REQUIRED PRECISION IN ADJUSTMENT

If we differentiate (9), we find that small changes in length Δd are related to small changes in center frequency $\Delta\omega_0$, by the equation

$$\Delta d \approx -\frac{c}{\omega_0^2}\left(\frac{2n+1}{2}\right)\pi\Delta\omega = -\frac{d_0}{\omega_0}\Delta\omega \quad (14)$$

where d_0 is the nominal cavity length. Thus, for example, with $R=99$ per cent, Fig. 3 indicates that a displacement $\Delta\delta = 5\times 1.0^{-3}$ rad is sufficient to cause about a 20 per cent delay variation in the delay characteristic. To maintain even this control requires an adjustment and temperature stability capability that corresponds to a cavity variation

$$\Delta d \approx 0.0025\lambda_0! \quad (15)$$

A. D. JACOBSON
T. R. O'MEARA
Hughes Research Lab.
Malibu, Calif.

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A Variable Characteristic Impedance Coaxial Line

ABSTRACT

The development of Time Domain Reflectometry (TDR) for UHF and microwave impedance measurements in coaxial systems has created a problem of calibrating the TDR system for accurate measurements of small reflections. A need for coaxial impedance standards has been resolved by the development of a variable impedance device which can be calibrated by the use of fixed coaxial standards.

This correspondence deals with the design and analysis of a variable impedance line. This line is described and its performance characteristics are discussed. Its measured characteristic impedance is compared at discrete points with the impedance obtained from empirical and approximate theoretical formulas.

INTRODUCTION

Until now, slotted lines and frequency domain reflectometers have been the two principal tools for UHF and Microwave Impedance Measurements. Recently, the development of TDR has enabled the measurements engineer to obtain information about the broadband impedance characteristics of coaxial lines and components almost at a glance. The TDR systems have been calibrated for accurate measurements of small reflections ($|\Gamma| < 0.005$) by the use of fixed coaxial impedance standards. A variable characteristic impedance device eliminates the inconvenicnce of inserting and removing fixed standards. Such a device has been constructed and analyzed.

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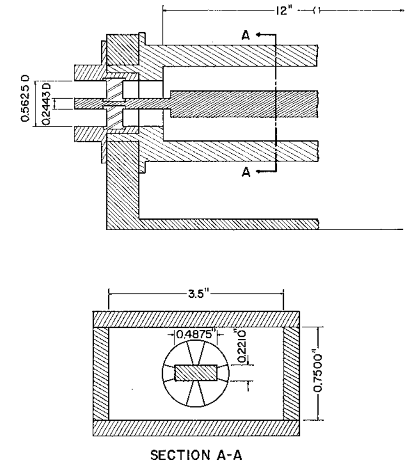
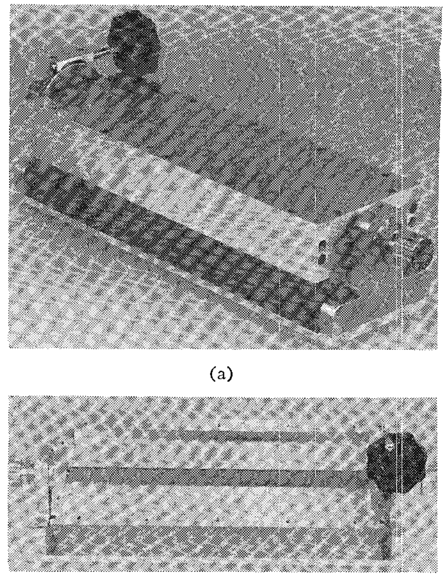


Fig. 1. Cutaway view of variable impedance rectangular line.



(a)

(b)

Fig. 2. (a) Photograph of variable impedance rectangular line. (b) Photograph of variable impedance rectangular line.

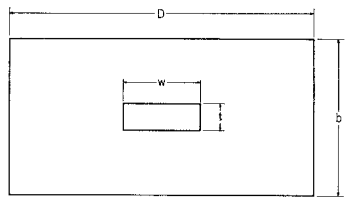


Fig. 3. Geometry of a rectangular coaxial line.

DESIGN AND DESCRIPTION

The variable impedance line discussed here is a rectangular coaxial transmission line with a stationary inner conductor and a rotating outer conductor. A worm gear drives the outer conductor through an angular range greater than 180°. Figure 1 is a cutaway view of the variable impedance line while Fig. 2 is a photograph of the exterior and interior of the line. When the conductors are aligned in the parallel plane configuration of Fig. 3, the notation used by other authors [1], [2], is suitable. Using the curves of Bates [1] and the configuration of Fig. 3, parameters of $w/b = 0.650$ and $t/b = 0.295$ with $b = 0.750$ inch yield a characteristic impedance of 55 ohms. The width D is sufficiently great that it may be considered infinite and, hence, does not enter into the calculation of Z; this line was constructed. On rotating the outer conductor through 90° and reversing the parameters, the same curves indicate an impedance of 44 ohms. This was the required range for the variable impedance line.

PERFORMANCE CHARACTERISTICS

The characteristic impedance of the variable impedance line was measured as a function of angle of rotation by means of a TDR system. Calibration of the system was accomplished by means of circular coaxial standards whose characteristic impedances were determined from

$$Z_s = \frac{59.958}{\sqrt{\epsilon}} \ln\left(\frac{d}{a}\right), \quad (1)$$

where, of course, d is the inner diameter of the outer conductor, a is the outer diameter of the inner conductor, ϵ is the relative dielectric constant of the medium, and Z_s is the characteristic impedance of the circular coaxial line.

Once the characteristic impedance Z_s of the fixed standard is known, the reflection coefficient Γ_s can be calculated from the usual relationship

$$\Gamma_s = (Z_s - Z_0)/(Z_s + Z_0). \quad (2)$$

Here Z_0 is a theoretical characteristic impedance which for the purpose of this experiment was 50 ohms. All subsequent reflection coefficients were also determined with respect to the same 50-ohm level.

If the reflection coefficient Γ_s is known, Γ_u the unknown reflection coefficient of the variable impedance line can be determined from the ratio

$$|\Gamma_u/\Gamma_s| = \left|\frac{b_u}{b_s}\right|$$

or

$$|\Gamma_u| = \left|\frac{b_u}{b_s}\Gamma_s\right|. \quad (3)$$

Here b_u is the amplitude of the reflected voltage corresponding to the reflection coefficient Γ_u, and b_s is the amplitude corresponding to the reflection coefficient Γ_s.

Using a known standard reflection coefficient Γ_s, the unknown reflection coefficient Γ_u was obtained by first measuring the ratio $|b_u/b_s|$ with the TDR system and then inserting the measured value into (3). Although the value of each of the reflected voltages is difficult to determine, the ratio of two such voltages in the same system can be found very accurately. The relative magnitudes of the reflected voltages of both the fixed standard and the variable line standard (as a function of the angle θ between the inner and outer conductors) were measured and recorded, and values of Γ_u were obtained as described. Equation (2) was then used to determine the characteristic impedance of the variable line as a function of θ. Figure 4 shows the measured results for the line just detailed. Examination of the data indicates that the characteristic impedance for this symmetrical configuration is periodic. The step discontinuities at the ends have largely been compensated for experimentally.

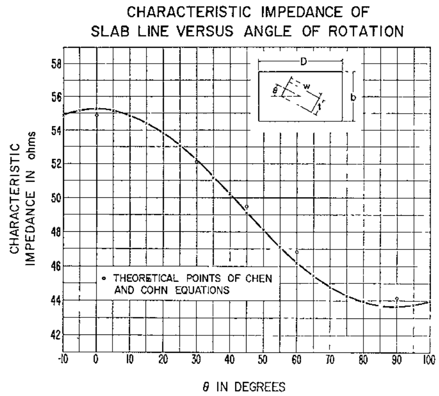


Fig. 4. Measured impedance variation of variable impedance rectangular line.

Conclusion

Table I is a comparison of the values measured with the TDR system with values obtained from an empirical formula based upon two approximate relations. The first of these is from Cohn [2]:

$$Z = \frac{94.15}{\dfrac{w/b}{1-t/b} + \dfrac{1}{\pi}\left\{\left(\dfrac{2}{1-t/b}\right)\ln\left(\dfrac{2-t/b}{1-t/b}\right) - \left(\dfrac{t/b}{1-t/b}\right)\ln\left[\dfrac{t/b(2-t/b)}{(1-t/b)^2}\right]\right\}}. \quad (4)$$

The second relation is from Chen [3]:

$$Z = \frac{94.15}{\dfrac{w/b}{1-t/b} + \dfrac{1}{\pi}\left\{\left(\dfrac{1}{1-t/b}\right)\ln\left(\dfrac{2-t/b}{t/b}\right) + \ln\left[\dfrac{t/b(2-t/b)}{(1-t/b)^2}\right]\right\}}. \quad (5)$$

Values of Z at orientations other than those given by the equations of Cohn and Chen for 0° and 90° were approximated from (4) and (5) by use of the emprical relationship,

TABLE I

Comparison of Measured Values with Values Obtained from an Empirical Formula Based Upon the Two Approximate Relationships of Cohn and Chen

$\frac{w}{b} = 0.650$ $\frac{t}{b} = 0.295$

$Z(\theta)$ ohms	measured	Chen	Cohn
$Z(0)$	55.25	54.86	54.83
$Z(30)$	52.20	52.18	52.16
$Z(45)$	49.15	49 50	49.48
$Z(60)$	46.20	46.83	46.81
$Z(90)$	43 65	44.15	44.13

$$Z(\theta) = \tfrac{1}{2}[Z(0)(1+\cos 2\theta) + Z(90)(1-\cos 2\theta)]. \quad (6)$$

[The use of (4) and (5) at 90° violates the dimensional restrictions imposed on them by their authors; nevertheless, good agreement is still obtained between computed and measured values. Further refinement of the technique coupled with more accurate theoretical relationships should provide even closer agreement. The TDR system has been shown to be a useful measurement tool for the determination of characteristic impedances of those transmission-line configurations for which no theoretical expression is available.

J. E. Cruz
R. L. Brooke
Radio Standards Lab.
National Bureau of Standards
Boulder Labs.
Boulder, Colo.

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