Construction and performance of antenna couplers for L, S, X, and Ku-bands

Steele, K. A.

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RADIO AND ELECTRICAL ENGINEERING DIVISION

CONSTRUCTION AND PERFORMANCE OF ANTENNA COUPLERS FOR L, S, X, AND K_u-BANDS

K. A. STEELE

OTTAWA

JUNE 1959

ABSTRACT

An antenna coupler may be used for coupling to small microwave antennas at very close spacing for the purpose of making comparative loss measurements on transmission systems terminated in antennas with similar near-field radiation patterns. The design of couplers for use at L, S, X, and K_u-bands is described and details of their performance are given.

CONTENTS

FIGURES

CONSTRUCTION AND PERFORMANCE OF ANTENNA COUPLERS FOR L, S, X, AND K_u-BANDS

- K.A. Steele -

INTRODUCTION

An antenna range is usually required when making comparative loss measurements on microwave transmission systems terminated at one end by antennas. Coupling from a distance is necessary only to provide a free-space termination for the antenna, since, in general, a small radiator cannot be placed in close proximity to an antenna without changing its impedance or radiation pattern. This can be avoided by using a coupling device which is reflectionless. An antenna coupler is intended to be used for coupling energy into an antenna at very close spacing without affecting the electrical characteristic of the antenna. The antenna couplers to be described are essentially small antennas loaded with radio-frequency absorbing material to make them nearly reflectionless to free space.

Couplers may be used for maintenance or production line testing of antennas and connected transmission systems by comparison with some standard. The standard is normally a similar system whose performance is known to be adequate. They are also useful in the laboratory for testing experimental antennas.

PERFORMANCE REQUIREMENTS

To perform its function as a coupling device to an antenna properly, a coupler must meet certain requirements on reflections, transmission loss, and radiation pattern.

a) Reflections

Ideally there should be no reflection from the aperture of the coupler to free space. In practice there is some, and it is measured in terms of the maximum change in VSWR of an antenna when the coupler is moved back and forth directly in front of it. An average coupler aperture reflection coefficient, ρ_c, can be computed from the measured maximum changes in antenna VSWR due to the presence of the coupler from:

$$\rho_c = \frac{\left[\frac{\text{Max. VSWR}}{\text{Min. VSWR}}\right]^{\frac{1}{2}} - 1}{\left[\frac{\text{Max. VSWR}}{\text{Min. VSWR}}\right]^{\frac{1}{2}} + 1},$$

if the coupler VSWR < antenna VSWR, or

$$\rho_c = \frac{[(\text{Max.VSWR})(\text{Min.VSWR})]^{\frac{1}{2}} - 1}{[(\text{Max.VSWR})(\text{Min.VSWR})]^{\frac{1}{2}} + 1},$$

if the coupler VSWR > antenna VSWR.

The ambiguity may be resolved by measuring the antenna VSWR without the coupler in front of it.

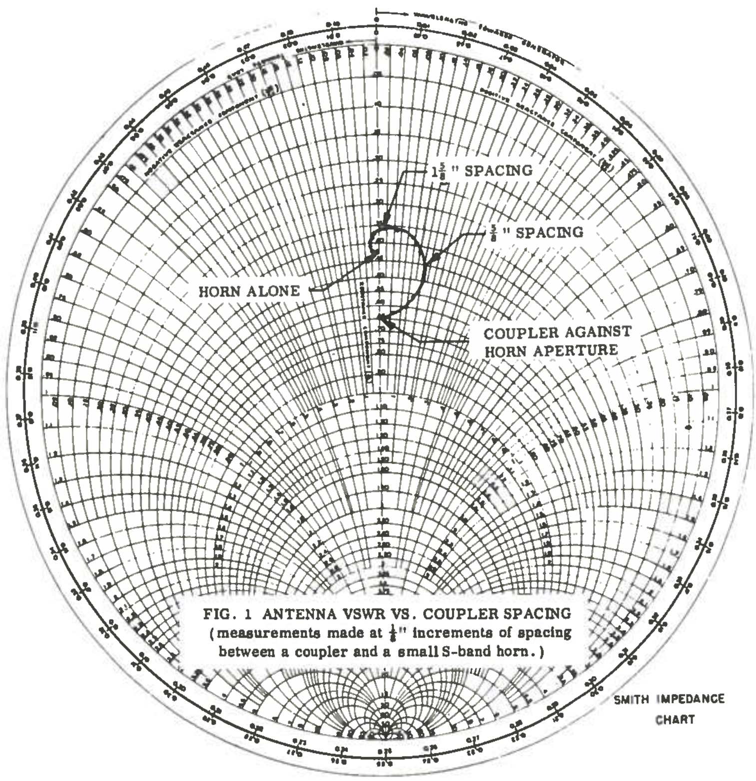


FIG. 1 ANTENNA VSWR VS. COUPLER SPACING (measurements made at 1/8" increments of spacing between a coupler and a small S-band horn.)

Fig. 1 illustrates the variation of antenna VSWR with coupler spacing for the case of a small S-band horn and S-band antenna coupler. A sketch of the equipment used to measure coupler reflection coefficient is shown on Fig. 2.

b) Transmission Loss

The amount of microwave absorber used in an antenna coupler to reduce reflections directly affects the transmission loss through the coupler. With sufficient absorber, the reflection from the coupler can be reduced almost to that from the surface of the absorber. However, this may result in higher transmission loss than can be tolerated. The loss must not reduce the power from the microwave source below the level needed for testing. If the transmission loss must be made small, some sacrifice in performance due to reflections may be necessary by reducing the amount of lossy absorber.

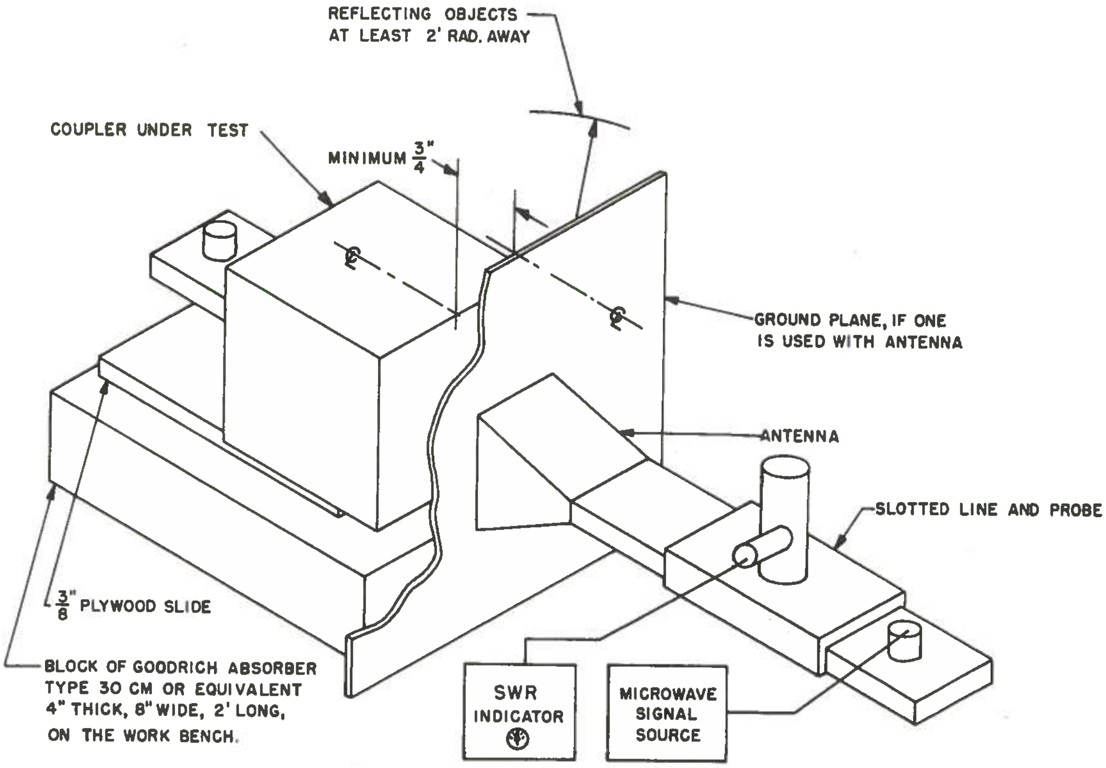


FIG. 2 EQUIPMENT USED FOR MEASUREMENT OF COUPLER REFLECTION COEFFICIENT

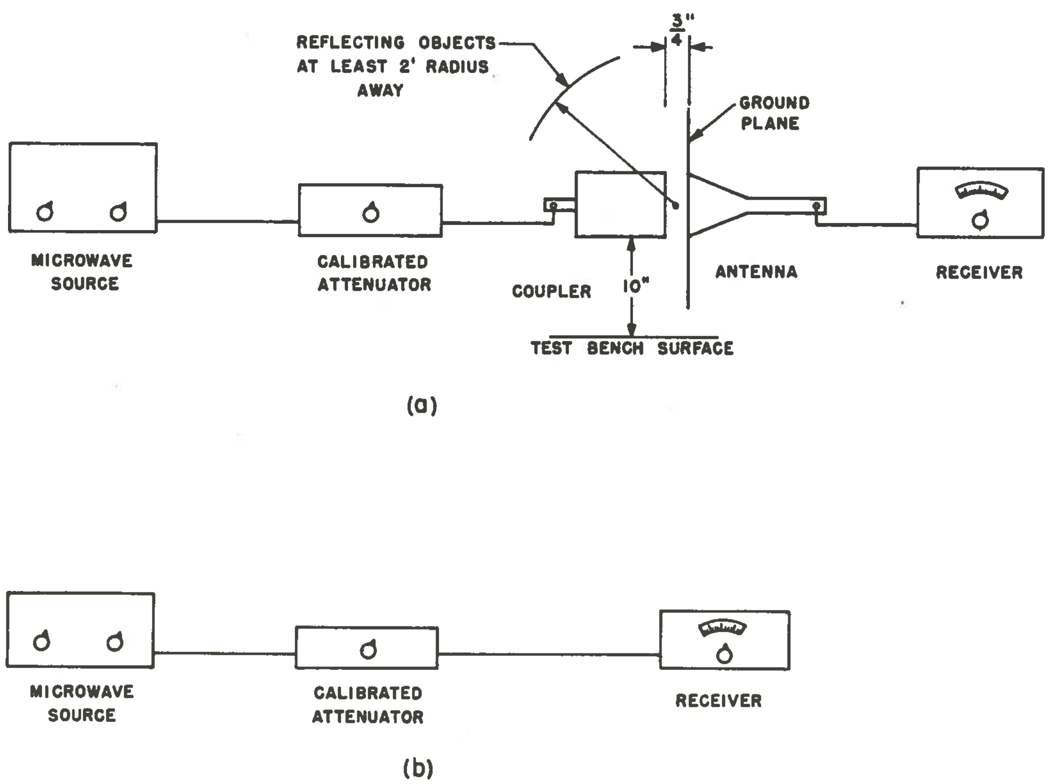


FIG. 3 EQUIPMENT USED FOR MEASUREMENT OF TRANSMISSION AND COUPLING LOSS

Transmission loss, including coupling loss, has been measured by a comparative method. The equipment set up for the measurement is illustrated in Fig. 3. The setting of the calibrated attenuator is noted for a convenient detected signal level at the receiver in the setup of Fig. 3 (a) and again noted for the same level at the receiver for the equipment connections of Fig. 3 (b). The difference between the two attenuator readings is the transmission and coupling loss of the antenna coupler for the particular test antenna. This includes antenna losses, but these are generally comparatively small.

c) Coupler Radiation Pattern

The radiation pattern of the antenna coupler should be fairly broad and smooth. Maximum coupling should occur for the coupler in position directly in front of a test antenna. This is largely dependent upon the coupler box size, the size and position of the radiator within the coupler, and to some extent on the orientation of the microwave absorber.

A broad coupler radiation pattern is necessary so that the coupling does not depend too critically on the location of the coupler relative to the antenna. Too broad a pattern should be avoided also, since this may decrease the coupling and may make measurements with the coupler very sensitive to reflections from nearby objects.

The coupler radiation pattern has been considered broad enough if a $\frac{1}{8}$ inch lateral movement of a coupler from its position directly in front of an antenna does not cause more than 1 db change in coupling. All of the couplers to be described meet this condition.

d) VSWR at Transmission Line Input

An antenna coupler may be used to couple energy to or from an antenna, and in either case it is generally desirable that the VSWR at its transmission line input be low. This is not usually a difficult problem since the absorber placed about the coupler radiator greatly reduces the radiator aperture mismatch.

DESIGN CONSIDERATIONS

a) Box

The size of the coupler box is determined by the size of the coupler antenna required and the amount of microwave absorber which is used. It serves as a protective covering for the coupler antenna and the absorber. The open end of the box must be large enough that reflections from the edges are not too great. This is dependent upon the near-field radiation pattern of the antennas to be tested.

b) Coupler Radiator

With the exception of the L-band coupler with a dipole radiator, all of the couplers designed to date have small horn radiators. Their size was determined experimentally to obtain suitable radiation patterns from the couplers.

c) Microwave Absorber

Two types of microwave absorber have been used in antenna couplers. A broad band hair material (B.F. Goodrich, Type 30 Cm and McMillan, Type H-2) is used in the L-band coupler and has been used in X-band and S-band couplers. This material is partly organic and may deteriorate under moist conditions. The other absorber used is a flexible foam material (Emerson and Cuming, Inc. Eccosorb AN-74, AN-75, AN-77) whose properties as an absorber are not permanently affected by moisture. Both of these absorbers should be stored in a dry place as their transmission loss and reflection coefficient are affected by moisture.

The lossy material is distributed throughout the volume of both of these types of absorber. It is not an even distribution, however, but varies from a very dense loading at the back face to a light loading at the front face of the material.

These absorbers are made to have less than a specified reflection coefficient over a certain band of frequencies. This is the only quantity of interest in their main field of application (lining anechoic rooms, reducing reflections from objects near microwave antennas, etc.). The attenuation through the material is not specified or held to very close limits. Since it may be important that the transmission loss of the couplers should not exceed a certain amount, a cut and try procedure must be used with each sheet of absorber. An alternative is to order absorber with a specified attenuation and the cut and try procedure need be done only for the first sheet used. The manufacturer of the flexible foam material has indicated that material with a specified attenuation can be supplied in quantity lots.

A comparison of the hair type and flexible foam type of absorbing material is given on Fig. 4 over part of L-band. This is given in terms of reflection coefficient and was measured in the same way as coupler reflection coefficient. The hair type of absorber performs better at L-band than the flexible foam material. This is the reason for using only hair material in L-band couplers. The performance of the two types of absorber is approximately the same at higher microwave frequencies.

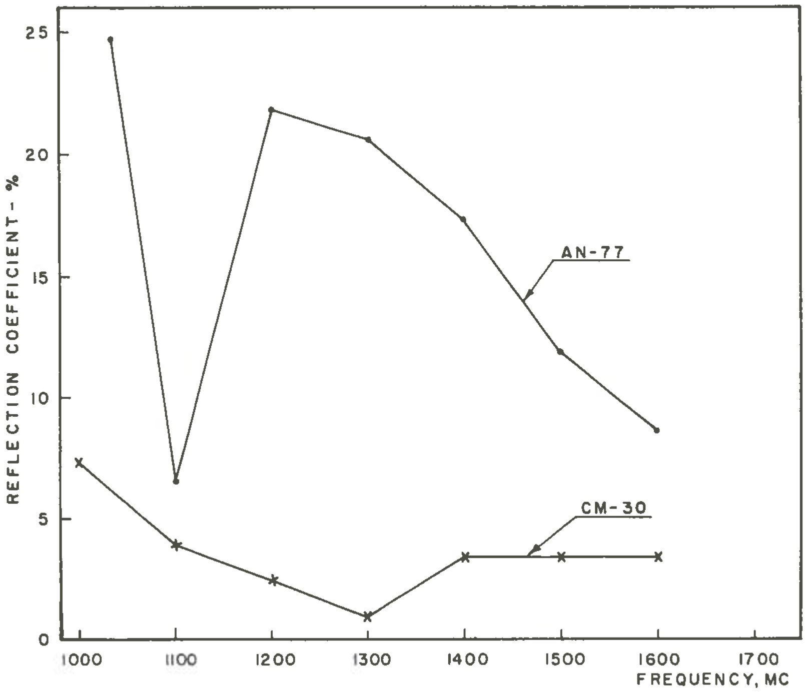


FIG. 4
COMPARISON OF ABSORBER MATERIALS
REFLECTION COEFFICIENT OF 8" X 8" PIECES

d) Weatherproofing

1) Plastic Foam A foam-in-place plastic foam (NOPCO P-502) was used to fill all the empty spaces within the coupler boxes. It protects the absorber against moisture and also holds the absorber pieces in place.

Precautions must be taken to ensure that pieces of absorber are not pushed out of position during the foaming process. A coupler box should be foamed with little or no restraint on the foam. This is especially important when foaming around an AN type of absorber. If the plastic foam forms under much pressure it will be forced into the absorber and may form a relatively dense plastic skin on the absorber surface. It has been found that this increases the reflection from the absorber.

Foaming the inside of couplers is most easily done in three or four stages. Small amounts of foam may be used to fill one section of the coupler box at a time.

2) Coupler Covers A mechanically strong, low reflection coefficient, moisture-proof cover is necessary for the aperture of the couplers, especially for use outside the laboratory. A number of covers of various thicknesses were

tested in each frequency band. Most of them were made of Fiberglas cloth impregnated with an epoxy resin or Fiberglas cloth faced with polyethylene.

The covers for X-band and K_u-band couplers present the most difficult problem as they must be very thin to avoid excessive surface reflection. Epoxy resin (Hysol type 6020) impregnated covers were made by brushing the resin onto the Fiberglas cloth when the cloth is formed over a suitable wooden mold. The mold is removed after the resin has been cured.

Polyethylene faced Fiberglas cloth covers were made as flat sheets only. The fabrication of shaped covers of this type would require accurately machined male and female molds. Covers were made by sandwiching the Fiberglas with four layers of 0.002 inch polyethylene (two layers on each side) between two aluminum plates ($\frac{3}{8} \times 6 \times 6$ inch), clamping the plates, and cooking in an oven at 380°F for about 20 minutes. Fewer layers of polyethylene were tried but this usually resulted in a cover with pinholes.

e) Posts

Four small metal posts mounted at the corners of the coupler boxes were used for locating couplers at a fixed distance from antenna apertures which are mounted flush on a ground plane. The posts extend forward from the coupler aperture and rest against the antenna ground plane. Various types of hooks or latching devices have been used to engage the posts on the ground plane temporarily so that the coupler is held in position at a fixed distance directly in front of the antenna aperture. The coupler-to-antenna spacing was normally about $\frac{3}{4}$ inch for all couplers.

No further description of the posts will be given as they are simply a mechanical aid in using the couplers in some applications. Posts of $\frac{1}{4}$-inch-diameter aluminum rod were used on all of the couplers to be described. They have very little effect on the coupler reflection coefficient.

COUPLER DESIGNS AND PERFORMANCE

Construction details and performance data are given for several couplers on the following pages. These couplers were specifically designed for making comparative loss measurements on microwave transmission systems terminated in small horn antennas flush-mounted on a ground plane. Antennas similar to these were used in making the reflection coefficient and transmission loss tests on the respective couplers.

The following are the horn aperture sizes of the antennas for which the couplers were designed:

L-Band	-	2 by $6\frac{7}{8}$ inches
S-Band	-	1 by $2\frac{3}{4}$ inches
X-Band	-	$\frac{1}{2}$ by 4 inches
K_u-Band	-	$\frac{5}{8}$ by 2 inches

In practice a fairly wide range of antenna aperture sizes can be tested with the same coupler. It is emphasized, however, that comparative measurements of loss between several transmission systems can be made only if all the antennas have similar near-field radiation patterns.

a) L-Band Couplers

Two types of L-band couplers were made. One uses a slot-fed dipole radiator and the other uses a T-fed slot (waveguide) radiator. The slot-fed dipole coupler will be treated in greater detail since its reflection coefficient is slightly lower than that of the other coupler.

As these couplers were to be used under very humid conditions it was considered desirable to use the flexible foam type of absorber. However, extensive experiments with AN-75 and AN-77 absorbers in L-band couplers were not successful in producing a coupler with a low enough reflection coefficient. Therefore, the hair type of absorber was used. It is loaded throughout its volume with plastic foam to inhibit possible absorption of moisture.

i) Dipole Coupler, 1000-2300 mc/s

Fig. 5 indicates details of the assembly of a dipole-fed L-band coupler. Details of the dipole radiator are given on Fig. 6.

Several sizes and shapes of coupler boxes were tested before the one shown on Fig. 5 was decided upon. It was considered to be the best compromise between overall size and performance. It was concluded that a considerably larger box would be required to make a significant reduction in reflection coefficient. Even so, the size as shown is relatively bulky for portable test equipment.

Performance curves for the coupler are given on Fig. 7.

ii) T-Fed Slot Coupler, 1000-2300 mc/s

No assembly of this coupler is given because the arrangement of the hair absorber is very similar to that used in the dipole coupler. The radiator is a T-fed slot. The slot waveguide dimensions are 2 inches by $6\frac{7}{8}$ inches and it is 5 inches deep. It is mounted in the bottom of a coupler box of the same dimensions as the dipole coupler. The coaxial line input is terminated in a type N

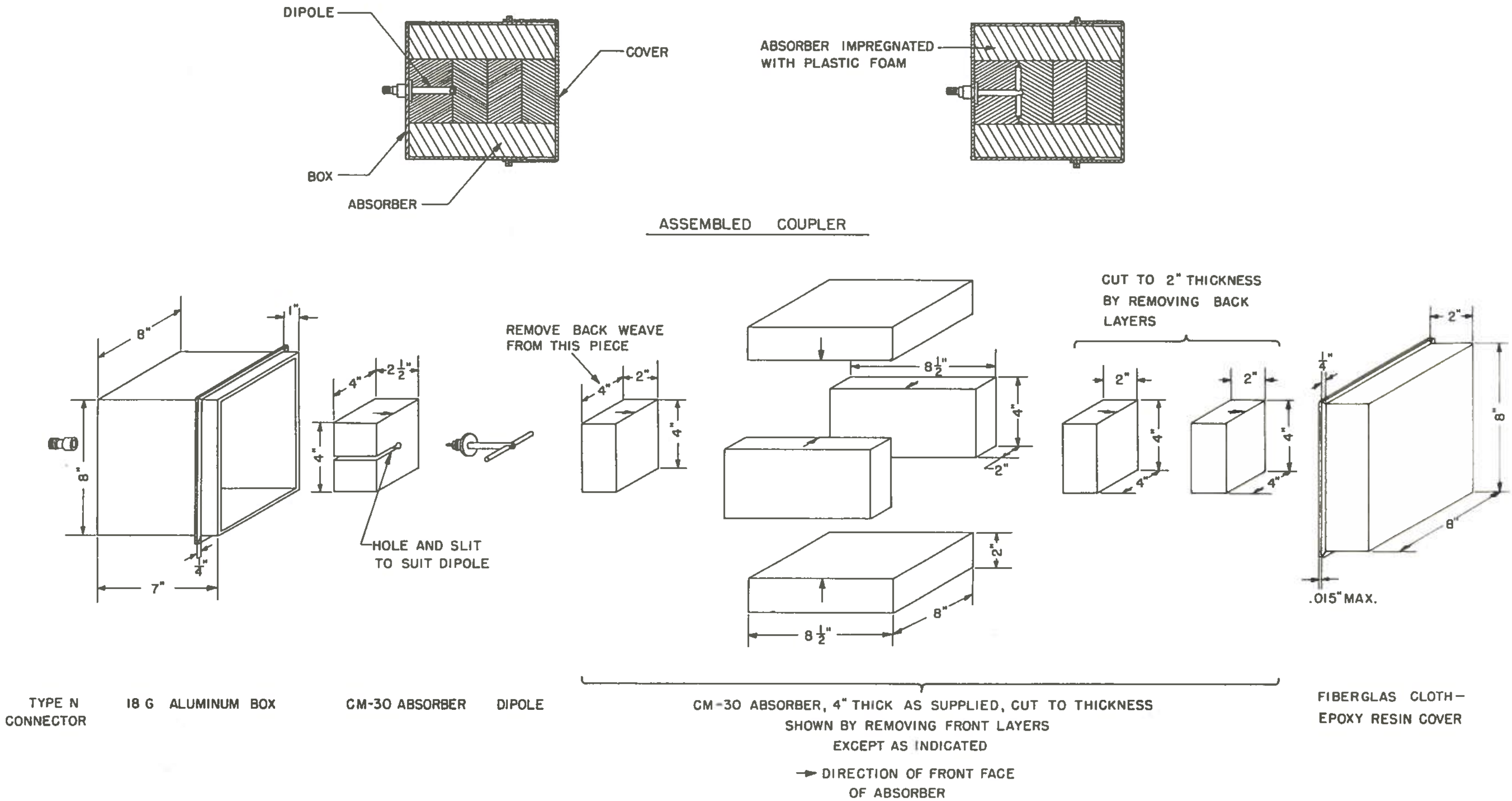
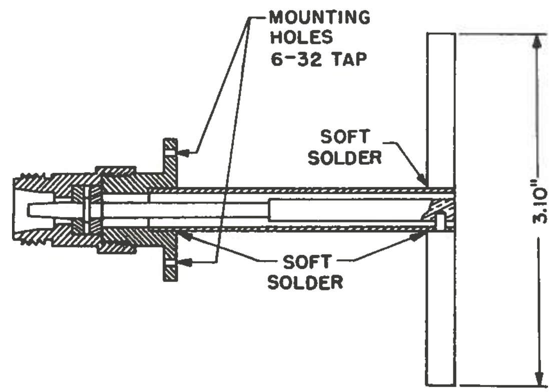


FIG. 5

L-BAND COUPLER, DIPOLE RADIATOR

CM-30 ABSORBER



ASSEMBLED DIPOLE

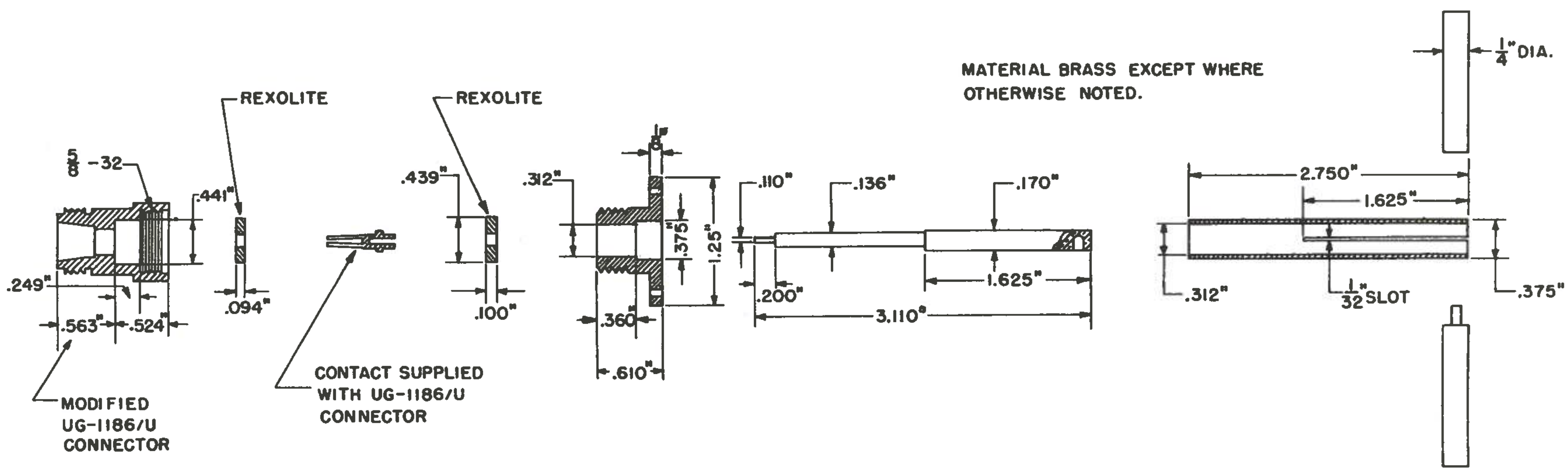


FIG. 6

DIPOLE FOR L-BAND COUPLER

connector mounted on the side of the box.

Performance curves for the T-fed slot coupler are given on Fig. 8.

By comparing Figs. 7 and 8, it may be noted that the dipole coupler has a lower VSWR to free space over a broad band, while the slot coupler has a more constant loss vs. frequency characteristic.

Both of these L-band couplers have similar covers. The cover is made of Fiberglas cloth impregnated with epoxy resin. The required shape is obtained by forming the cloth over a wooden mold, painting on the resin, and curing the cover in place on the mold. Mold release type 122S (Emerson and Cuming, Inc.) is applied to the wooden mold initially to facilitate removal of the cover when the resin has been cured.

Fairly thick covers may be used at L-band without increasing reflections from the coupler appreciably. Covers of Fiberglas cloth-epoxy resin construction up to about 0.015 inch thickness may be used without having much effect on coupler performance.

It may be noted on Fig. 5 that some of the microwave absorber pieces protrude from the open end of the metal coupler box. This was done on both types of L-band coupler and was necessary to reduce the reflections from the edges of the metal box.

b) S-Band Couplers

Three types of S-band couplers were made which are sufficiently different in performance to warrant individual attention. The principle physical difference between them is in the type and arrangement of the microwave absorber. The boxes and horn radiators are similar.

i) Hair Absorber Coupler, 2400-5500 mc/s

The first S-band couplers designed were made with the hair type of microwave absorber . These may be very useful in the laboratory, but under field conditions deterioration of the absorber may occur in spite of the protection afforded by the plastic foam and the cover. The cover is not removable from this coupler. The glass cloth is impregnated with the resin while being

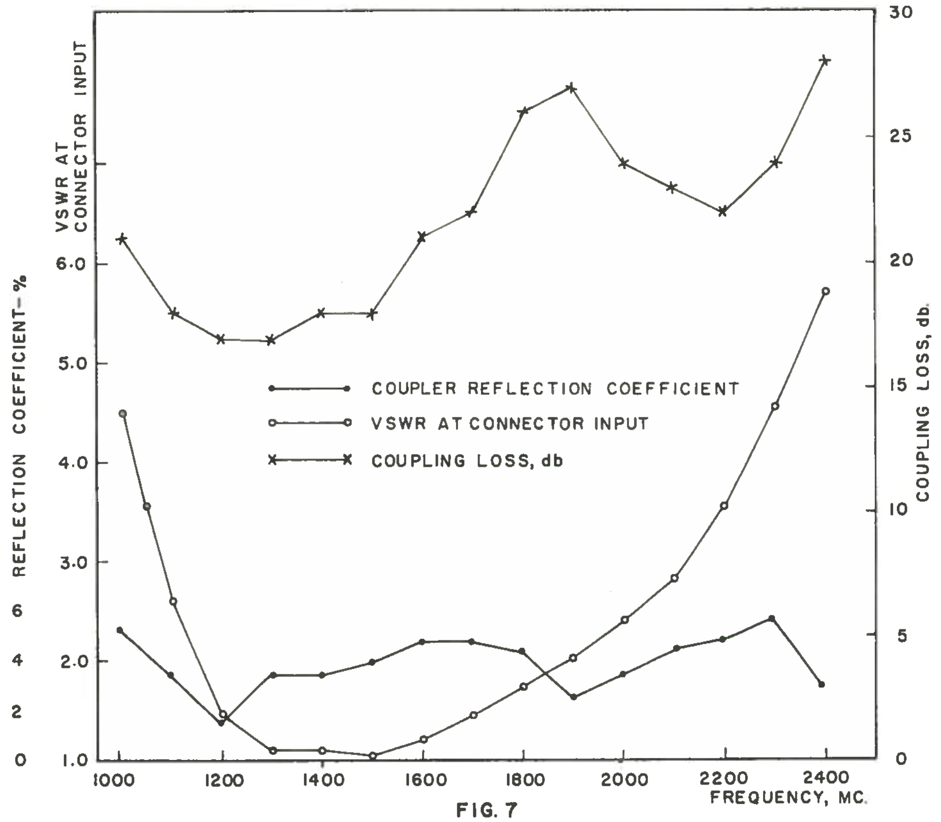


FIG. 7

L-BAND COUPLER, DIPOLE RADIATOR
HAIR ABSORBER TYPE CM-30

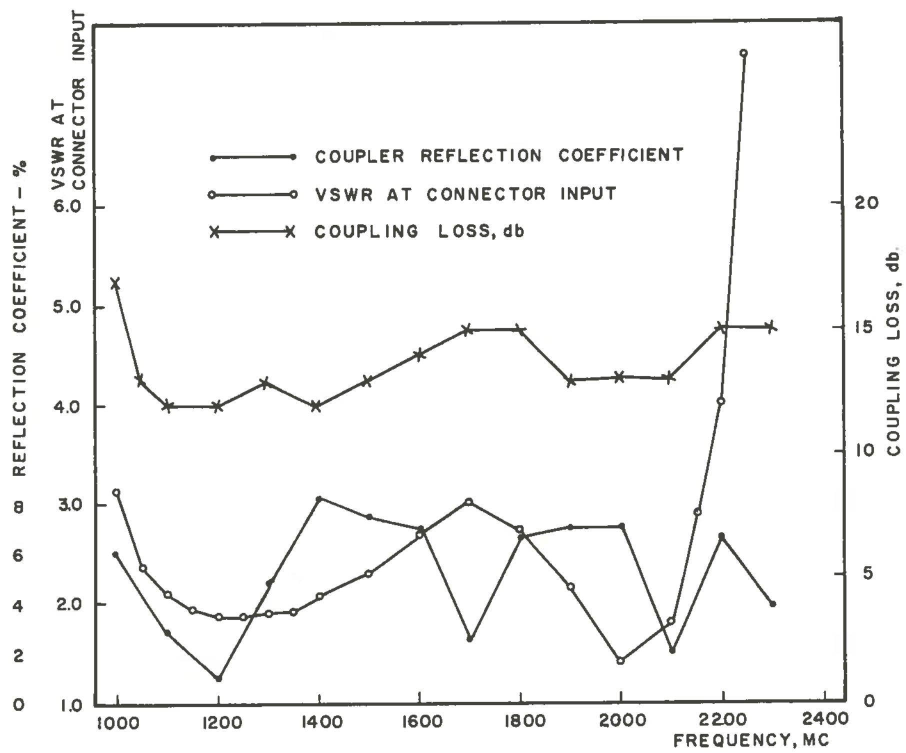


FIG. 8

L-BAND COUPLER, T-FED SLOT RADIATOR
HAIR ABSORBER TYPE CM-30

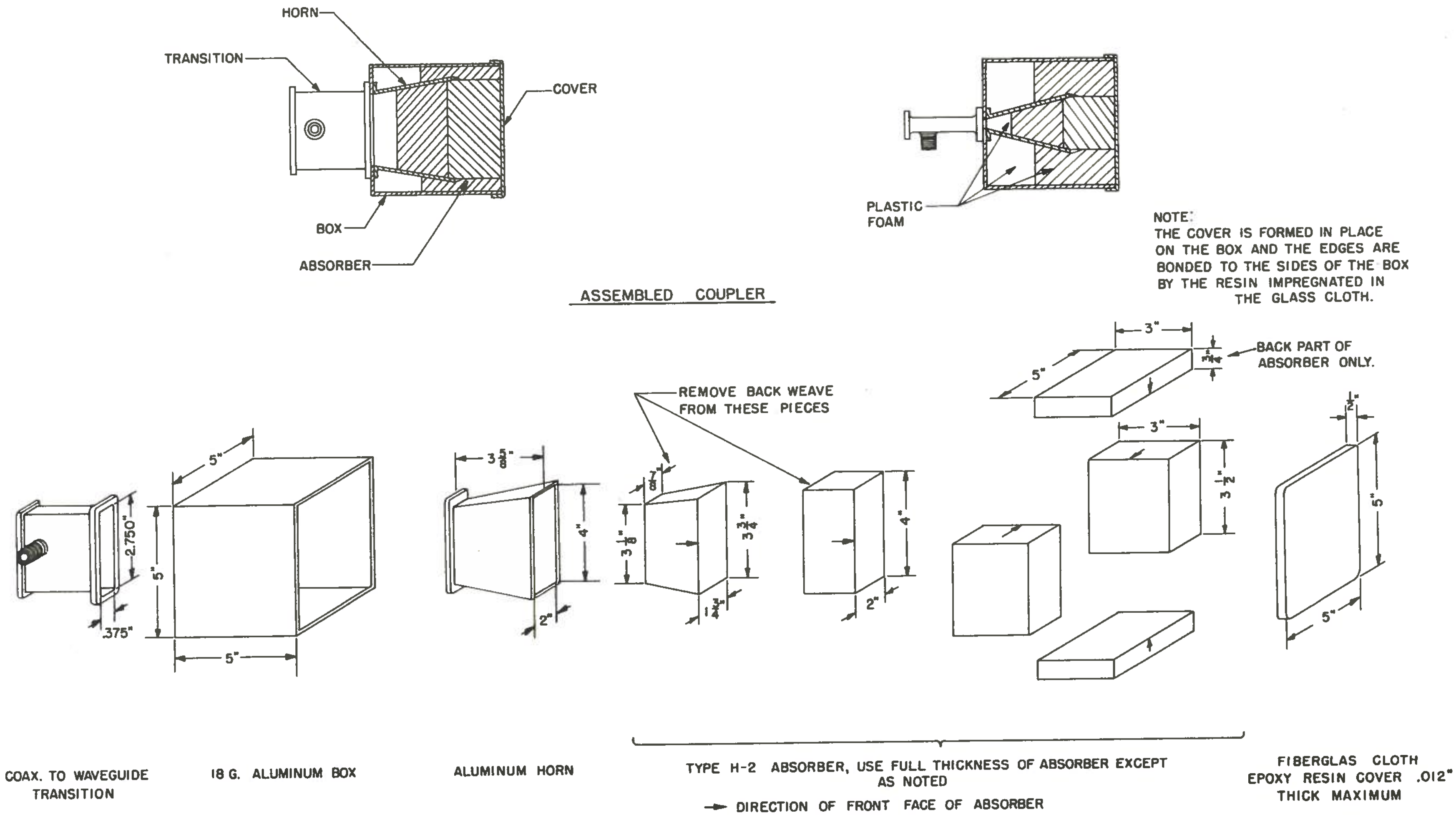


FIG. 9

S-BAND COUPLER—HAIR ABSORBER, TYPE H-2

held in place over the coupler aperture. The cured resin adheres very well to the metal sides of the coupler box.

The assembly of a hair absorber S-band coupler is shown on Fig. 9. Performance curves are given on Fig. 10.

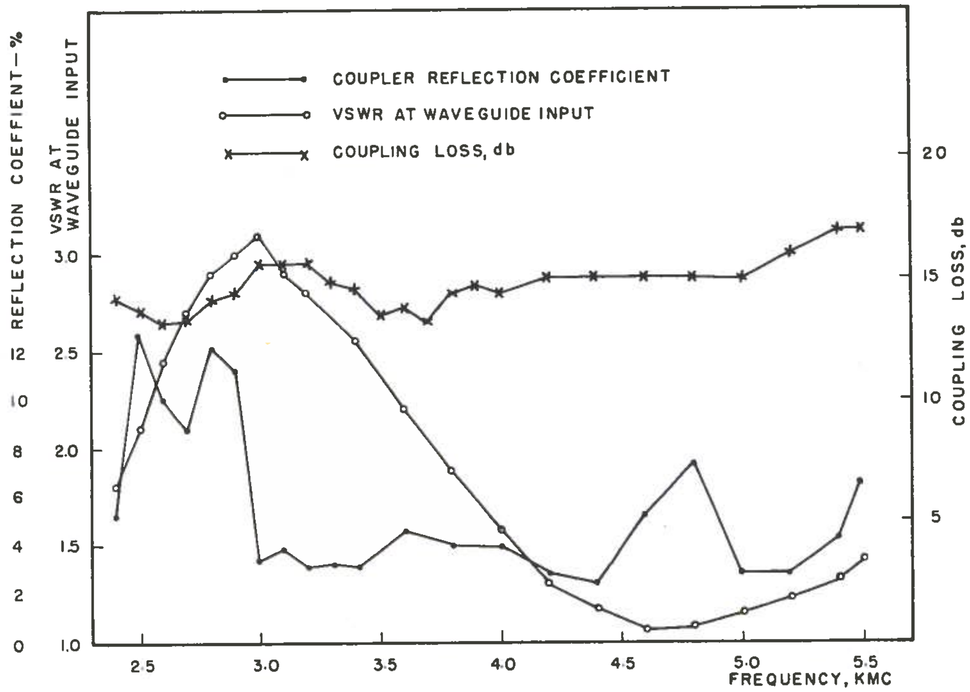


FIG. 10
S-BAND COUPLER
HAIR ABSORBER, TYPE H-2

ii) S-Band Coupler, Type I, 2400-5500 mc/s

Type AN-75 flexible foam absorber is used in this coupler. It was found that minimum reflections could be obtained by using the front two layers only of this material. The basic sheet consists of three layers, each layer back from the front being successively more heavily loaded with lossy material. Placement is such that the plane of the layers at the coupler aperture is normal to the aperture plane. The cover for this coupler is Fiberglas cloth faced with polyethylene. It is clamped to the coupler between a metal cover gasket and a $\frac{1}{4}$ inch flange around the coupler box opening. A suitable adhesive (Bostik 4585 or 3M Brand Type EC1140 cement) is used between the cover and the box flange to obtain a waterproof seal. This type of cover can be replaced fairly easily should it become damaged. The cover is mechanically strong and yet is very flexible.

The assembly details and performance curves for a Type I S-band coupler are given on Figs. 11 and 12, respectively.

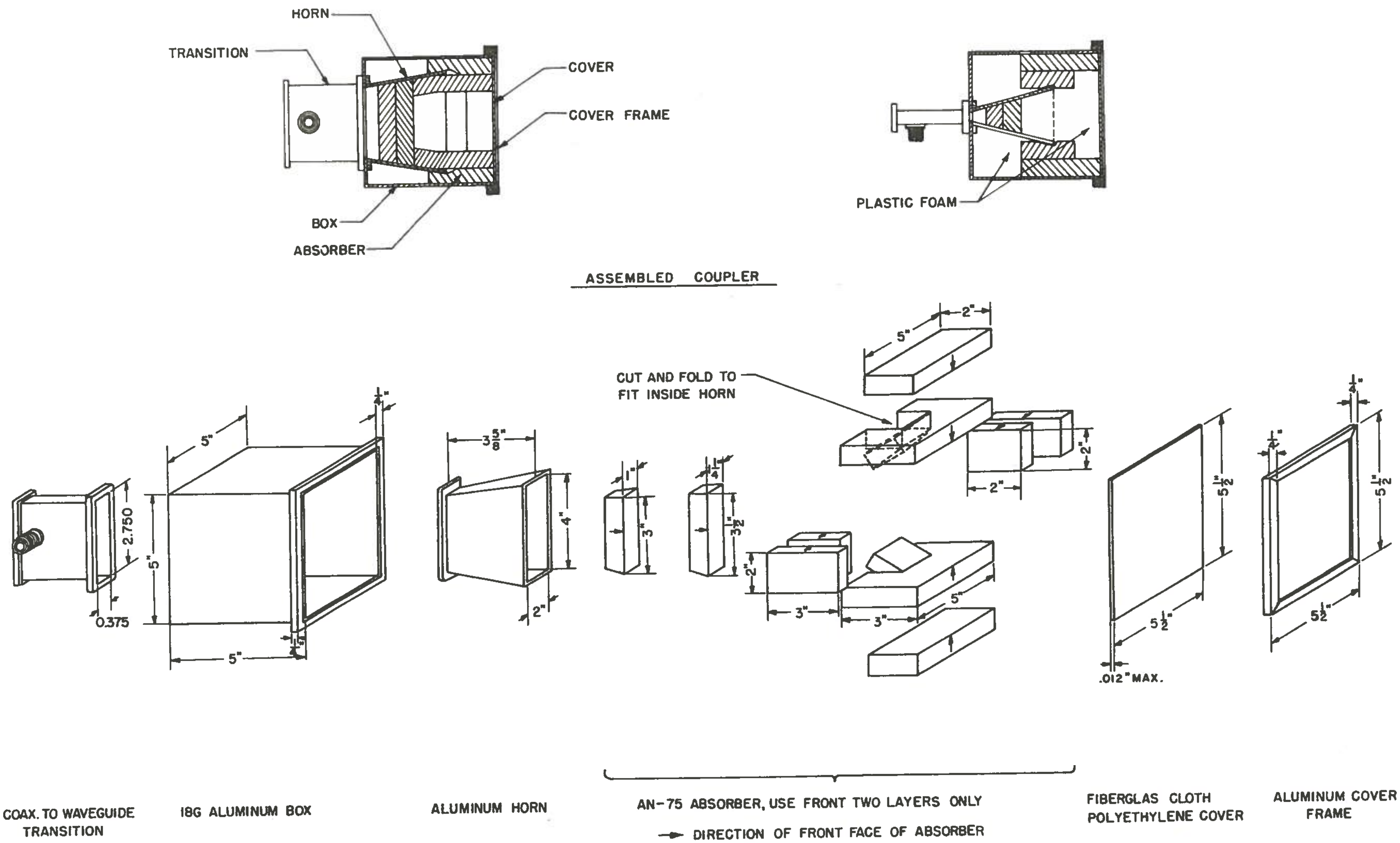


FIG. 11
S-BAND COUPLER, TYPE I
AN-75 ABSORBER

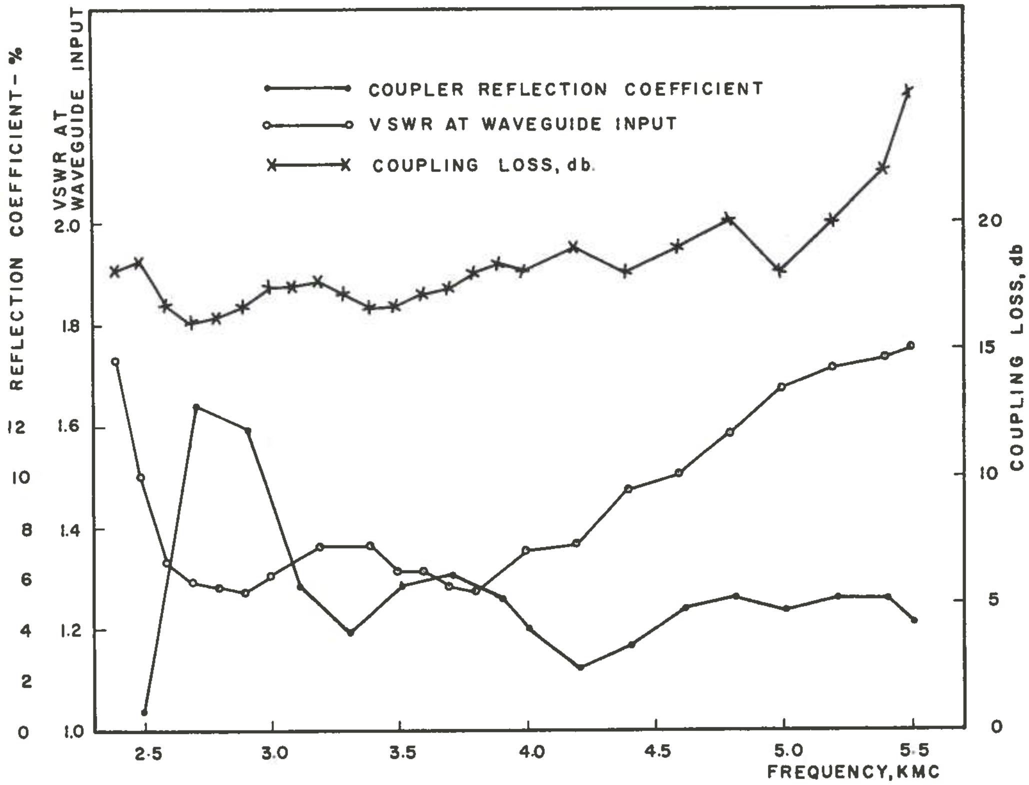


FIG. 12
S-BAND COUPLER, TYPE I
AN-75 ABSORBER

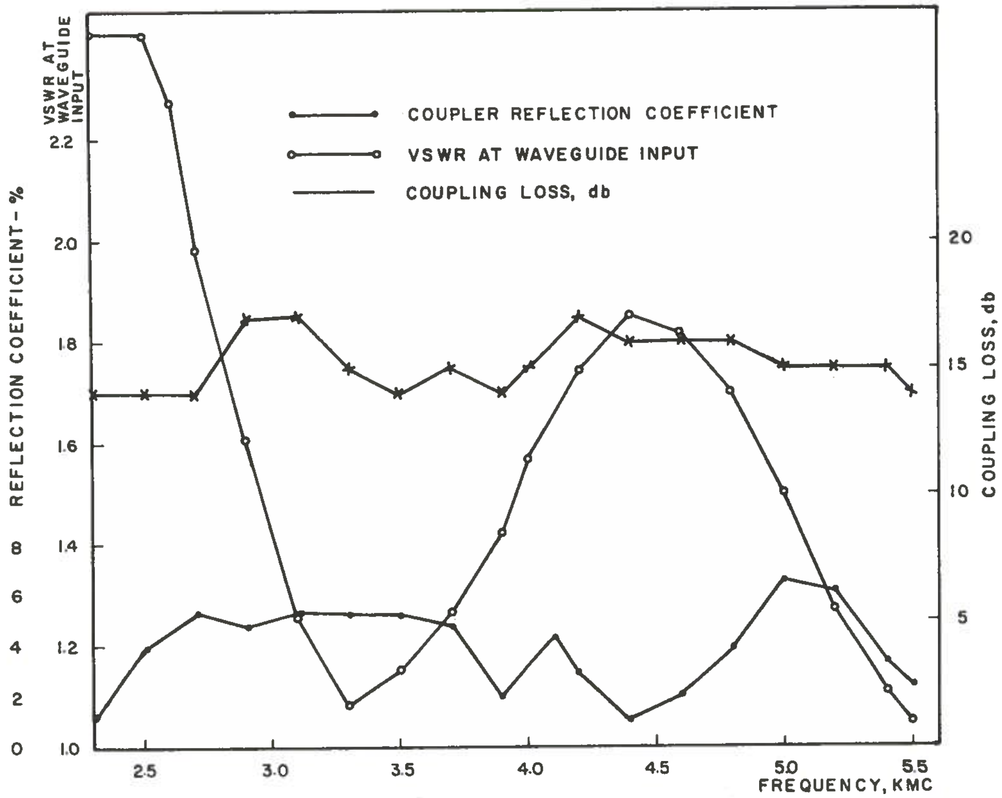


FIG. 13
S-BAND COUPLER, TYPE II
AN-75 ABSORBER

The reflection coefficient of this coupler is greater than 5% below 3100 mc/s. The principle reason for this is that the coupler box is too small. At the lower S-band frequencies reflections from the edges of the box increase considerably. It is known that a significant reduction in reflection coefficient can be attained at frequencies below 3000 mc/s if the coupler box is made $5\frac{1}{2}$ inches wide in the E-plane instead of 5 inches. The performance of this coupler is degraded also because of additional reflections from the $\frac{1}{4}$ inch cover flanges.

iii) <u>S-Band Coupler, Type II, 2400-5500 mc/s</u>

This coupler is very similar to the Type I coupler except that the metal coupler box is $\frac{1}{2}$ inch shorter and a molded Fiberglas cloth-epoxy resin cover is used. The absorber is type AN-75 and its placement within the box is exactly the same as in the Type I box. As the box is shorter, the absorber protrudes from it by $\frac{1}{2}$ inch. The molded cover is shaped, like the L-band cover, to cover the absorber and seal on a $\frac{1}{4}$ inch flange which is located $\frac{1}{2}$ inch below the open edges of the metal coupler box. The box size, cover, and cover flange shown on Fig. 20 for the X-band Type II coupler are identical to those for the S-band Type II coupler.

With this construction, reflections from the edges of the metal coupler box are reduced without increasing the physical size of the coupler.

Performance curves for the S-band Type II Coupler are given on Fig. 13.

c) <u>X-Band Couplers</u>

As at S-band, three different designs of X-band couplers were constructed. A preliminary model was made with the hair-type of microwave absorber. The other two couplers use the flexible foam type of material.

i) <u>X-Band Coupler, Hair Absorber, 8000-11,000 mc/s</u>

This coupler is included to illustrate a simple design which may be useful for laboratory testing. Although its reflection coefficient is generally higher than that of the flexible foam absorber couplers, it should not be concluded that the flexible foam material is necessarily a better absorber electrically at X-band. Little experimentation with placement of the hair absorber was done. Instead, the aim was to make a reliable coupler of low reflection coefficient with the flexible foam material. This was also the case with the S-band couplers.

Assembly details of the Hair Absorber X-band coupler are shown on Fig. 14. Performance curves are given on Fig. 15.

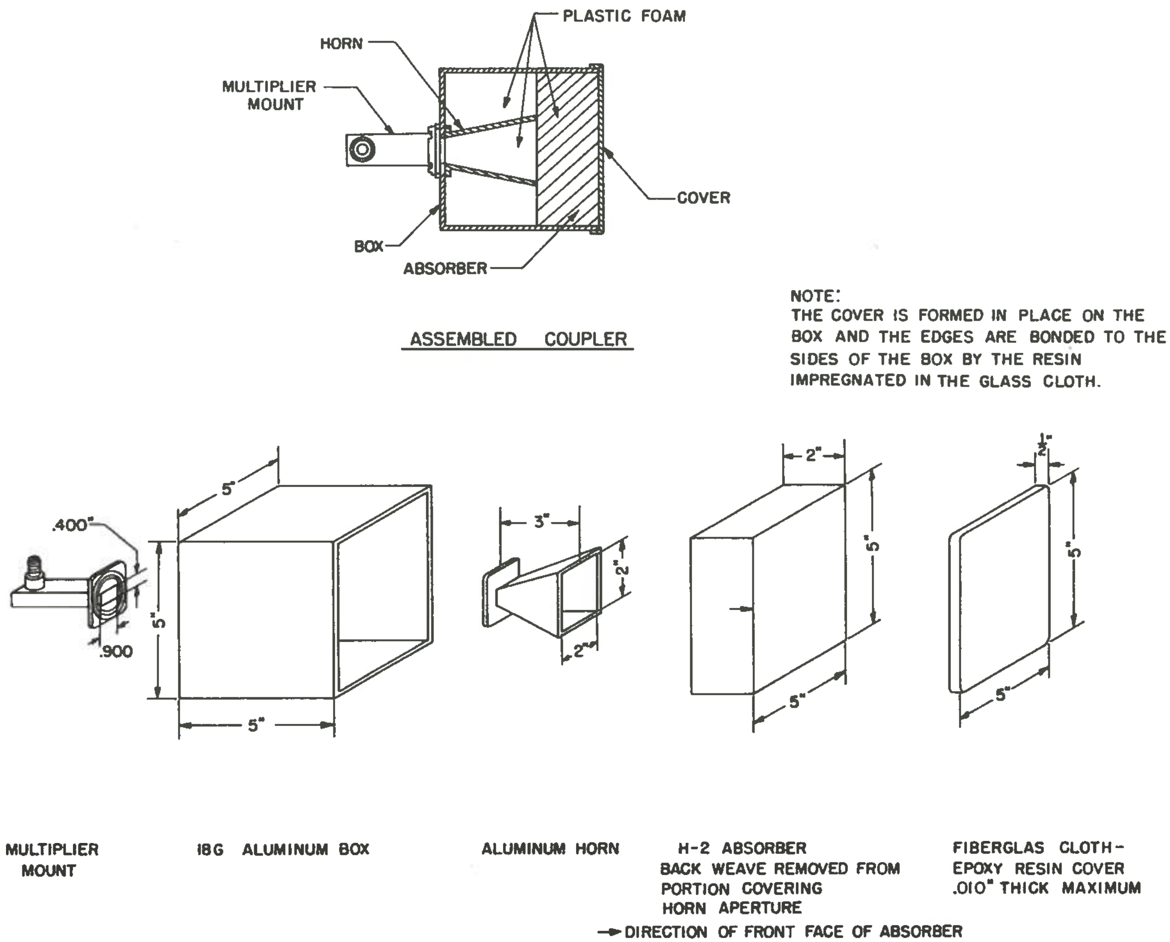


FIG.14

X-BAND COUPLER—HAIR ABSORBER, TYPE H-2

$\frac{1}{2}$ X 1 INCH WAVEGUIDE

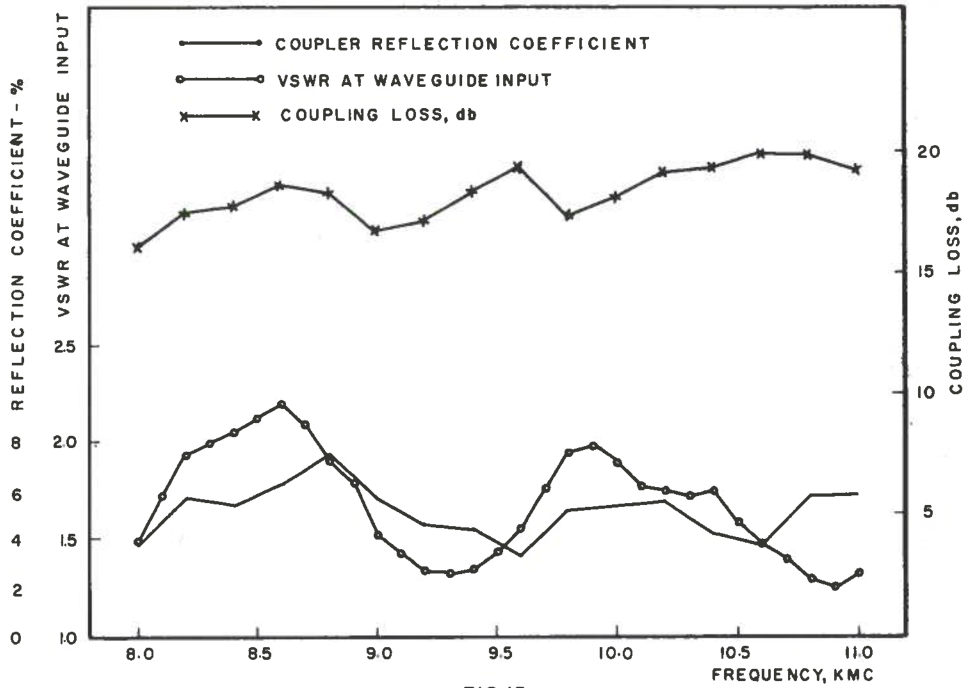


FIG. 15
X-BAND COUPLER
1/2" x 1" WAVEGUIDE
HAIR ABSORBER TYPE H-2

ii) <u>X-Band Coupler, Type I, 8000-11,000 mc/s</u>

This coupler was designed for field testing small X-band receiving antennas. The coupler is normally connected to a microwave source by a short length of flexible, coaxial transmission line and test signal is radiated from the coupler toward the antenna of the microwave transmission system being tested. Comparative measurements require a stable source of test signal. In this case the microwave source, transmission line, and coupler must be stable. Available coaxial cables were found to be either not flexible enough or their transmission loss at X-band was too variable. This coupler was therefore operated with a frequency multiplier mount connected to its waveguide input. An S-band source is used, and the third harmonic output of the multiplier mount is transmitted from the coupler. This system has been found to be quite stable (with a stable microwave source). RG-55/U cable transmits the S-band energy from the source to the multiplier mount on the coupler.

Since the amplitude of the X-band harmonic is approximately 20 db below the S-band power input, the transmission loss of this antenna coupler was made as low as possible without unduly increasing the reflections.

The same type of cover is used as on the S-band, Type I coupler.

Fig. 16 shows assembly details of the X-band, Type I coupler and Fig. 17 gives performance curves.

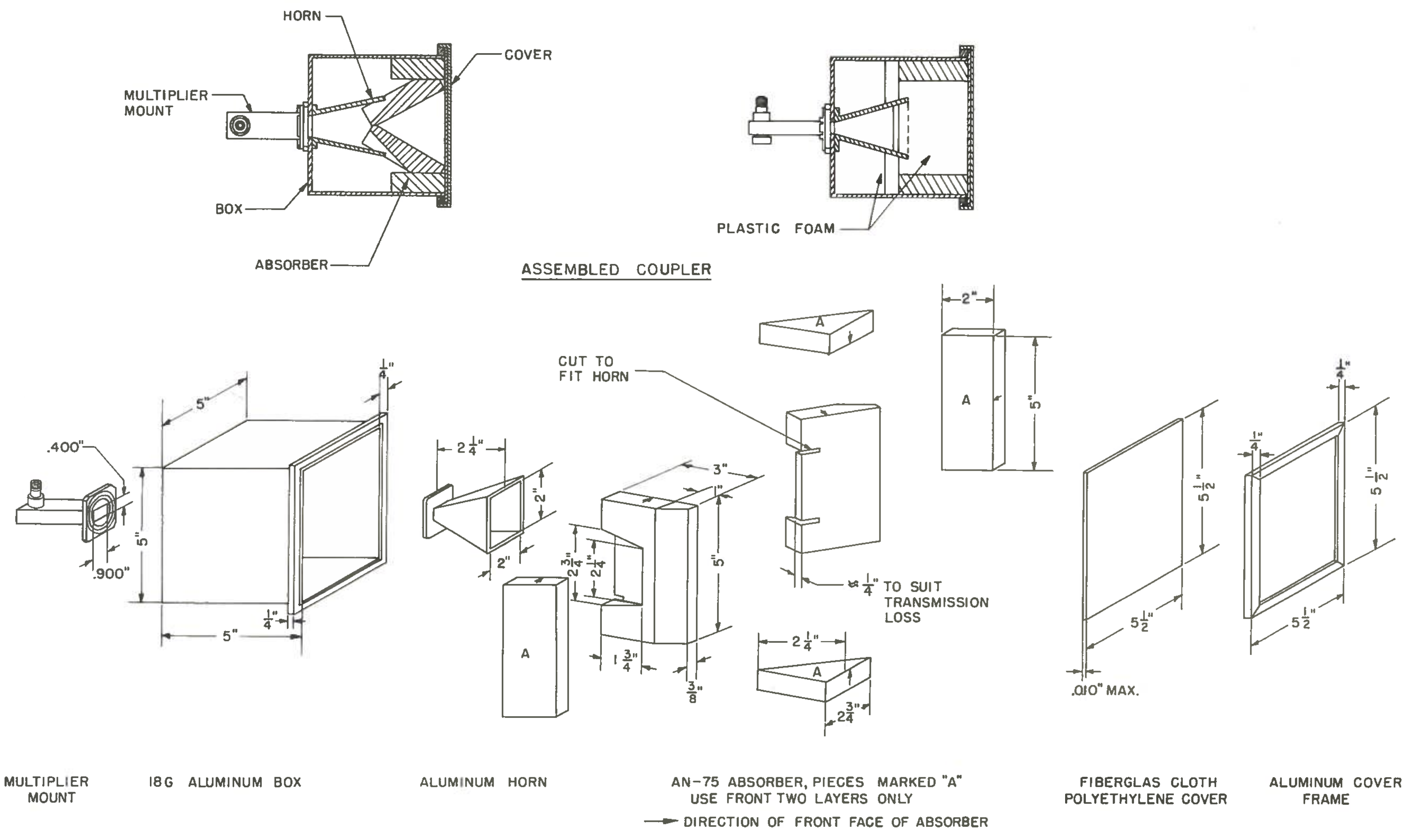


FIG. 16

X-BAND COUPLER, TYPE I

AN-75 ABSORBER, $\frac{1}{2}$" x 1" WAVEGUIDE

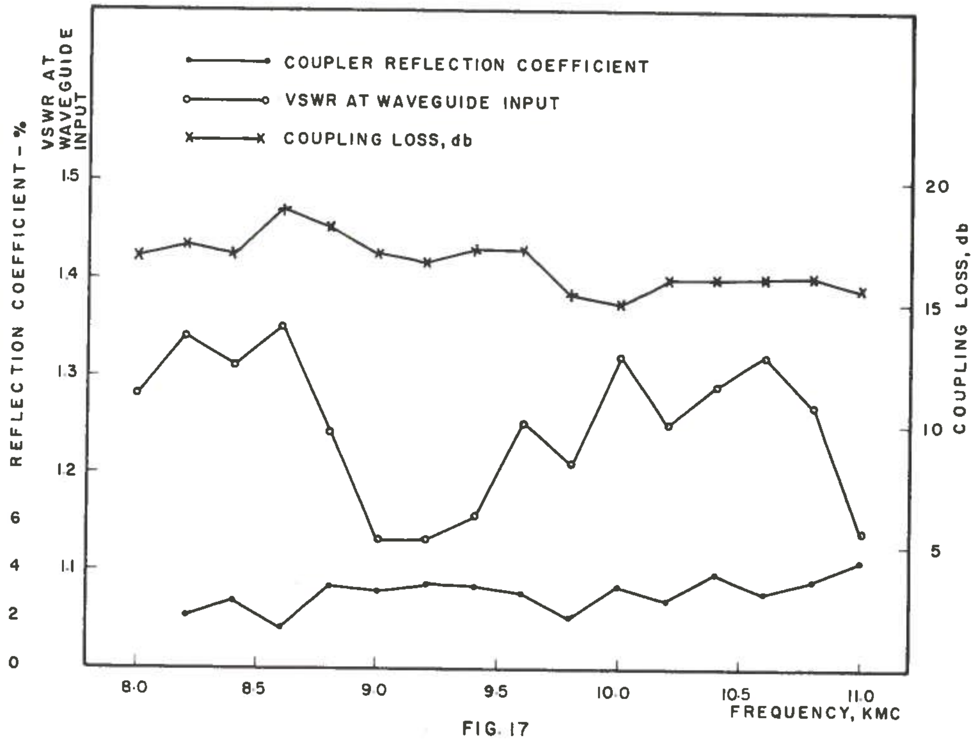


FIG. 17
X-BAND COUPLER, TYPE I
1/2" x 1" WAVEGUIDE
AN-75 ABSORBER

The Fiberglas cloth-reinforced plastic covers of 0.010 inch thickness have an increasingly more significant effect on coupler reflections, beginning at the lower X-band frequencies. Curves of coupler reflection coefficient with several different covers, are shown on Fig. 18. The curves shown include the effect of the cover flange, except in the case for no cover.

It should be noted that a cover of 0.007 inch Fiberglas cloth and 0.008 inch polyethylene is not 0.015 inches thick. In the heat sealing process most of the thickness of the polyethylene is absorbed into the cloth. The finished thickness of this cover would be approximately 0.010 inches. The 0.007 inch cloth - 0.008 inch polyethylene combination was the cover finally chosen for the X-band Type I coupler.

Fig. 19 shows reflection coefficient curves at different stages in assembly for an X-band Type I coupler. The posts are for locating the coupler at a fixed spacing from the aperture of an antenna. They are a set of four metal rods attached to the coupler at the cover flange and are about $\frac{1}{4}$ inch in diameter and $1\frac{1}{2}$ inches long. The posts and foam have very little effect on reflections. In Fig. 19, the largest contribution to increased reflections is caused by the cover itself.

iii) <u>X-Band Coupler, Type II, 5500-11,000 mc/s</u>

This coupler was designed for use over a broader bandwidth than the preceding two X-band couplers. The coupler horn radiator is tapered to $1\frac{3}{8}$ inch by

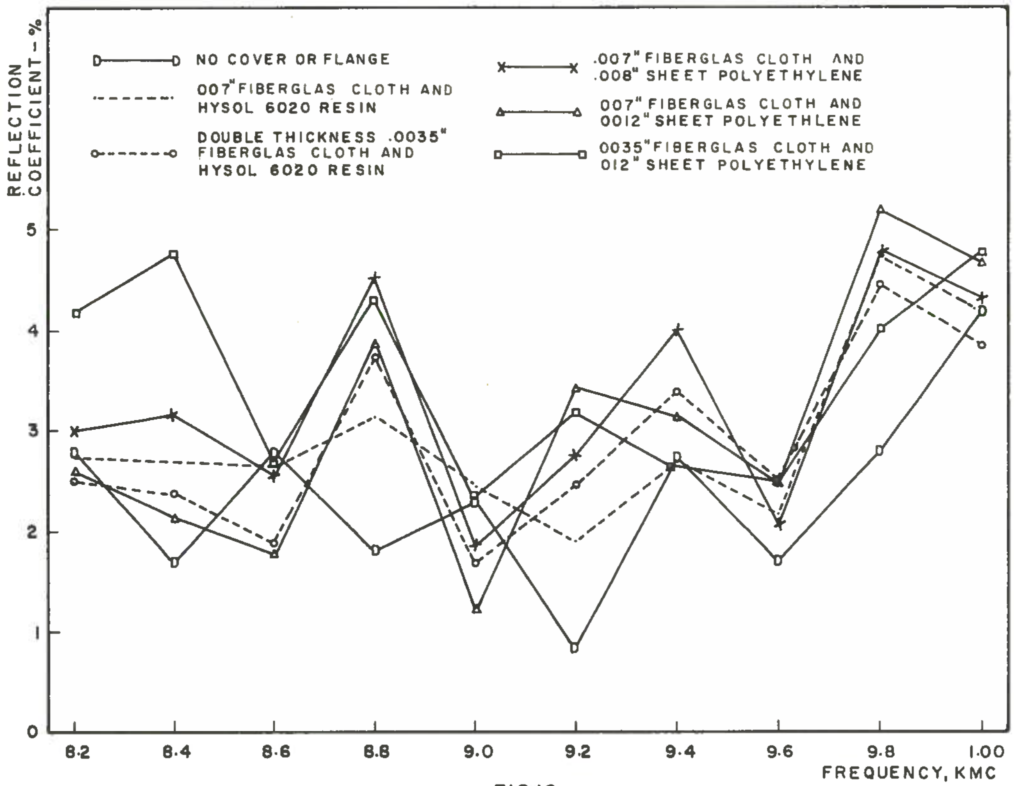


FIG.18
EFFECT OF VARIOUS COVERS AT X-BAND

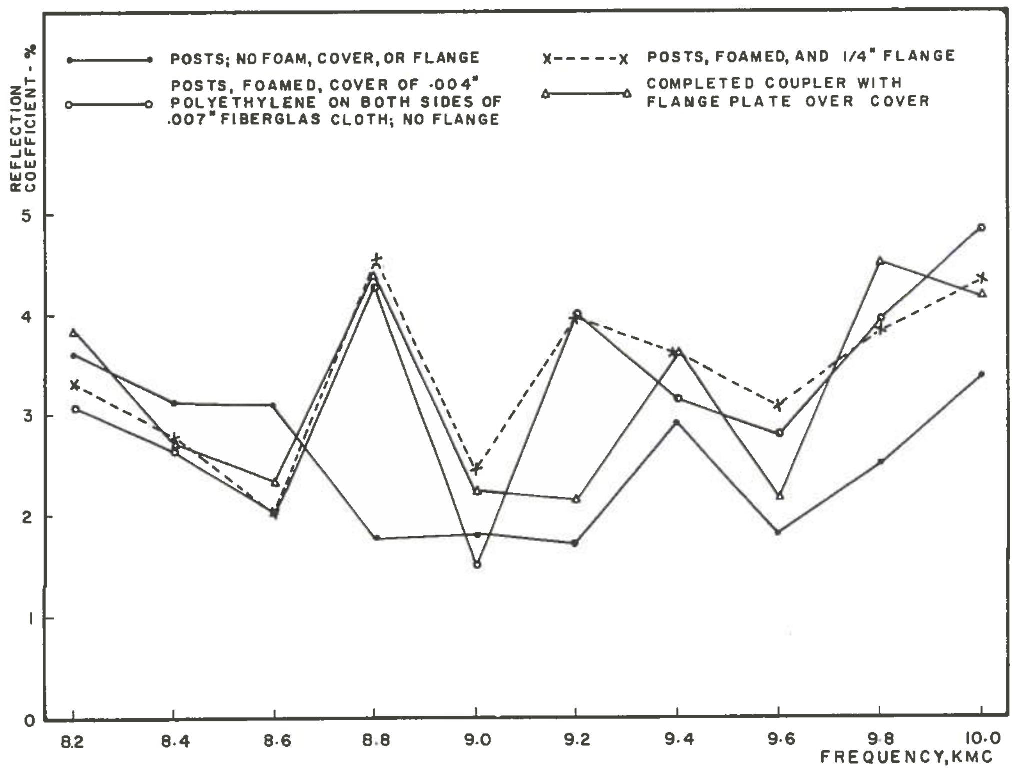


FIG.19
EFFECT OF PLASTIC FOAM, COVER, FLANGE, AND POSTS AT X-BAND
X-BAND COUPLER, TYPE I, 1/2" x 1" WAVEGUIDE
AN-74 ABSORBER

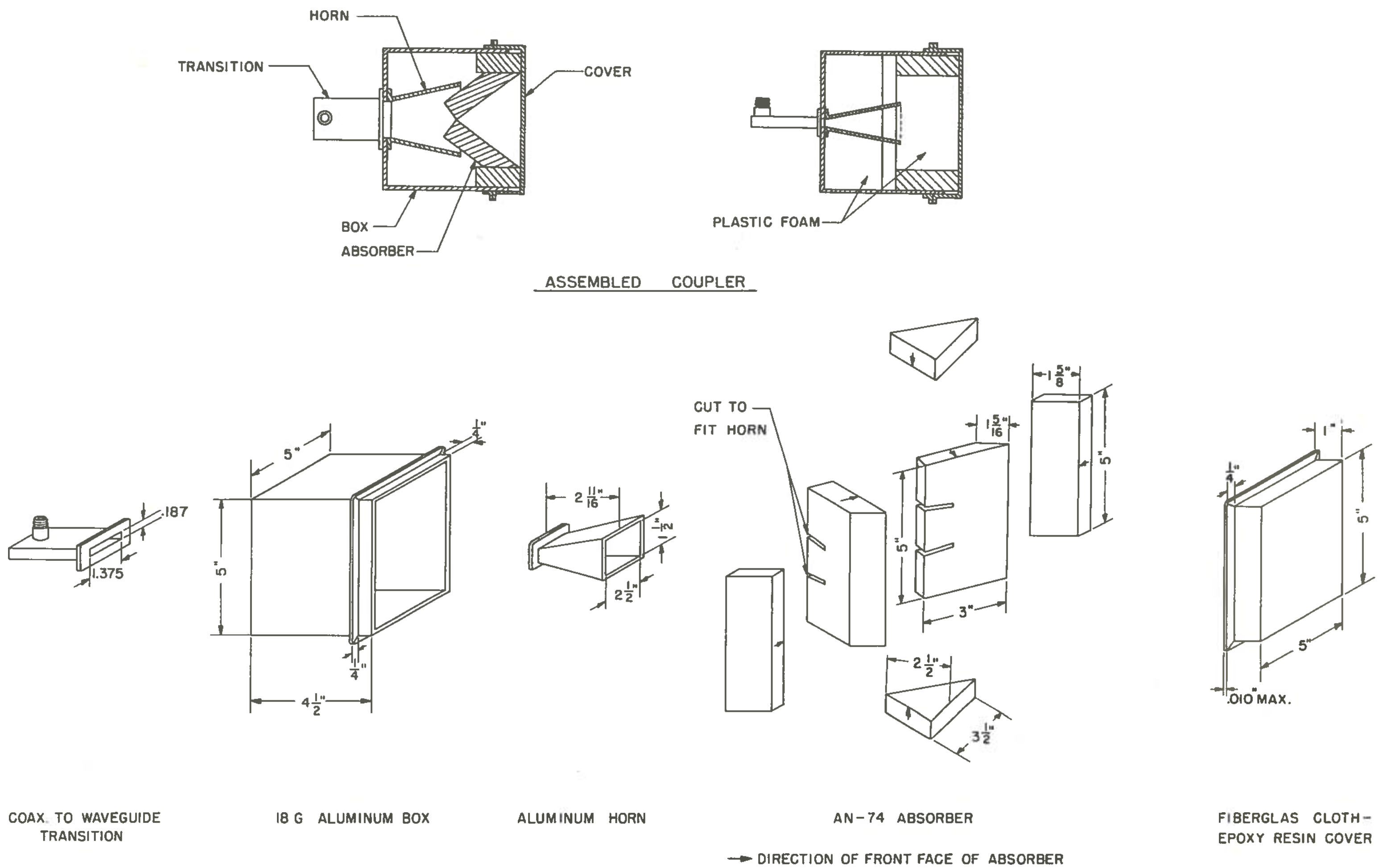


FIG. 20

X-BAND COUPLER, TYPE II

AN-74 ABSORBER, $1\frac{3}{8} \times \frac{3}{16}$ WAVEGUIDE

$\frac{3}{16}$ inch waveguide and the coupler may be used from 5500 to 11,000 mc/s.

Construction details are shown on Fig. 20. The coaxial to waveguide transition used with this coupler is a scaled version of an S-band "toll ticket" transition described by Cohn [1].

Coaxial transmission line such as RG-9/U is generally used to connect the microwave source to the coupler. Considerable care must be exercised, when making comparative measurements, that the cable is not flexed too much or the cable transmission loss may vary excessively. This is one reason why a frequency multiplier mount is used with the Type I X-band coupler for field testing of antennas. The Type II coupler was made primarily for laboratory testing.

Performance curves for the X-band Type II coupler are given on Fig. 21.

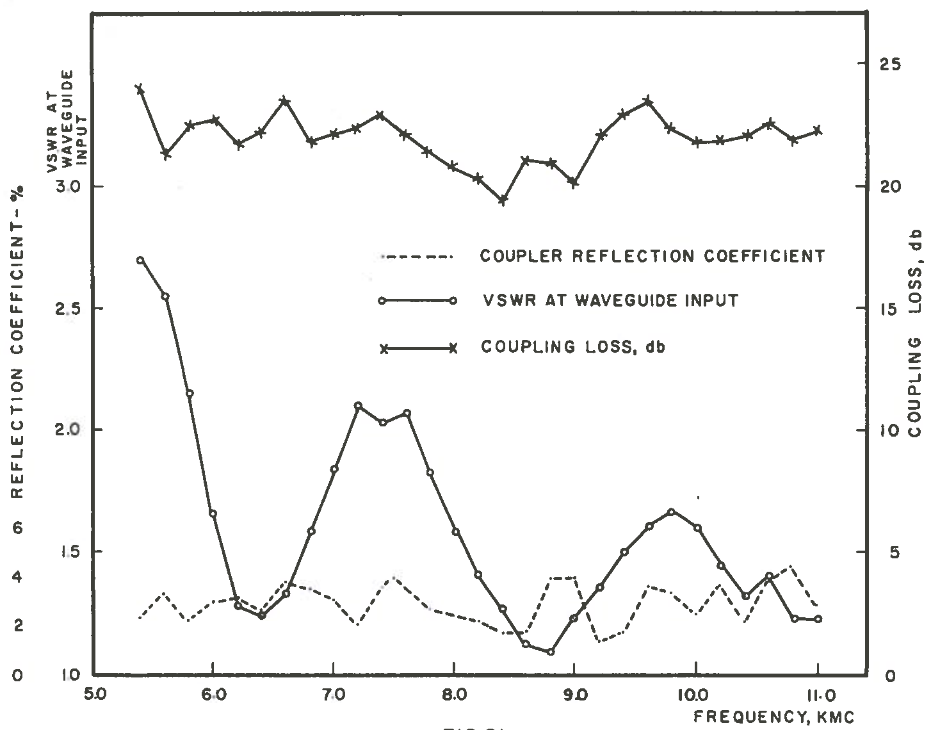


FIG. 21
X-BAND COUPLER, TYPE II
$1\frac{3}{8}" \times \frac{3}{16}"$ WAVEGUIDE
AN-74 ABSORBER

d) K_u-Band Coupler

The cover for the K_u-band coupler presented a greater problem than those for the lower frequency couplers. The cover and not the microwave absorber or box is the limitation on minimum reflections. Very little success was obtained with any type of flat cover. The cover shown with other assembly details of the K_u-band coupler on Fig. 22 had the lowest reflections of any tested. Lower reflections back to the antenna result from the sloped faces of this cover compared with the simpler flat covers used on the other couplers. The effect of the thickness of this type of cover on the coupler reflection coefficient is shown on Fig. 23. The periodicity of the coupler input VSWR and reflection coefficient curves is probably due to a relatively large reflection at the coupler radiator aperture. In this coupler the radiator is simply the open end of a waveguide, and no microwave absorber is used directly over the open waveguide to reduce the transmission loss.

This coupler was designed to be used with a frequency multiplier mount operating from a type-2K26 klystron source. The transmission loss was minimized to compensate for high conversion loss in the frequency doubler. The coupler may also be used with a K_u-band source, but the transmission line to the coupler must be waveguide since the insertion loss of coaxial cable is too high and too variable.

Performance curves for the K_u-band coupler are given on Fig. 24.

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References

1. Cohn, S.B. Design of Simple Broad-band Waveguide-to-Coaxial-Line Junctions. Proc. IRE: 35, 920-26, 1947

2. Steele, K.A. An Anechoic Antenna for Comparison of Losses in Microwave Antenna Systems. Trans. EIC 3: 9-12, 1959

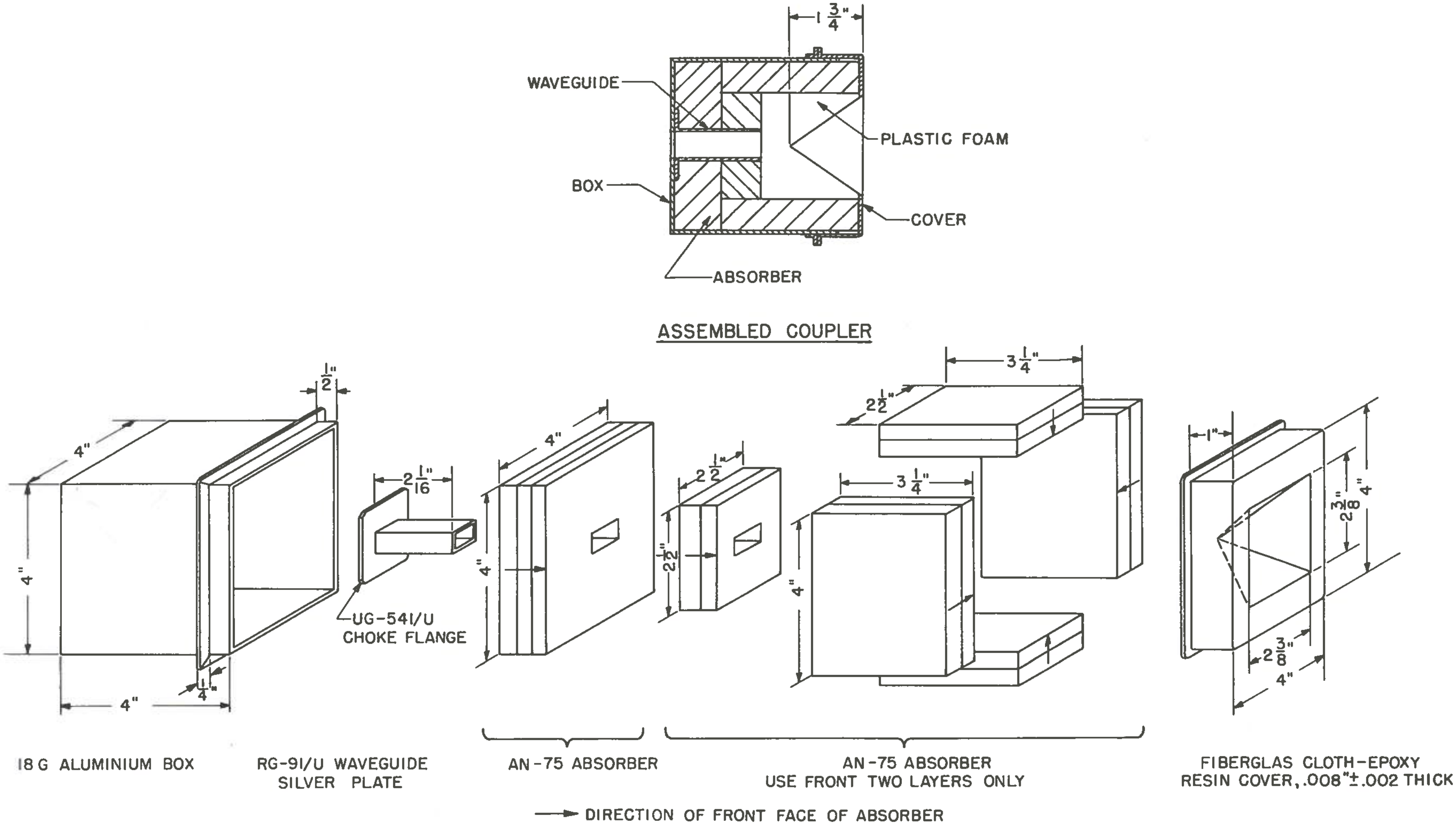

FIG. 22

K_U - BAND COUPLER

AN - 75 ABSORBER

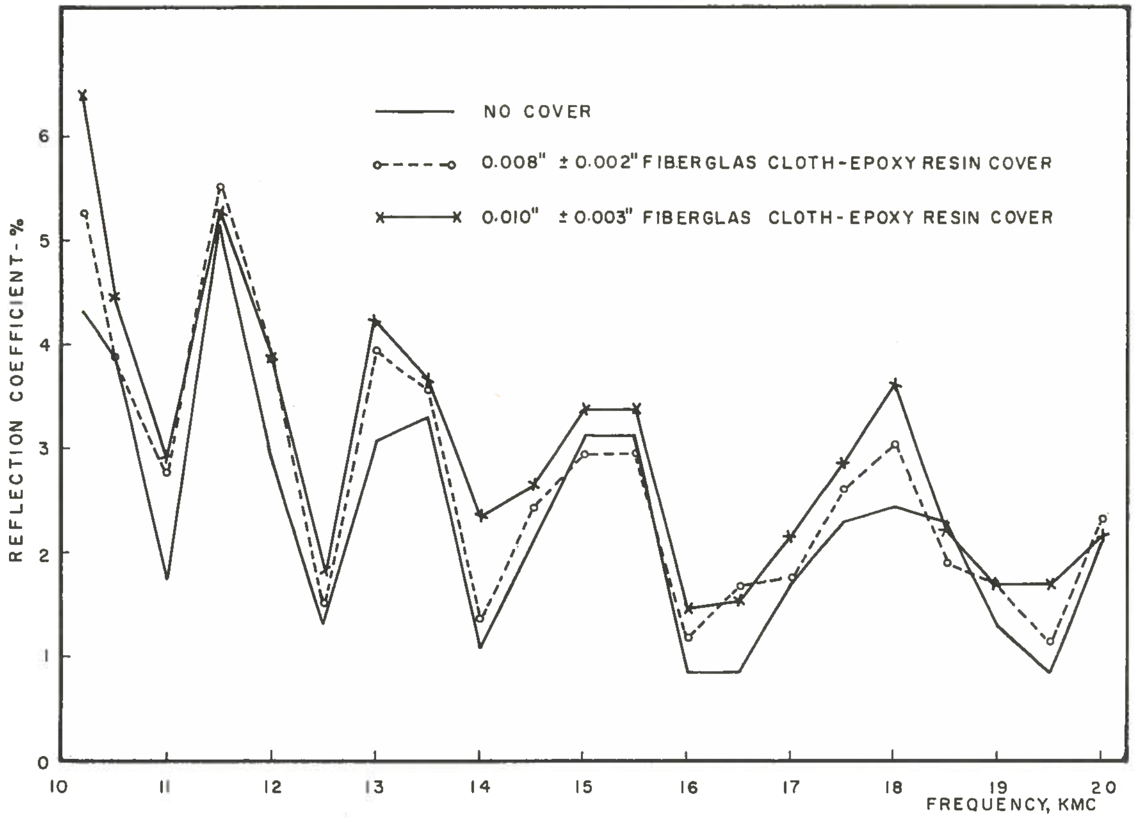

FIG.23
EFFECT OF COVER THICKNESS AT K_U-BAND

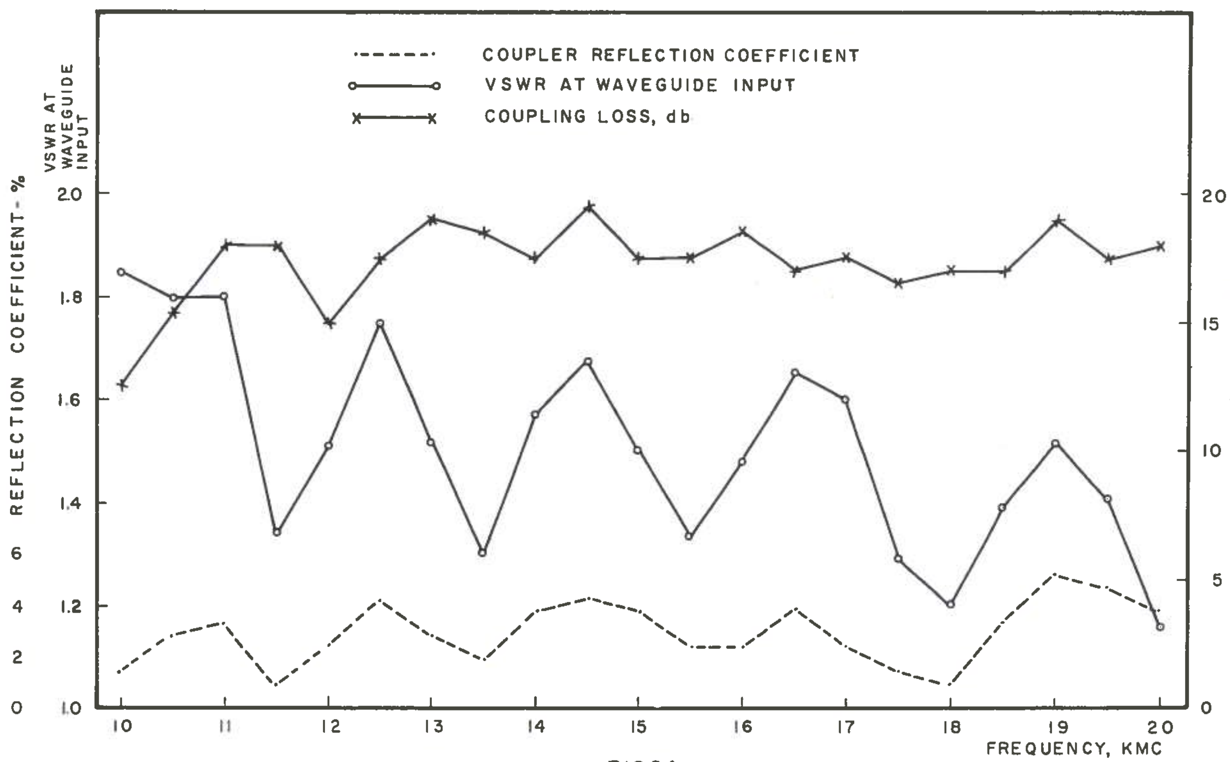

FIG.24
K_U-BAND COUPLER
AN-75 ABSORBER