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RADIO AND ELECTRICAL ENGINEERING DIVISION

A SPRING-FINGER REACTIVE POST FOR WAVEGUIDE

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OTTAWA

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ABSTRACT

A variable susceptance for use with waveguides is described, in which the usual choke joint is replaced by spring fingers. Some applications of this device at X-band are mentioned.

A SPRING-FINGER REACTIVE POST FOR WAVEGUIDE

- A.C. Hudson -

INTRODUCTION

In the design of waveguide devices, such as radar mixers, a variable susceptance is frequently required. This is often provided by an adjustable post located partially across the narrow dimension of the waveguide. This report describes such a device in which the conventional choke joint between the post and the waveguide wall is replaced by contacting spring fingers, with some reduction in cost.

In certain applications a further reduction in cost may result from locating the device at a waveguide corner.

METHOD OF CONSTRUCTION

Fig. 1 is a scale drawing of a spring-finger reactive post for use at a frequency of 9375 megacycles per second in 0.400" by 0.900" I.D. waveguide. The dimensions and heat-treating details for the beryllium copper may be obtained from Fig. 2. The essential feature is that the spring fingers on the beryllium copper sleeve make a positive centripetal pressure on the movable probe, with the result that a choke joint is not needed. The use of the beryllium copper spring fingers was first suggested by Mr. H.C. Aubrey of this Division.

Fig. 3, which is taken from Reference 1, indicates a similar construction used to couple two waveguides.

FIELD EXPERIENCE

Since the publication of References 1 and 2, a number of these posts have been employed and no difficulty with the spring fingers has been observed. The information in this report has therefore been collected to facilitate construction in the event that a further application should arise.

LOCATION AT AN H-PLANE CORNER

In the mixer of Reference 2, two H-plane bends or corners were required. It was possible to locate the adjustable posts at these corners with the result that the construction cost could be reduced. The reduction in cost comes about because there is no need to match the corners nor is there any need to clean the solder from the inside of the waveguide joint, the small added susceptance due to projections of solder having negligible effect.

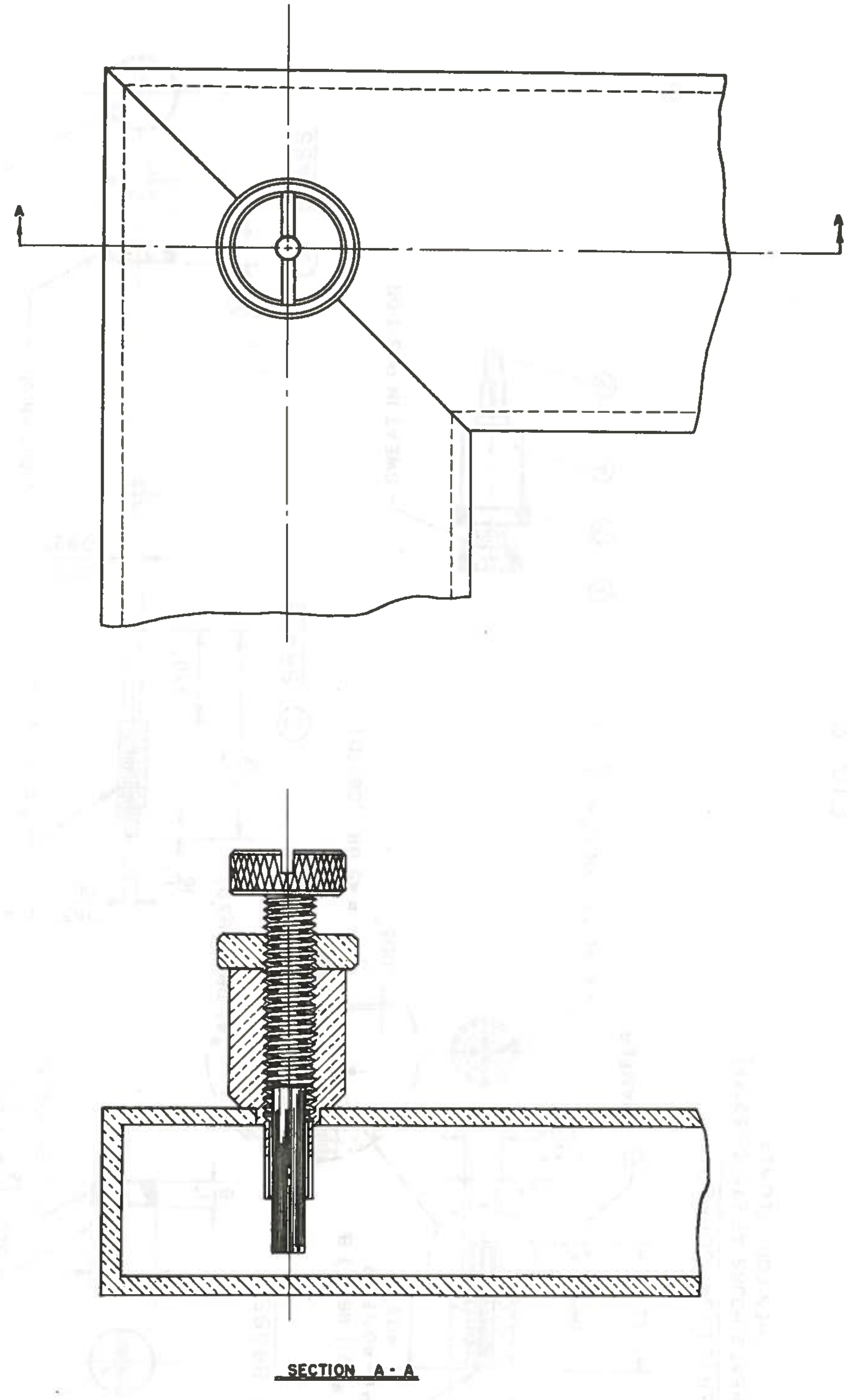

FIG. I
SPRING-FINGER POST MOUNTED AT A WAVEGUIDE CORNER

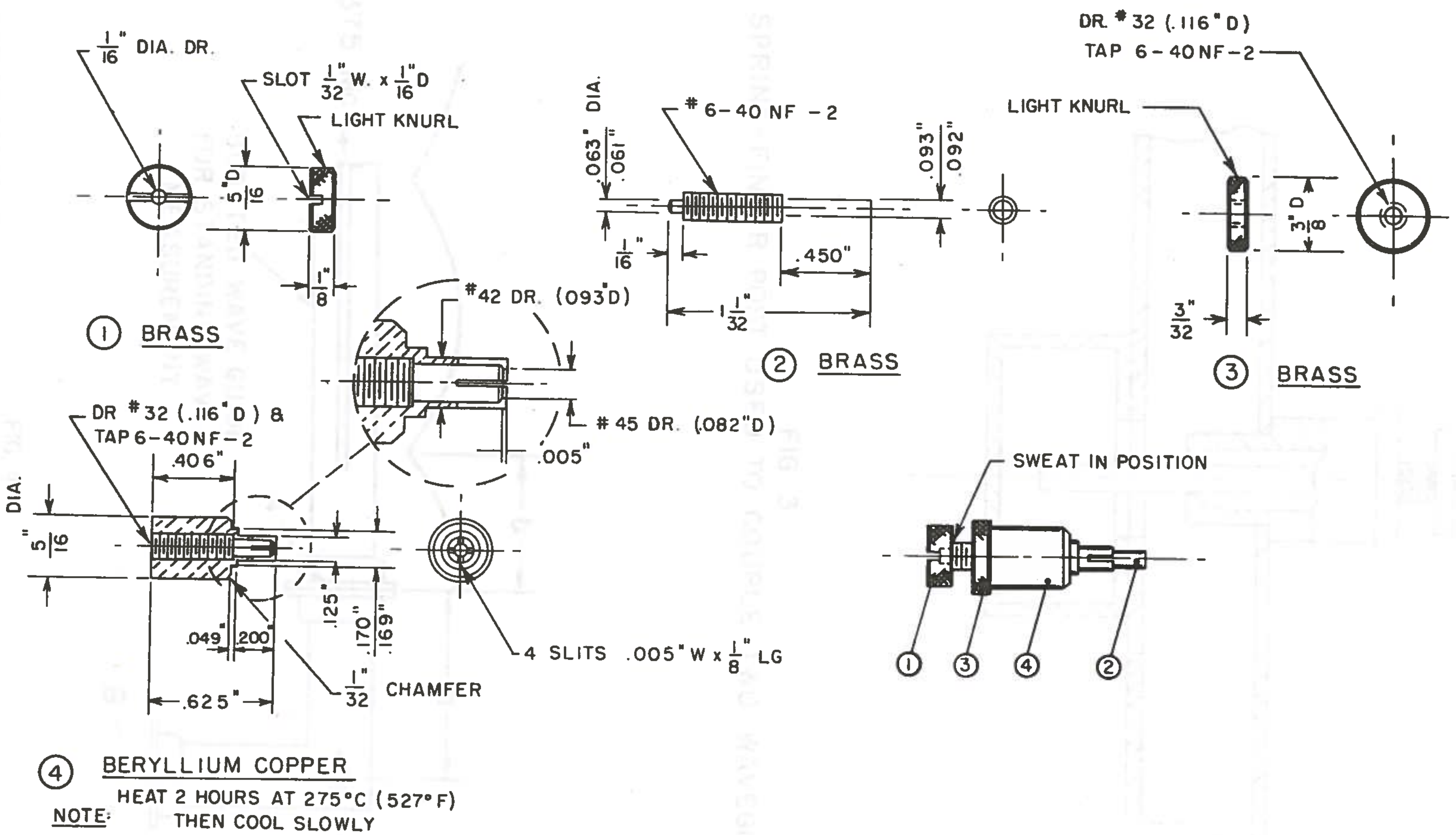

FIG. 2

DETAILS OF SPRING-FINGER POST

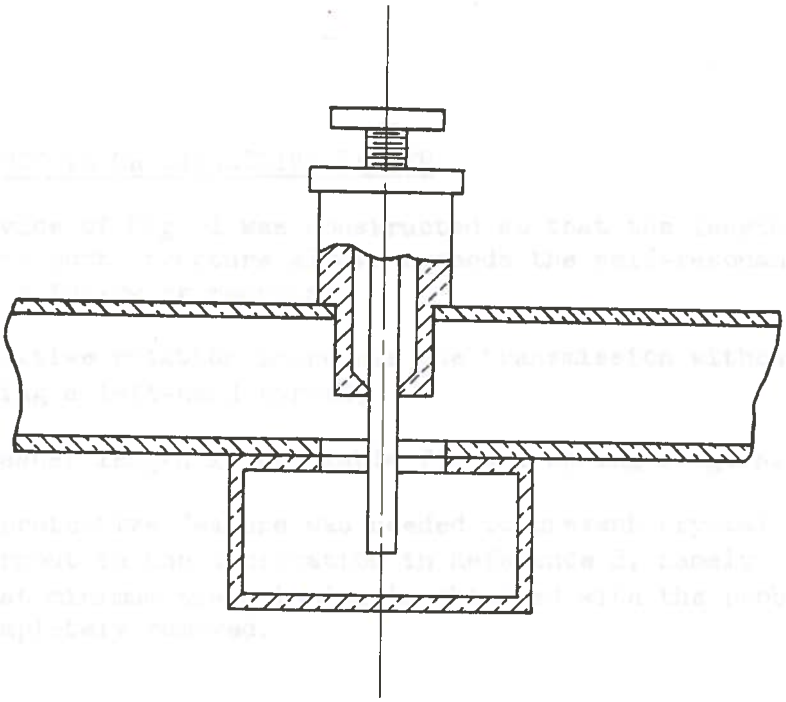

FIG. 3
SPRING-FINGER POST USED TO COUPLE TWO WAVEGUIDES

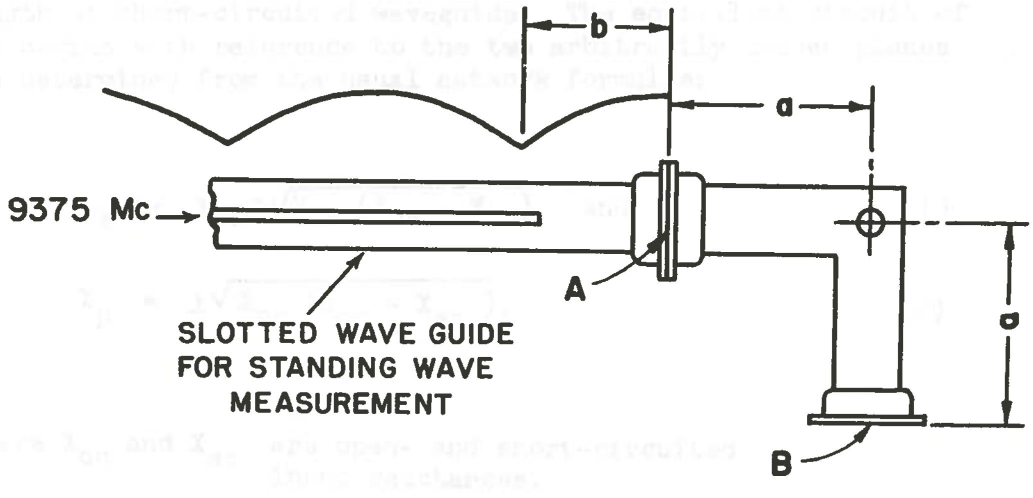

FIG. 4
MEASUREMENT OF REFLECTION FROM CRYSTAL-CURRENT ADJUSTING SCREW

CHOICE OF INDUCTIVE OR CAPACITIVE LENGTH

The device of Fig. 1 was constructed so that the length of the complete post structure always exceeds the self-resonant length, for the following reasons:

1. Positive rotation increases the transmission without using a left-hand thread.

2. Greater length is available for the spring fingers.

3. A protective feature was needed to prevent crystal burnout in the application in Reference 2, namely that minimum transmission is obtained with the probe completely removed.

DETERMINATION OF EQUIVALENT CIRCUIT OF POST AND CORNER COMBINATION

An adjustable post mounted in a waveguide corner, as in Fig. 1 was constructed, with the dimension "a", Fig. 4, from the center line of the post to the face of each choke flange arbitrarily set at 1.760 inches. The distance "b" from the standing-wave minimum to the reference plane A was measured in guide wavelengths with a standing-wave probe. Two readings were taken, with a short circuit and an open circuit at output B. The short circuit was a brass plate across the choke flange; the open circuit, a quarter-wave-length of short-circuited waveguide. The equivalent circuit of the device with reference to the two arbitrarily chosen planes was determined from the usual network formulae:

$$X_s = X_{oc} \mp \sqrt{X_{oc}(X_{oc} - X_{sc})}, \quad \text{and} \qquad (1)$$

$$X_p = \pm\sqrt{X_{oc}(X_{oc} - X_{sc})}, \qquad (2)$$

where X_{oc} and X_{sc} are open- and short-circuited input reactances.

This has been done at a frequency of 9375 megacycles per second for various positions of the adjustable screw and the results are plotted in Fig. 5. The sign of the root has been chosen arbitrarily since limited equivalence is adequate for the equivalent circuit.

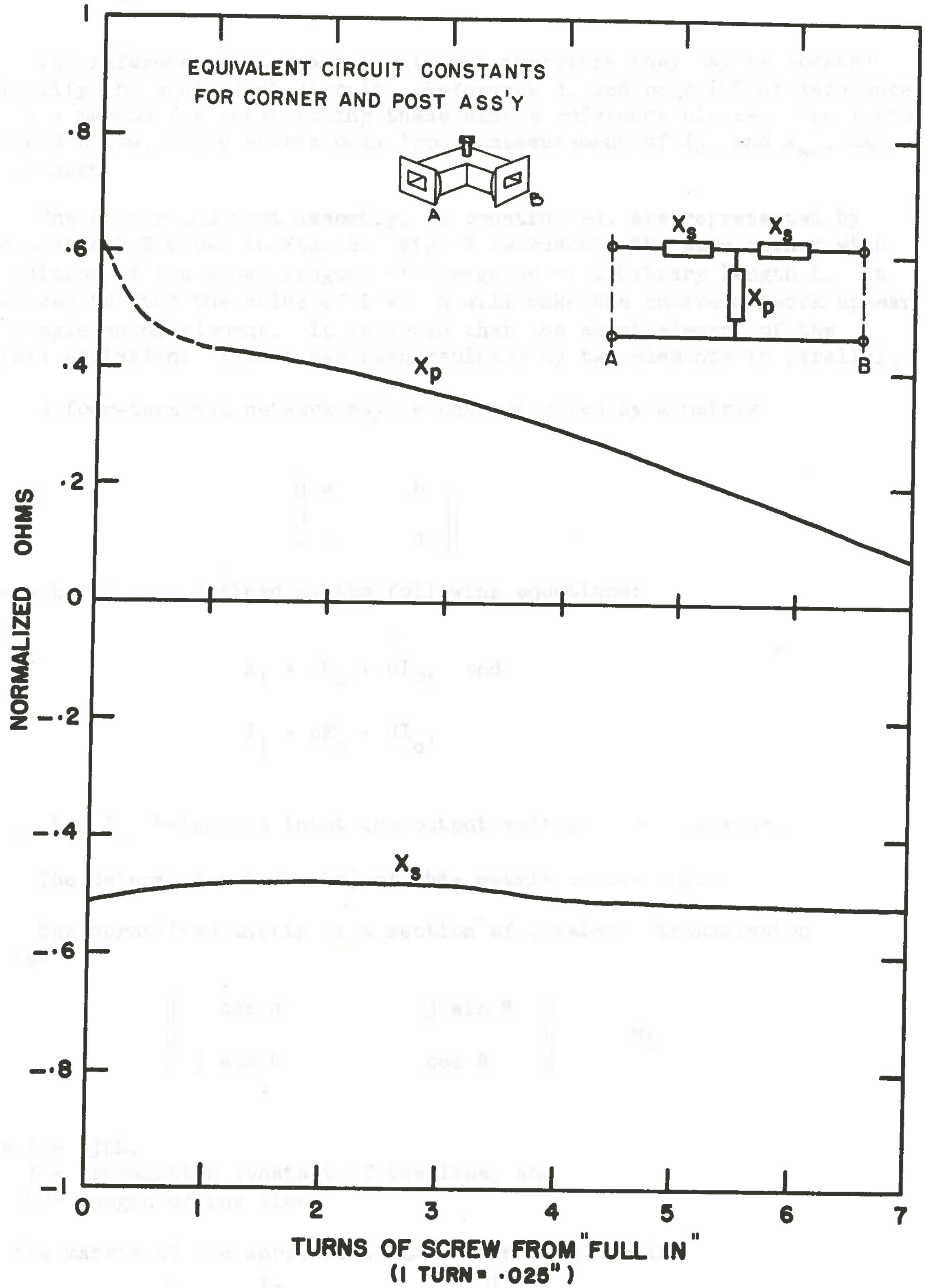

FIG. 5

MEASURED CONSTANTS OF EQUIVALENT CIRCUIT OF CORNER

The reference planes are arbitrary; therefore they may be located to simplify the equivalent circuit. Reference 3, and page 109 of Reference 4, give a method for establishing these simple reference planes. The method described below, which starts only from a measurement of X_{oc} and X_{sc}, may also be used.

The corner and post assembly, as constructed, are represented by the equivalent T shown in Fig. 6. Fig. 7 represents the same corner with the addition of two equal lengths of waveguide of arbitrary length L. It is desired to find the value of L which will make the entire network appear as a single shunt element. It is noted that the shunt element of the original equivalent circuit has been replaced by two elements in parallel.

A four-terminal network may be characterized by a matrix

$$\begin{Vmatrix} a & b \\ c & d \end{Vmatrix}$$

where a,b,c,d, are defined by the following equations:

$$E_1 = aE_o + bI_o, \quad \text{and}$$

$$I_1 = cE_o + dI_o,$$

E_1, I_1, E_o, I_o, being the input and output voltages and currents.

The determinant (ad - bc) of this matrix equals unity.

The normalized matrix of a section of lossless transmission line is:

$$\begin{Vmatrix} \cos\theta & j\sin\theta \\ j\sin\theta & \cos\theta \end{Vmatrix} \qquad M_1$$

where $\theta = -j\gamma L$,
γ = propagation constant of the line, and
L = length of the line.

Also the matrix of the appropriate L-section (Fig. 7) is:

$$\begin{Vmatrix} (1 + \frac{X_s}{2X_p}) & jX_s \\ \frac{-j}{2X_p} & 1 \end{Vmatrix} \qquad M_2$$

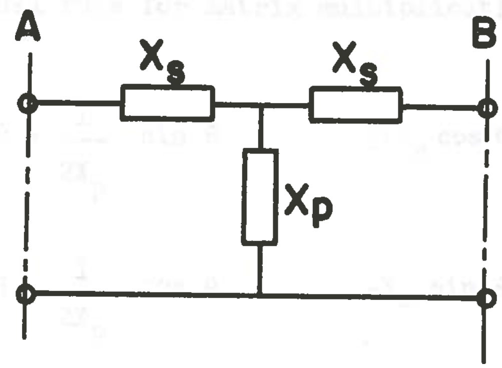

FIG.6
EQUIVALENT CIRCUIT OF CORNER

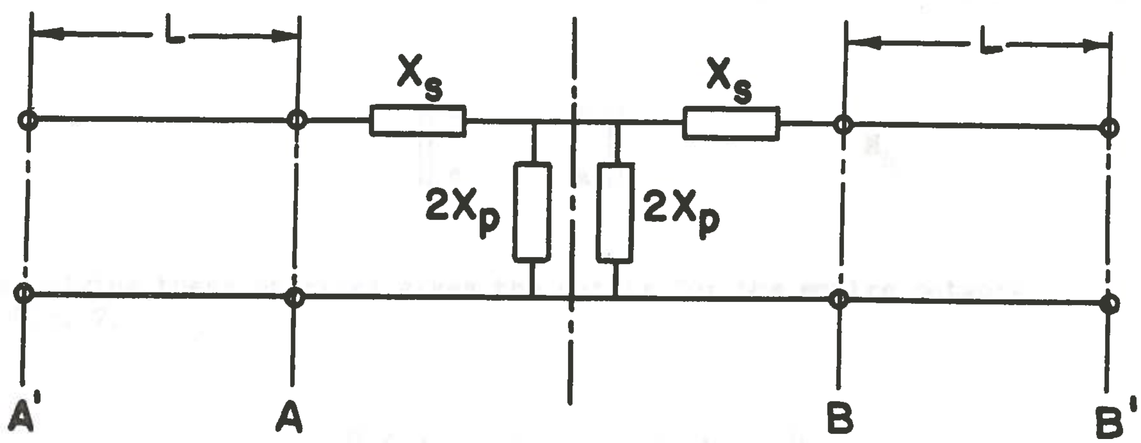

FIG.7
EQUIVALENT CIRCUIT OF CORNER WITH ADDED TRANSMISSION LINE

Thus the matrix of the portion of Fig. 7 to the left of the center line is M_1M_2.

Applying the usual rule for matrix multiplication, the matrix becomes:

$$\begin{Vmatrix} \left(1 + \frac{X_s}{2X_p}\right)\cos\theta + \frac{1}{2X_p}\sin\theta & j(X_s\cos\theta + \sin\theta) \\ j\left(1 + \frac{X_s}{2X_p}\right)\sin\theta - \frac{1}{2X_p}\cos\theta & -X_s\sin\theta + \cos\theta \end{Vmatrix}$$

$$= \begin{Vmatrix} a & b \\ c & d \end{Vmatrix} \qquad M_3$$

The matrix of this network with the input and output reversed is:

$$\begin{Vmatrix} d & b \\ c & a \end{Vmatrix} \qquad M_4$$

Multiplying these matrices gives the matrix for the entire network of Fig. 7.

$$\begin{Vmatrix} (ad + bc) & (2ab) \\ (2dc) & (ad + bc) \end{Vmatrix} \qquad M_5$$

The matrix of a reactive shunt element is:

$$\begin{Vmatrix} 1 & 0 \\ \frac{-j}{X'_p} & 1 \end{Vmatrix} \qquad M_6$$

If Fig. 7 is to be equivalent to a pure shunt element, then:

$$ad + bc = 1$$
$$2ab = 0$$
$$2cd = -\frac{j}{X'_p}$$

and also, $ad - bc = 1$;

from which, $ab = bc = 0$.

Thus, either $a = c = 0$, or $b = 0$.

It is clear that $a = c = 0$ is trivial, thus $b = 0$; hence:

$$X_s \cos\theta + \sin\theta = 0,$$

from which $\tan\theta = -X_s$. (3)

This establishes the length of line which will make the network a shunt element. The admittance of the shunt element is:

$$Y = 2dc$$

$$= 2j\,(-X_s \sin\theta + \cos\theta)\left[\left(1 + \frac{X_s}{2X_p}\right)\sin\theta - \frac{1}{2X_p}\cos\theta\right] .$$

Dividing through by $\cos^2\theta$ and replacing $\tan\theta$ by $-X_s$:

$$Y = -2j\cos^2\theta \quad (X_s^2 + 1)\,\frac{(2X_sX_p + X_s^2 + 1)}{2X_p} . \qquad (4)$$

Replace $\cos^2\theta$ by its value $\dfrac{1}{1 + \tan^2\theta} = \dfrac{1}{(X_s^2 + 1)}$

$$X'_p = \frac{X_p}{2X_sX_p + X_s^2 + 1} .$$

It may be seen from Fig. 5 that the value of X_s is approximately constant at 0.5 normalized ohms. The choice of reference planes to make the corner appear as a shunt element is then essentially independent of the depth of the adjustable post, since Equation (3) states that the location of these planes is a function of X_s only, and not of X_p.

Assuming these planes to be established, Equation (4) may be used to obtain the data of Fig. 8 which shows the equivalent shunt reactance that appears in parallel with the waveguide as a function of post penetration.

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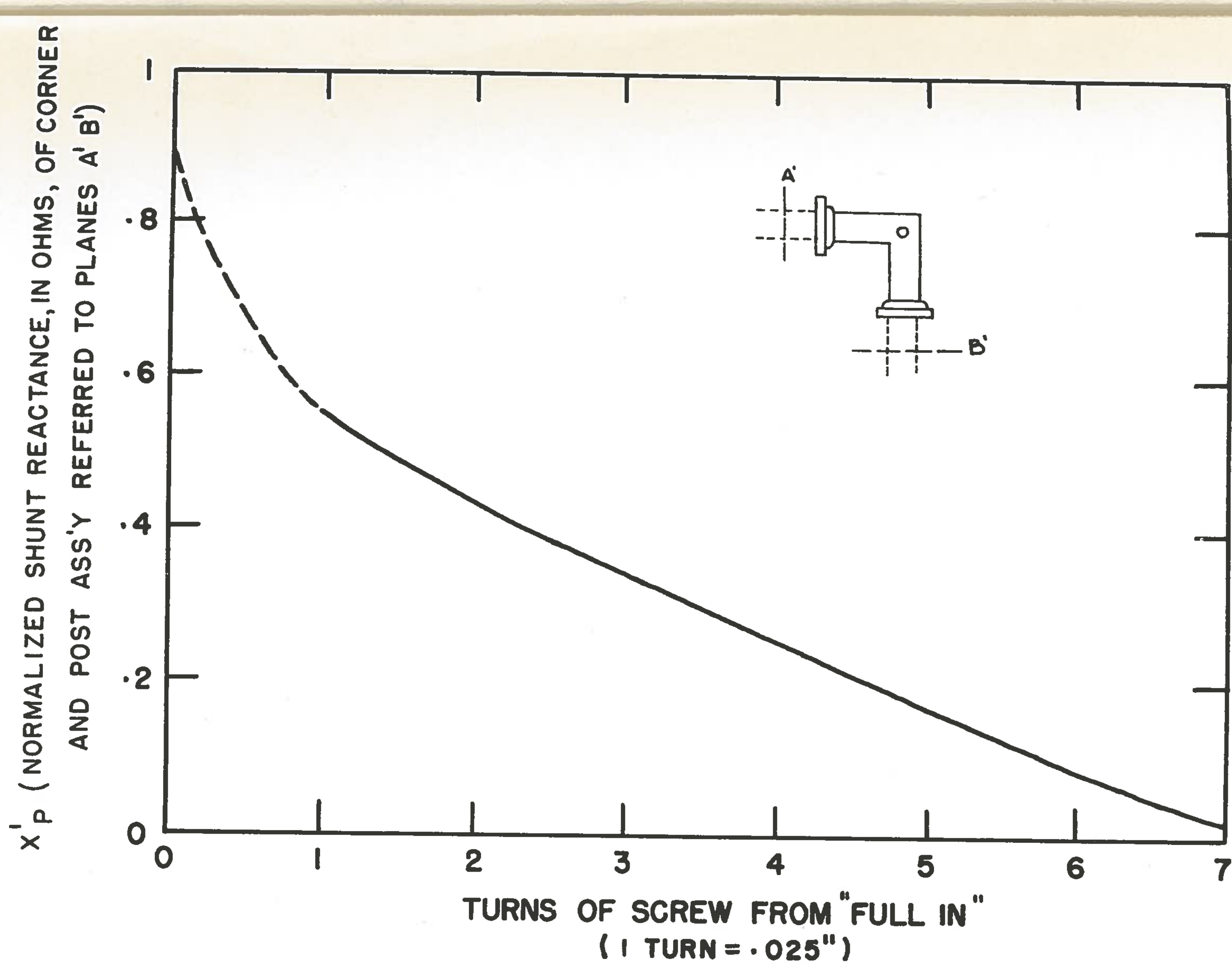

FIG. 8

X'_P VERSUS POST DEPTH