IV-6 NON-RECIPROCAL REMANENCE PHASE PHASE SHIFTERS IN H-GUIDE

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Introduction

Considerable attention is being given to the development of miniature microwave components for phased array applications. The H-guide configuration shown schematically in Fig. 1 and in cross-section in Fig. 2 can be miniaturized readily by employing a dielectric rib with a high dielectric constant and by closing the magnetic flux path outside the microwave region with a composite magnetic circuit.[1] By contrast, waveguide remanence phase shifters[2] cannot be miniaturized as readily because a reduction of width increases the frequency sensitivity, and a reduction of height produces a loss of phase shift as a result of the corner effects.[3]

Technical Discussion

It is assumed that the transverse electric field of the fundamental mode is parallel to the z-axis and is given by $e = E(x)\, e^{i\beta y}$. An exponential time dependence is implied. The electric field distribution across the waveguide is assumed to be

$$E_1 \cos k_1 x$$

$$E_2\, e^{ik_2 x} + E_2^*\, e^{-ik_2 x}$$

$$E_3\, e^{-\alpha x}$$

The suffixes 1, 2, and 3 refer to the dielectric, ferrite and air regions of the waveguide.

The characteristic equation of the H-guide is

$$\frac{\tan\left(k_2(x_2 - x_1)\right)}{\mu k_2} = \frac{\alpha - k_1 \tan k_1 x_1}{\mu\epsilon_2 - \beta^2 + (\mu^2 + \kappa^2)\alpha k_1 \tan k_1 x_1 \pm \kappa\beta(\alpha + k_1 \tan k_1 x_1)}$$

where

$$k_1^2 = \omega^2 \mu_o \epsilon_o \epsilon_1 - \beta^2$$

$$k_2^2 = \omega^2 \mu_o \epsilon_o \left(\frac{\mu^2 - \kappa^2}{\mu}\right) \epsilon_2 - \beta^2$$

$$\alpha^2 = \beta^2 - \omega^2 \mu_o \epsilon_o$$

μ and κ = the complex diagonal and off-diagonal terms of the ferrite tensor permeability

ϵ = complex dielectric constant

The width W_3 in Fig. 1 is defined as the boundary of the region wherein 999/1000 of the incident energy is contained.

(Eq. 1) is solved with the aid of a computer for a variety of magnetic and dielectric parameters and dimensions.

Some preliminary computer results indicate that a rutile-loaded ($\epsilon_1 = 80$) structure develops phase shift which is almost linear with the remanence magnetization. The available phase shift per inch with low-loss ferrite should be about 80 degrees per gc with an insertion loss of less than .3 db per 360 degrees phase shift. The differential phase shift can be made almost constant over a 40% frequency band by employing a rib width W_1 greater than $.02\lambda$ where λ is the free-space wavelength. The effective phase shifter width W_3 is equal to $.3\lambda$ in typical rutile-loaded structures.

The miniature phase shifter of Fig. 2 does not quite conform to the theoretical model of Fig. 1 at the upper ground plane. However, the measured phase shift of 130 degrees per inch at 3 gc compares favorably to the computed value of 150 degrees per inch. The bandwidth of more than 10% is limited by the transition from microstrip to H-guide. The insertion loss of 1 db per 360 degrees is substantially greater than the computed value of 0.4 db. Several sources for this discrepancy are being investigated, including the possibility that the loss tangent of the rutile exceeds the assumed value of 0.001.

Conclusions

Since the rutile dielectric constant varies appreciably with temperature, this particular device should be operated in a temperature controlled environment. However, other configurations, using stable dielectric materials, can be temperature stabilized with the composite magnetic circuit.

Except for the convenience of no end walls, the H-Guide phase shifter has little to recommend it over the waveguide phase shifter for conventional applications, as both phase shifters have similar electrical performance [2, 3, 4], although the absence of end walls makes it feasible to assemble a number of phase shifters between common ground planes for phased array applications. For applications requiring compactness, or where an effective coupling means to strip and microstrip lines is required, the H-Guide is more desirable than other configurations.

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3. W.J. Ince and E. Stern, Proc. Int. Conf. on Microwave Behavior of Ferrimagnetics and Plasmas, IEE, London, England (Sept. 1965).
4. E. Schlomann, IEEE Trans. MTT, 14, pp. 15-23 (Jan. 1966).

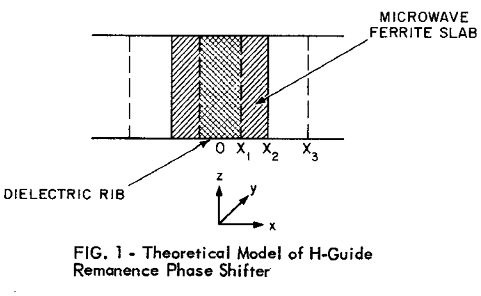

FIG. 1 - Theoretical Model of H-Guide Remanence Phase Shifter

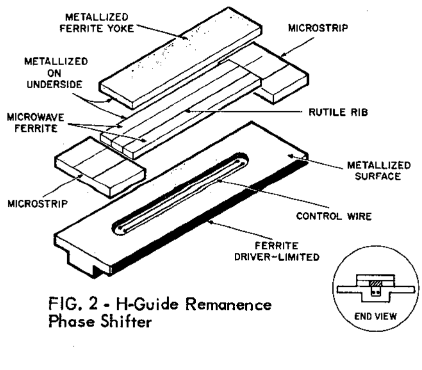

FIG. 2 - H-Guide Remanence Phase Shifter