An Adjustable Sliding Termination for Rectangular Waveguide*

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Summary—**A new adjustable sliding termination for rectangular waveguide has been developed. The termination is of simple design and can easily be adjusted to have reflection coefficients from zero to nearly unity in magnitude and any desired phase. In addition to the usual applications of adjustable sliding terminations for rectangular waveguide, it provides a suitable design for an adjustable transfer or secondary standard of impedance for rectangular waveguide systems.**

Introduction

ADJUSTABLE sliding terminations for rectangular waveguide are useful for a variety of purposes, including calibration of microwave impedance measuring devices, obtaining the directivity of directional couplers, and determining the parameters of waveguide junctions.

An adjustable sliding termination for rectangular waveguide was described by Grantham in 1951.[1] Several years later, a similar termination was produced commercially. This termination[2] differed from its predecessor in details of construction of the dissipative element and the reflecting antenna. Both of these terminations were designed primarily to provide minimum reflection and could not be adjusted over a wide range of vswr (voltage standing-wave ratio). The commercial termination has a vswr range of 1.005 to 1.15. The principle of the double slug tuner was used[3] to obtain an adjustable sliding termination with a somewhat greater range of adjustment. An adjustable sliding termination having a wide range of vswr was described by Kato and Sakai,[4] but it was not possible to adjust this termination for cancellation of reflections.

Principle of Operation

As shown in the diagram of Fig. 1, this termination slides inside a rectangular waveguide and consists of a short-circuiting piston to which is attached a dissipative strip supported by a dielectric rod, which can rotate and slide relative to the piston. The phase of the reflection from the strip can be varied by sliding the strip, while the magnitude of the net reflection from the short circuit can be varied by rotating[5] the strip. With independent control of these two motions, complete cancellation of reflections can be obtained. On the other hand, with the strip surface perpendicular to the electric field, minimum losses occur in the strip and almost perfect reflection is obtained. It is possible to adjust the termination to any intermediate condition, then to slide the entire assembly, to obtain almost any reflection coefficient desirable.

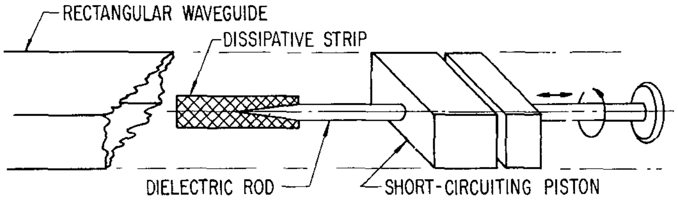

Fig. 1—Essential features of termination.

Theory

Apparently, the analysis of the fields inside a rectangular waveguide containing an arbitrarily positioned dissipative strip has not yet been published. Lacking this basic information, a rigorous analysis of the action of this termination has not been attempted. An approximate study based upon microwave circuit theory is given below.

As shown in Fig. 2, the termination can be regarded as an attenuator terminated in a short-circuited line of variable length. In terms of the scattering coefficients[6] S_{11}, S_{12}, and S_{22} of the attenuator, the input voltage reflection coefficient is

$$\Gamma_1 = S_{11} - \frac{S_{12}^2}{S_{22} + e^{j2\beta l}}, \tag{1}$$

where $\beta = 2\pi/\lambda_G$, and λ_G equals the wavelength in the waveguide. The condition for cancellation of reflections ($\Gamma_1 = 0$) is

$$S_{12}^2 = S_{11}e^{j2\beta l}(1 + S_{22}e^{-j2\beta l}). \tag{2}$$

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[1] R. E. Grantham, "A reflectionless wave-guide termination," *Rev. Sci. Instr.*, vol. 22, pp. 828–834; November, 1951.

[2] W. A. Andrews, U. S. Patent No. 2,701,861.

[3] R. C. Ellenwood and W. E. Ryan, "A uhf and microwave matching termination," Proc. IRE, vol. 41, pp. 104–107; January, 1953.

[4] N. Kato and T. Sakai, "Waveguide Type Variable Impedance Circuit and its Application for Rieke Diagram," Rep. of the Microwave Communication Res. Committee in Japan, p. 7; December, 1955.

[5] G. C. Southworth, "Principles and Applications of Waveguide Transmission," D. Van Nostrand Co., Inc., New York, N. Y., pp. 374–376; 1950. An attenuator employing a rotating strip is described.

[6] Scattering coefficients are the elements of the scattering matrix. See C. G. Montgomery, R. H. Dicke, and E. M. Purcell, "Principles of Microwave Circuits," M.I.T. Rad. Lab. Ser., McGraw-Hill Book Co., Inc., New York, N. Y., vol. 8, pp. 146–149; 1948.

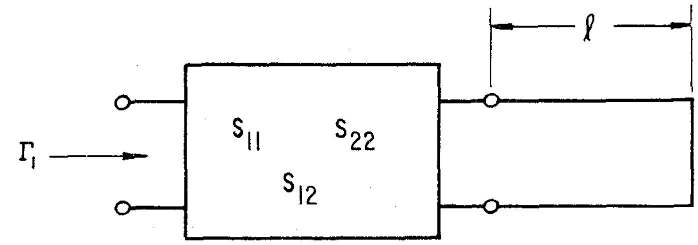

Fig. 2—Approximate equivalent circuit representation.

Normally, $|S_{11}|$ and $|S_{22}|$ are much less than unity, and the approximate condition for cancellation of reflections is

$$S_{12}^2 \approx S_{11} e^{j2\beta l}. \quad (3)$$

Rotation of the strip will, in general, change both $|S_{12}^2|$ and $|S_{11}|$. A typical variation of these quantities with θ (the angle between the electric field direction and the normal to the surface of the strip) is shown in Fig. 3(a). At the angle θc, the magnitudes of S_{12}^2 and S_{11} are equal, and it is possible to obtain cancellation of reflections by sliding the strip, varying l. If the strip is too short, $|S_{12}^2|$ will not decrease enough to equal $|S_{11}|$, as shown in Fig. 3(b). However, it is possible to increase $|S_{11}|$ by adding a reflecting object at the end of the strip, so that cancellation of reflections can again be obtained as in Fig. 3(c).

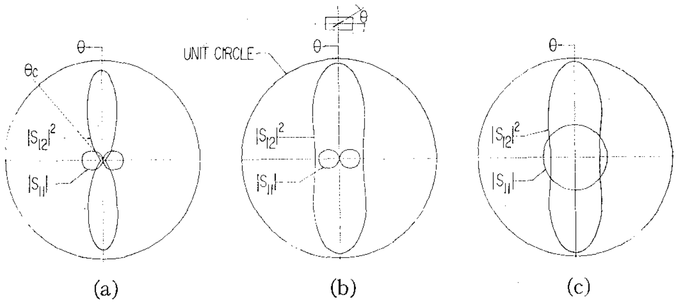

Fig. 3—Dependence of $|S_{11}|$ and $|S_{12}^2|$ upon rotation of thin rectangular strip: (a) rectangular strip 0.35 inch×1.5 inches, (b) rectangular strip 0.35 inch×0.75 inch, and (c) metal reflector added to increase $|S_{11}|$.

Design

A number of considerations can influence the design of the termination. If the primary need is for a reflection-free termination, with no need for a wide range of vswr, it seems advisable to use a thicker strip of dissipative material such as Synthane. The extra thickness can give added strength to a long, tapered strip, which will require less rotation to achieve cancellation of reflection, and give a smoother adjustment which is less frequency sensitive than with shorter strips. Examples of such a design are shown in Fig. 4, and a diagram of typical variation of $|S_{12}^2|$ and $|S_{11}|$ is shown in Fig. 5.

If a wide range of adjustment of vswr is desired, a thin strip is required. IRC resistance strip may be used

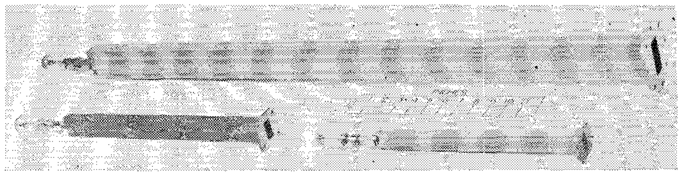

Fig. 4—Adjustable sliding loads for different waveguide sizes.

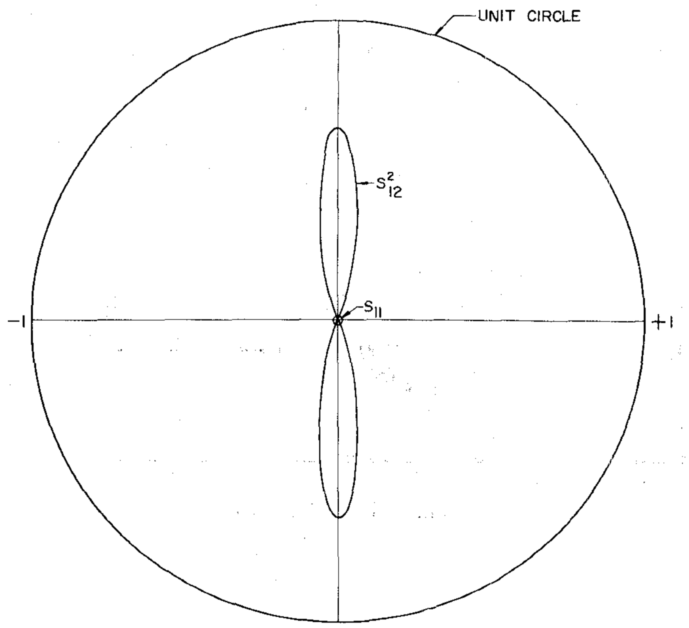

Fig. 5—Variation of $|S_{11}|$ and $|S_{12}^2|$ with rotation of thick tapered strip.

to obtain fairly high ranges, but a dissipative film on a thin mica strip is capable of greater range. A thin film has little strength and it may be desirable to add a reflecting disk or rod as shown in Fig. 6. The disk or rod permits a shorter strip to be used, while retaining the ability to cancel reflections.

Control of the mechanical motion required may be achieved by the arrangements shown in Figs. 7 and 8, next page. Independent control of the sliding and rotation of the strip is achieved in both arrangements, but in Fig. 8, the strip may be rotated and slid by hand until the clamping screw is used, which clamps the dielectric rod supporting the strip so that it can only be moved by the limited fine adjustments A and B. One adjustment of sliding (knob A) and an independent adjustment of rotation (knob B) are provided.

As a matter of practical interest, an adjustable load having satisfactory performance over the recommended frequency range of RG-52/U waveguide was constructed, using a rectangular IRC resistance strip 200 ohms per square, 0.35 inch×1.50 inches. The strip was not tapered, but mounted on a dielectric rod as was shown in Fig. 1.

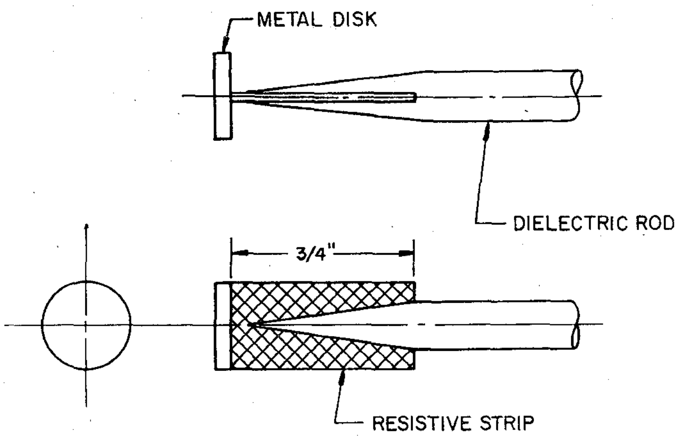

Fig. 6—Short strip and reflecting disk.

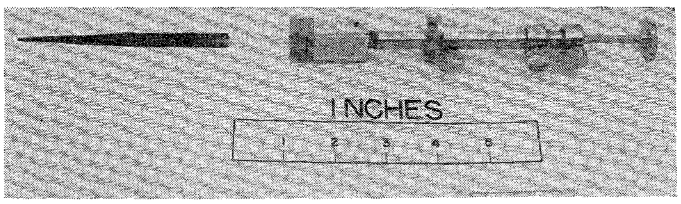

Fig. 7—Mechanical controls permitting independent adjustment of rotation and sliding, with control locking.

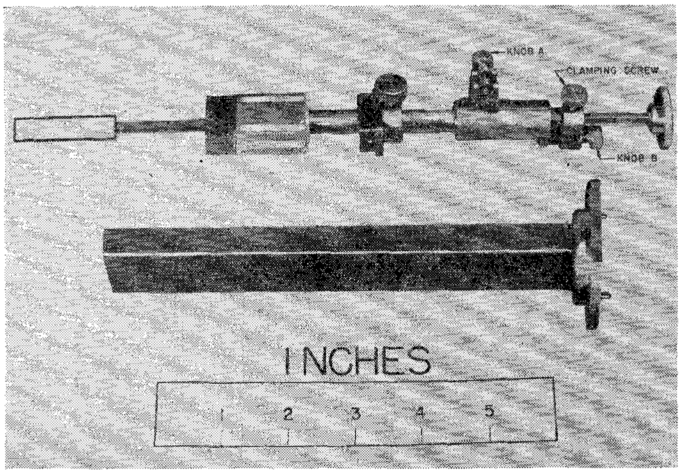

Fig. 8—Mechanical controls permitting coarse manual adjustment and locking, followed by fine independent adjustments of rotation and sliding.

ACKNOWLEDGMENT

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Field Displacement Isolators at 4, 6, 11, and 24 KMC*

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Summary—**Performance of ferrite field displacement isolators at various frequency bands is described. Single and double-slab isolators have been constructed in rectangular waveguide. Four single-slab isolators are reported in the following frequency bands: 3700–4200 mc; 5925–6425 mc; 10,700–11,700 mc and 23,500–24,470 mc; one double-slab isolator is described in the frequency range 10,700–11,700 mc.**

INTRODUCTION

THE field displacement isolator consists of a rectangular slab of ferrite partially filling a rectangular waveguide.[1] The ferrite slab is transversely magnetized and has resistance material appropriately disposed on one of its sidefaces (see Fig. 1, opposite). Basically, this device produces isolation for the following reasons: When a microwave travels through the device in a given direction, the polarization of the rf magnetic field in the plane perpendicular to the biasing magnetic field is opposite in sense to that which it would be for the reverse direction of propagation. As a result, the rf magnetic field interacts differently with the spin precessions of the electronic magnetic moments for the two directions of propagation, and this leads to different electric field distributions across the waveguide for the two directions of propagation[2] (see Fig. 2). If this difference in electric field strengths at one face of the ferrite can be made large, resistance material, suitably placed on the ferrite, will attenuate reverse traveling waves to a much larger degree than forward traveling waves, and isolation is thereby effected.

The above principles have been applied with success to an isolator at 6 kmc (0.2-db forward loss, 30-db reverse loss, 1.06 vswr over the band 5925–6425 mc). The

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[1] A. G. Fox, S. E. Miller, and M. T. Weiss, "Behavior and applications of ferrites in the microwave region," *Bell Sys. Tech. J.*, vol. 34, pp. 5–103; January, 1955.

[2] B. Lax, H. J. Button, and L. M. Roth, "Ferrite phase shifters in rectangular waveguide," *J. Appl. Phys.*, vol. 25, pp. 1413–1419; November, 1954.