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Study of Heat Loss in Isolated Microstripline

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ABSTRACT

In this paper, I present about the study of heat loss in isolated microstripline. Microwave ovens, microwave drying machine useful in paper industries etc. have been designed utilizing this temperature loss. Thus, microwave temperature becomes power tools for industrial and commercial applications and also for the study of some basic properties of materials. For the calculation of this rise of temperature and its dependence of geometry of the structure and operating frequency we must study the characteristic impedance of the structure and the phase velocity of the wave traveling through the structure.
KEYWORDS: Heat Loss, VSWR, Microwave, Microstripline Couplers.

I. INTRODUCTION

With the development of solid-state devices operating in giga hertz range of frequency it has become necessary to develop and design different forms of planar transmission structures which are more suited than co-axial line and wave guides. These structures suffer from different types of losses like radiation, conduction and dielectric losses. The presence of conduction strip and dielectric substrate causes heating effect or loss of energy in terms of heat. It is important to study such heat loss during the propagation of microwave in giga hertz range of frequency. For the growing need of microwaves in industrial applications and in commercial purposes microwave heating becomes important for study. Microwave ovens, microwave drying machine useful in paper industries etc. have been designed utilizing this energy loss. Thus, microwave heating becomes power tools for industrial and commercial applications and also for the study of some basic properties of materials. The loss of electro-magnetic power due to microwave propagation in the microstripline structure consisting of conducting and dielectric material generates heat in the structure. The work involves the mathematical formulation of the problem and related computational work.

II. FORMULATION OF CHARACTERISTIC IMPEDANCES FOR EVEN AND ODD-MODES OF A MICROSTRIPLINE COUPLER

When a microstripline is placed parallel to another microstripline, coupler is formed. The power flowing in one line is coupled to the other line either in same direction or in opposite direction. The power flowing in same direction is referred to as even-mode of propagation. Power flowing in opposite direction is referred to as a odd-mode of propagation.

For the present study of characteristic impedances in the case of even and odd-modes derivation of the equation for both modes begin with the consideration of a basic single microstripline conductor. The characteristic impedance can be calculated with the help of elementary transmission line equation expressed as

$Z_o = 1/V_P C_P$ --------------- (1)

Where,

V_P = phase velocity of the wave traveling along the microstrip line.

C_P = capacitance per unit length of the line.

The capacitance of the line is the result of the combination of different components.

These are:

C_{PP} = parallel plate capacitance between lower surface of the microstrip and the ground plane and is given by

$C_{PP} = [\epsilon_{reff} / c.\eta] . (w/h)$ ---------------- (2)

C_{PPU} = capacitance between the upper surface of the microstrip and the ground plane which is expressed as

$C_{PPU} = (2/3) [\epsilon_{reff} / c.\eta] . (w/h)$ ----------------- (3)

C_f = the fringing capacitance at the edges of the microstrip and is expressed

$C_f = [\epsilon_{reff} / c.\eta] . (2.7/Log4h/t)$ ---------------- (4)

Where,

w = Microstrip width, ϵ_{reff} = The effective dielectric constant of the medium,

h = Height of the substrate, η = Free space impedance = 377 Ω,

c = The velocity of light in free space = 3.0×10^8 m/sec.

t = microstrip thickness.

Thus, the total capacitance (C_P) of the isolated microstrip structure is expressed as

$C_P = C_{PP} + C_{PPU} + C_f$

or $C_P = (\epsilon_{reff} / c.\eta) (w/h) + (2/3) (\epsilon_{reff} / c.\eta) (w/h) (\epsilon_{reff} / c.\eta).(2.7/Log4h/t)$ ---- (5)

This is the expression of the capacitance of the microstrip structure in terms of its geometric parameters.

The phase velocity V_P can be calculated by the formula

$V_P = c / \sqrt{\epsilon_{reff}}$ --------------- (6)

For wide strip, $\epsilon_{reff} \approx \epsilon_r$, and

For narrow strip, $\epsilon_{reff} \approx (\epsilon_r + 1) / 2$

Where, ϵ_r = relative dielectric constant.

From equations (3.3.1), (3.3.5) and (3.3.6), we get

$Z_o = (\eta/\sqrt{\epsilon_{reff}}) . [1/[(w/h) + (2w/3h) + (2.7/Log4h/t)]]$ ---------------- (7)

The calculations made on the basis of this expression give the characteristics impedance, the propagation constant and other transmission parameters of a single microstrip structure.

When the second conductor is introduced close to the first one, the field distribution gets altered. In even-mode the electric field lines follow the pattern fairly similar to that of the isolated conductor. In case of odd-mode, the two conductors are linked by the electric field lines.

The form of equation (7) obtained for the isolated microstrip line are also useful in calculating the characteristic impedance of microstrip coupler in even- and odd- modes. In the even-mode C_P is replaced by C_{Pe} and in the odd-mode by C_{Po}. Since the electric field lines are distributed in air and below the conductor in the dielectric substrate, the dielectric medium now becomes inhomogeneous. Due to in homogeneity the phase velocity (V_P) for the isolated case is replaced by V_{Pe} for the even- mode and V_{Po} for the odd- mode. Further in place of ϵ_{reff} the effective dielectric constants $(\epsilon_{reff})_{eo}$ are to be used for even and odd-modes separately. Similarly, Z_{oe} and Z_{oo} represent the characteristic impedances for even-and odd- modes respectively.

III. STUDY OF HEAT LOSS IN ISOLATED MICROSTRIPLINE

For the study of heat loss and its variation with stripwidth exhaustive computational and manual works have been performed both for even and odd-modes of propagation. In the results obtained have been placed in table 1 and graph between rise in temperature and stripwidth have been plotted as shown in graph 1. It has been observed that with increase of stripwidth characteristic impedance both for even and odd-modes decreases effective permittivity for even-mode and odd-mode increases slightly. This causes increase of thermal loss and subsequent increase in rise of temperature. Variation of rise in temperature in case of even-mode is slightly greater than that in case of odd-mode.

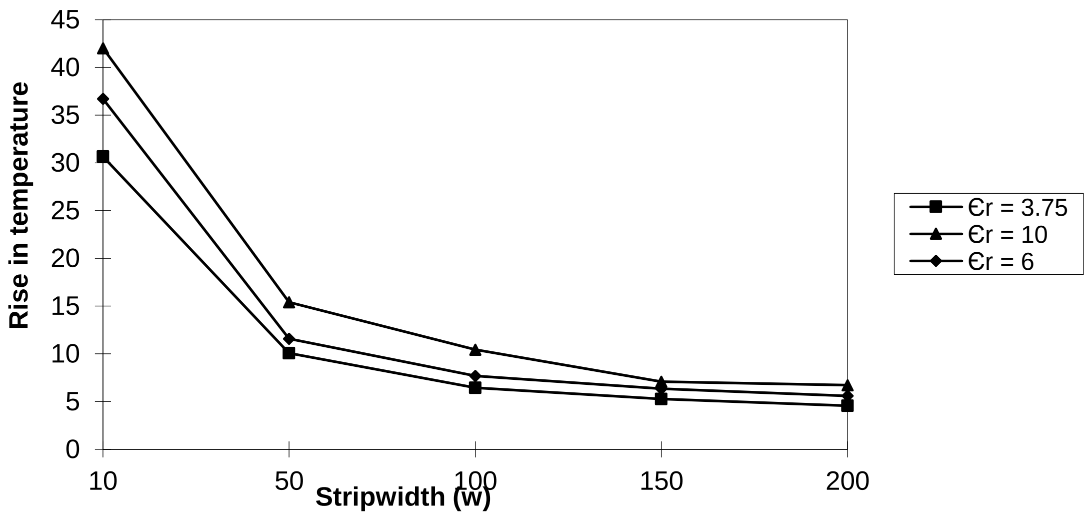
Table No. 1: Variation of heat loss of isolated microstripline taking relative permittivity as a parameter

h = 100 mils, w = 100 mils, f = 3 GHz

w (mils)	ϵ_r = 3.75			ϵ_r = 6			ϵ_r = 10		
	α_d x 10^{-2} dB/m	α_c dB/m	ΔT °C	α_d x 10^{-2} dB/m	α_c dB/m	ΔT °C	α_d x 10^{-2} dB/m	α_c dB/m	ΔT °C
10	2.26	2.29	30.68	2.73	2.74	36.73	4.07	3.13	42.04
50	2.68	0.75	10.09	3.09	0.86	11.59	4.29	1.14	15.42
100	2.74	0.48	6.48	3.19	0.57	7.72	4.38	0.77	10.47
150	2.75	0.39	5.28	3.29	0.47	6.38	4.47	0.53	7.11
200	2.87	0.34	4.58	3.77	0.41	5.61	4.56	0.49	6.74

Graph No.1: Variation of heat loss with stripwidth of isolated microstripline taking relative permittivity as a parameter

h = 100 mils, w = 100 mils, f = 3 GHz



IV. CONCLUSION

In the results obtained have been placed in table 1 and graph between rise in temperature and stripwidth have been plotted as shown in graph 1. It has been observed that with increase of stripwidth characteristic impedance both for even and odd-modes decreases effective permittivity for even-mode and odd-mode increases slightly. This causes increase of thermal loss and subsequent increase in rise of temperature. Variation of rise in temperature in case of even-mode is slightly greater than that in case of odd-mode.

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