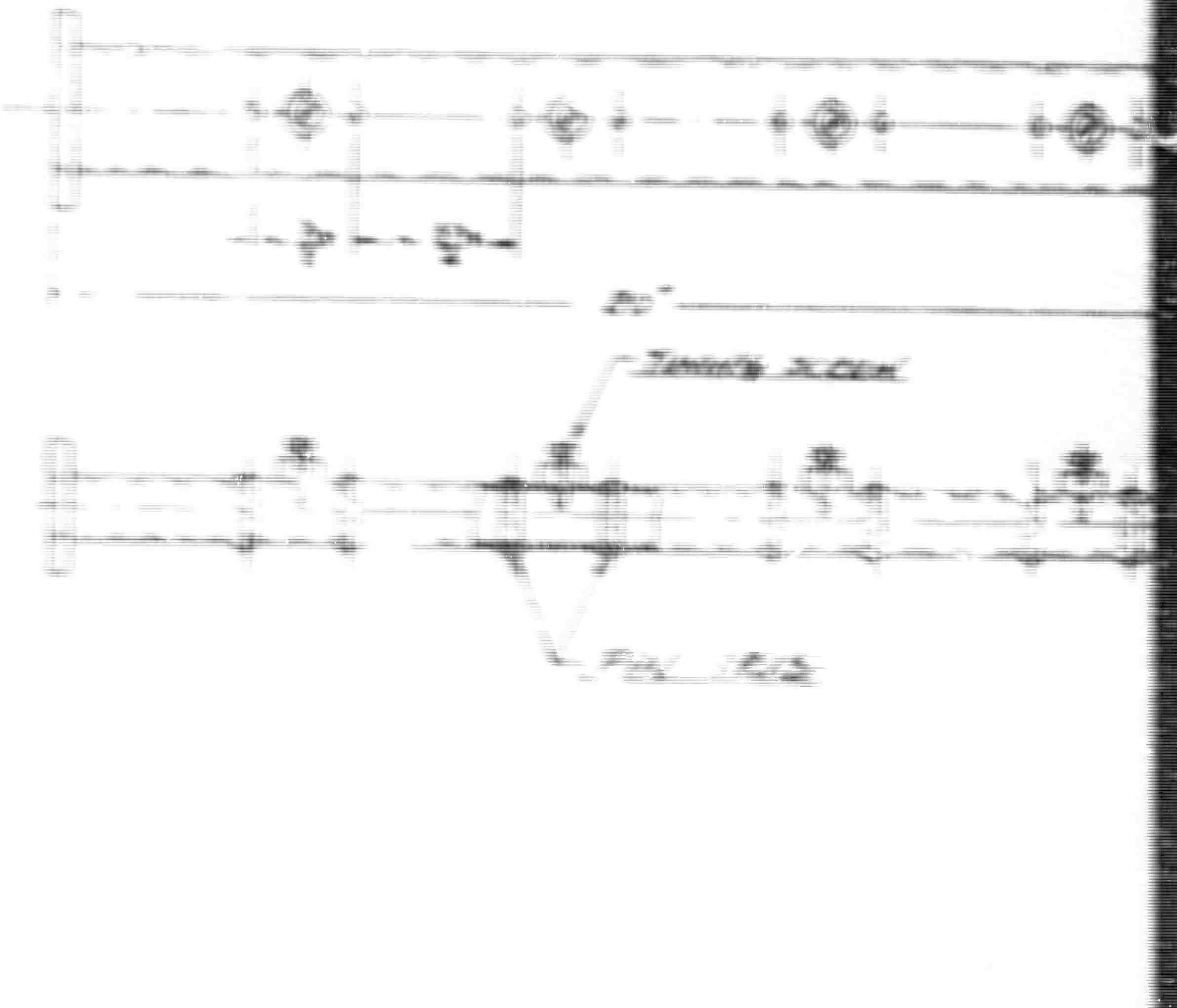

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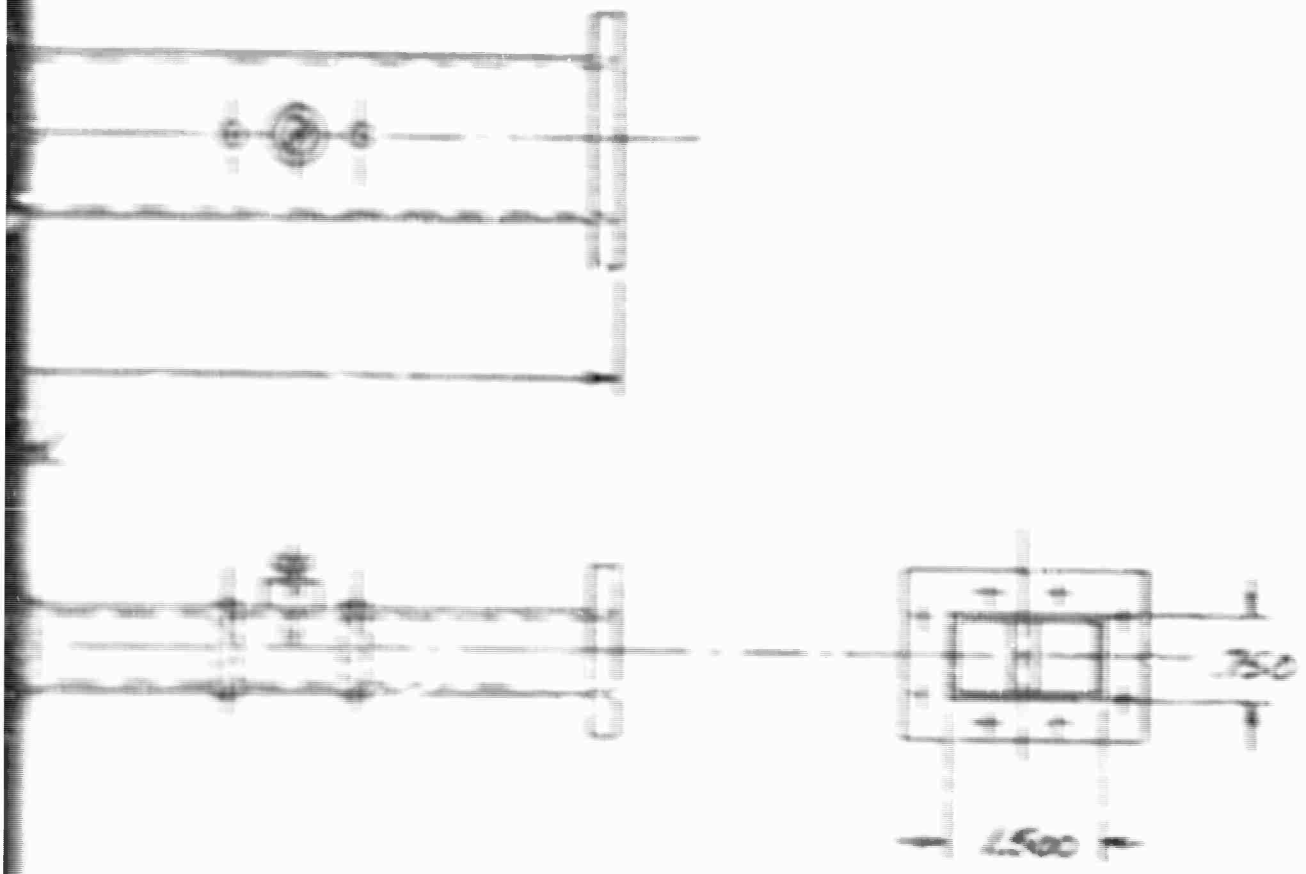

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FIG. 8 FOUR STAGE FILTER

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data several four stage filters were constructed which were modified by the addition of a tuning screw at the center of each stage. These showed a narrower bandwidth than 43.5 MC, which was attributed partially to the effect of the screw on the single stages and partially to the changed center frequency. A third generation design was then made in which the bandwidth per stage was increased to compensate for the narrowing effect. This resulted in 42.0 MC bandwidth, 1.0 db ripple and 1.65 db insertion loss. Since these results compare favorably with the design goals, 6 additional filters of this design are being fabricated with production methods. One additional problem discovered in the early experiments was the extreme sensitivity of the design to the method of attaching the posts to the guide. Various methods using screws, pressure, painting and brazing were tried and it was concluded that brazing alone would give repeatable results. The remaining problem to be resolved by the six units under construction is whether the designs have sufficient tuning range to cover the 12 bands; if not, six additional filters will be designed.

Corporate Feed

The corporate feed is made up of 19 power dividers with associated line lengths. These dividers are of four types all of which are E-plane dividers. The first is a 4:1 divider with right angle output arms. The second type is a 1:1 divider also with right angle output arms. The remaining two are 1:1 dividers with in-line output arms at prescribed spacing between arms. The physical and electrical differences require separate designs for each. The design approach is the same given in the above section on power dividers at the horn, i.e., iris "π" or "T" matching of 3-port junction. The design objectives for all four types is a maximum VSWR of 1.35 with a maximum variation of power division of ± .25 db for each output. Test results on these units are tabulated below:

Type	Coupling (db) Arm 1	Arm 2	Maximum VSWR At Input
4:1	1±0.1	7±0.2	1.15
1:1	3±0.1	3±0.1	1.12
IB	3±0.1	3±0.1	1.12
IA	3±0.1	3±0.1	1.16

Comparison of the table with the design goals shows all units to be well within specifications.

4. CONCLUSIONS AND FUTURE WORK

This report has delineated the problems involved in the development, design and test of microwave components for the prismatic correction system with solution of each problem. The results achieved have been well within the design objectives. Thus, except for the filters, the microwave component design has been successfully completed. In addition, the filter breadboard design is completed and fabrication of prototypes is in process. Final filter design is well within grasp.

The next quarter's work will be concerned mainly with the fabrication of the larger quantities full system components. Testing of sub-assemblies will be performed to assure the final integration of all the parts. This testing will include pattern testing of the horns and feeds, calibration of the filters for the required bands, and testing of the antenna range and the reflector array.

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13. ABSTRACT

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