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Study of Variation of Rise in Temperature with Relative Permittivity

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ABSTRACT

In this paper, I present about the study of variation of rise in temperature with relative permittivity. 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: Relative Permittivity, VSWR, Microwave, Microstripline Couplers.

I. INTRODUCTION

The presence of conduction strip and dielectric substrate causes heating effect or loss of energy in terms of temperature. It is important to study such temperature during the propagation of microwave in giga hertz range of frequency for designing the structures as this rise in temperature also limits the average power of the 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 have to study the characteristic impedance of the structure and the phase velocity of the wave traveling through 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 VARIATION OF RISE IN TEMPERATURE WITH RELATIVE PERMITTIVITY

For the study of rise in temperature in case of even and odd-modes and its variation with relative permittivity exhaustive computational and manual have been carried out. Results obtained have been placed in table 1 and graph has been plotted between rise in temperature and relative permittivity as shown in graph 1. It has been observed that with increase of permittivity thermal losses increases due to the presence of substrate material and metal strip both for even and odd-modes. But in case of odd-mode loss is greater than that in even-mode. The subsequent rise in temperature in case of odd-mode is larger than that in case of even-mode. This rise of temperature increases with relative permittivity.

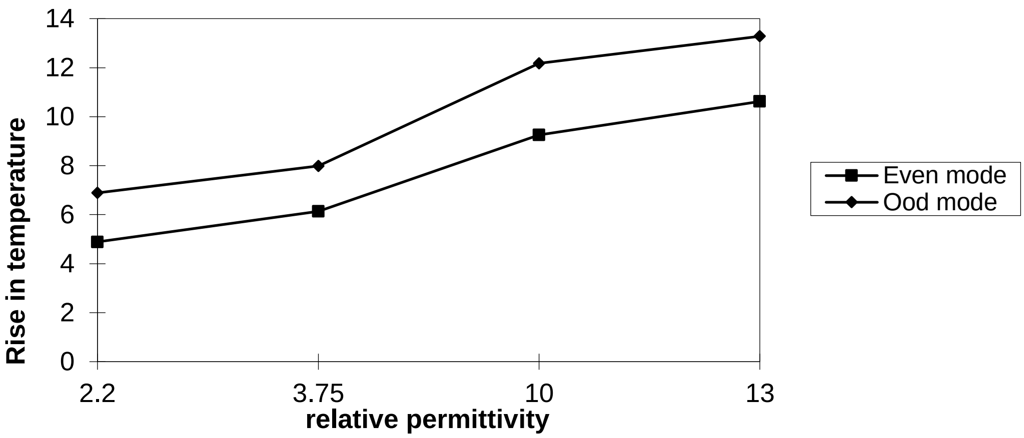
Table No. 1: Variation of rise in temperature with relative permittivity for even and odd-modes

w = 100 mils, s = 100 mils, h = 100 mils, t = 0.01 mils

ϵ_r	Even-mode			Ood-mode		
	α_d dB/m	α_c dB/m	ΔT °C	α_d dB/m	α_c dB/m	ΔT °C
2.2	0.012	0.37	4.88	0.011	0.52	6.898
3.75	0.019	0.46	6.15	0.016	0.58	7.98
10.0	0.025	0.69	9.27	0.022	0.91	12.17
13	0.028	0.789	10.63	0.025	0.97	13.29

Graph No. 1: Variation of rise in temperature with relative permittivity for even and odd-modes

w = 100 mils, s = 100 mils, h = 100 mils, t = 0.01 mils



IV. CONCLUSION

The thermal effects and rise in temperature can be controlled by changing these parameters. It has been observed that with increase of permittivity thermal losses increases due to the presence of substrate material and metal strip both for even and odd-modes. But in case of odd-mode loss is greater than that in even-mode. The subsequent rise in temperature in case of odd-mode is larger than that in case of even-mode. This rise of temperature increases with relative permittivity.

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