STUDIES ON DIELECTRIC LOADED WAVEGUIDES AND THEIR APPLICATIONS

THESIS

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بسم الله الرحمن الرحيم

وقل اعملوا فسيرى الله عملكم ورسوله والمؤمنون

صدق الله العظيم

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CONTENTS

LIST OF SYMBOLS

ε	: The dielectric constant of the material
ε_r	: Relative dielectric constant = $\varepsilon/\varepsilon_o$
ω	: Angular frequency
ε_o, μ_o	: Permittivity and permeability of free space
$\vec{E}_x$, $\vec{E}_y$ & $\vec{E}_z$	: Electric field component along x, y & z directions
$\vec{H}_x$, $\vec{H}_y$ & $\vec{H}_z$	: Magnetic field component along x, y and directions
a, b	: Cross sectional dimensions of the rectangular waveguide a = 2.286 cm, b = 1.016 cm.
d	: Thickness of the dielectric slab
β_o	: Phase constant of the empty rectangular waveguide
β	: Phase constant of the loaded rectangular waveguide
f	: Frequency
K_x, K'_x	: Transverse propagation constants in the X-direction in the air and dielectric regions inside the rectangular waveguide
K_y, K'_y	: Transverse propagation constants in the Y-direction in the air and dielectric regions inside the rectangular waveguide.

SUMMARY

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In this thesis, four structures of a rectangular waveguide loaded with a dielectric slab have been studied. The slab has been placed at the centre or at one side of the guide either parallel to the electric field E-plane where the dominant mode is the transverse electric (H_{10}-mode) or parllel to the magnetic field H-plane where the dominant mode is the longitudinal section magnetic (LSM_{1F}-mode). In the four cases the normalized phase shift due to the insertion of the dielectric slab in the waveguide has been computed as a function of the slab thickness for different values of the dielectric constant. The computations have been made by using the characteristic equations derived from the exact solution of the various structures. The dependence of the phase shift on the slab position and on the frequency of the propagating wave has also determined. It is found that the phase shift has a maximum value when the slab is placed at the centre of the waveguide parallel to the E-plane. For a slab of a certain thickness (d) and relative dielectric constant ε_r, the phase shift increases by increasing the frequency of the propagating wave. The phase shift also increases by increasing both the slab thickness and the relative dielectric constant.

Measurements have been performed for the four structures at frequency f = 9.65 GHz. Three materials have been tested : Teflon (ε_r = 2.027), Trolitul (ε_r = 2.504) and polyvenylchloride

(PVC) (ε_r = 2.742). The material samples have been machined as slabs of different thicknesses ranging from 1 mm to 1 cm and extended over the whole length of the slotted line. The measured values of the phase shift have been compared with the theoretically computed values and accuracy curves for the experimental measurements have been given. These curves give the error percentage in measuring the phase constant for the loaded waveguide as a function of the slab thickness. The comparison has indicated that the error in measurements is minimum when the slab is placed at one side of waveguide parallel to the H-plane and the error increases as the slab thickness increase. Also it is found that the error in measurements depends on the material used. It increases by increasing the dielectric constant ε_r. The analysis of the theoretically computed and experimental curves give an idea about the phase variation in the various waveguide structure so that a wide range phase shifter can be designed.

INTRODUCTION

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The study of the dielectric loaded waveguides is found to be of a great interest from many authors, Yonshengxu [20], Bruno & Bridges [13], Casey [14] and Inder & Gupta [8] aimed to determine the relative dielectric constant of the material inside the waveguide. Findakly & Haskal [15] and Tsandoula [19] treated to develope a microwave components such as microwave filters, matching transformers and phase changers. Some studies have been made in order to design devices capable of changing the phase shift over a minimum range of 360° with minimum error. For this aim, Bland [16] used waveguide phase shifting techniques with some dielectric slab parallel to the E-plane. Findakly & Haskel [15] and Sadha [17] studied the same structures by using ferrites slabs. Other authors, Gardial & Parriaux [18] and Gardial & Vardervorst [7] studied the dielectric loaded waveguide with slabs parallel to the H-plane, in order to define the behaviour of the phase variation through the transcendental equation of the waveguide structure.

This thesis discuss the variation of the phase shift in the dielectric loaded rectangular waveguide when the dielectric slab is parallel to the E-plane or parallel to the H-plane. Using an iterative analysis technique, the dependence of the phase shift on some parameters (such as, the slab thickness, the dielectric constant, the frequency and the slab position) will be computed and represented graphically.

Experimental verification of the theoretically obtained results will be performed using dielectric slabs of different materials : Teflon (ε_r = 2.027), Trolitul (ε_r = 2.504) and Polyvenylchloride (PVC) (ε_r = 2.742) with different thicknesses. Finally a comparisons between theoretical and experimental results are made. From which an excellent coincidence between them is obtained. By showing of the obtained results, an idea about the best structures, that can give a wide range of the phase changing is obtained.

CHAPTER I

THEORETICAL STUDIES ON DIELECTRIC SLAB LOADED RECTANGULAR WAVEGUIDE

I-1) Dielectric Slab Placed at One Side of a Rectangular Waveguide Parallel to the E-Plane :

Fig. (I.1a) represents a rectangular waveguide of dimensions a and b in which a dielectric slab of thickness d is placed at one side parallel to the electric field plane (E-plane). The dielectric is considered as a lossless material of relative dielectric constant ε_r. The propagating wave is the transverse electric mode(H_{10}-mode)with electric and magnetic field components E_y, H_x and H_z.

The wave equations in the dielectric and air are written as [1]

$$(\nabla_t^2 + K_x'^2)\ \vec{H}_z = 0 \qquad \text{in the dielectric}$$

$$(\nabla_t^2 + K_x^2)\ \vec{H}_z = 0 \qquad \text{in air} \qquad (I-1)$$

where K_x and K_x' are the propagating constants in the air and the dielectric respectively

$$K_x^2 = \omega^2\varepsilon_o\mu_o\varepsilon - \beta^2$$

$$K_x'^2 = \omega^2\varepsilon_o\mu_o\varepsilon_r - \beta^2 \qquad (I-2)$$

β is the phase constant, ε_o and μ_o are the permittivity and the permeability of free space, ε_r is the relative