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STUDY OF HEAT LOSSES IN COUPLED MICROSTRIPLINE STRUCTURE

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ABSTRACT

In this paper, we discussed the analytical study of the heat losses in coupled microstripline structure due to wave propagation in the Gigahertz of frequency. All the parallel line couplers, whether mode of propagation is true TEM or not, have the even and odd-mode property which always results in even- mode characteristic impedance (Z_{oe}) and odd-mode characteristic impedance (Z_{oo}). For the study of the characteristic impedance of the microstripline coupler we develop the mathematical formula for even and odd-mode and then we will calculate the results. With the help of these results design synthesis technique is used to obtain the geometrical parameters of a coupler of given parameters.

KEYWORDS: MICs, Directional Couplers, Ch. Impedance

1. INTRODUCTION

The mathematical formulation is based on the conformal transformation technique developed by H.A. Wheeler and Calculation is based on the computer programming developed by S. K. Kaul using closed form formula of Schwarzmann. This technique is too much popular now-a-days and provides an easy approach for the analysis and synthesis of single and coupled microstriplines and other structures useful in MIC's. Parallel plate striplines support pure TEM mode of propagation but microstrip cannot support pure TEM mode as it is an inhomogeneous structure and it supports quasi-TEM mode. However, at low frequency the mode of propagation closely resembles the TEM mode. Wheeler calculated capacitances, phase velocities and impedances of single and coupled strips. Following these various approximate methods have been adopted by Crystal, H. Howe MAR Gunston, Policky and Stover etc. Bryant and Weis used Green's function technique and calculated the even- and odd- mode impedances of the coupled microstrip lines. S. Akhatarzad, Thomas R. Rowbotham and Peter B. Johns, M.K. Krage and G.I. Haddad also calculated the even- and odd- mode characteristic impedances of coupled microstrip using different techniques. E. Yamashita and R. Mitra presented an analysis based on variation principle. These results were found in reasonable agreement amongst themselves. Banmali, Rawat and Babu using methods of images calculated the characteristic parameters and founded them in close agreement with each other. The results obtained by image method were intermediate between Wheeler's two results for wide and narrow strips [1-5].

2. FORMULATION OF THE PROBLEM OF A MICROSTRIPLINE COUPLER

The study of microstripline coupler involves the analysis of even- and odd- modes of propagation. In the even-mode, energy traveling down, one microstrip line is coupled into a parallel line and travels in the same direction, where as in the odd-mode energy travels in the reverse direction after coupling. The derivation of the equation for the modes begins with the consideration of a basic single microstrip conductor shown in Fig (1). The characteristic impedance can be calculated with the help of elementary transmission line equation expressed as $Z_o = 1/V_P C_P$, 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 indicated in fig (1). These are: C_{PP} = parallel plate capacitance between lower surface of the microstrip and the ground plane and is given by

$C_{PP} = [\varepsilon_{reff}/c.\eta]. (w/h)$ ---------- 1

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

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

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

$C_F = [\varepsilon_{reff}/ c.\eta]. (2.7/Log4h/t)$ ---------- 3

Where, w =microstrip width, ε_{reff} = the effective dielectric constant of the medium, h=height of the substrate, Z_o=free space impedance = 377 Ω , c=the velocity of light in free space = 3.0 X 10^8 m/sec, t = microstrip thickness. Thus the total capacitance (C_P) of the isolated microstrip structure is expressed as

$=C_{PP} + C_{PPU} + C_F$ or

$C_p=(\varepsilon_{reff} / c.\eta) (w/h) + (2/3) (\varepsilon_{reff} / c.\eta) (w/h) (\varepsilon_{reff} / c.\eta)(2.7/Log4h/t)$------ 4

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

$V_P = c / \varepsilon_{reff}$ -------- 5

For wide strip, ε_{reff} , ε_r , and For narrow strip, ε_{reff} , $(\varepsilon_r + 1) / 2$

Where, ε_r = relative dielectric constant. From equations (1, (2) and (3), we get

$Z_o = (\varepsilon/\varepsilon_{reff}). [1/[(w/h) + (2w/3h) + (2.7/Log4h/t)]]$ -------- 6

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 [5-7].

3. EVEN MODE CHARACTERISTICS IMPEDANCE (Z_{OE})

The total capacitance is constituted by the following components: C_{PPE}= parallel plate capacitance as equation 2 for even mode. C_{PPU} = capacitance between upper surface of the conductor and ground plane as equation (3) C'_{PPU} = capacitance between strip conductor and ground plane enclosed between two striplines.

$(2\epsilon_{reff} / 3 c.\eta). (w/h). (1/ [(w/s) + 1]]$ -------- 7

C_F = Fringe capacitance at the edge of the striplines as equation 4.

C'_F = Fringe capacitance between two edges of the microstripline.

$(\epsilon_r / c.\eta) (2.7/\log(4h/t)) . (1/[(w/s) + 1]]$ -------- 8

Thus the total capacitance for even-mode coupled lines is expressed as

$C_{PE} = C_{PPE}+(1/2)C_{PPU}+ (1/2)C_F + (1/2)C'_{PPU} + (1/2)C'_F$ ------ 9

Now we can write the characteristic impedance for even-mode configuration as

$Z_{oe}=(\eta/\sqrt{\epsilon_{reff}}).[1/ [(w/h) + (w/3h) + (1.35/\log(4h/t))+ (w/3h).$
$(1/((w/s)+1)) +1.35/\log (4h/t)). (1/ ((w/s) + 1))]]$ ----- 10

and for t = 0

$Z_{oe} = (\eta /\sqrt{\epsilon_{reff}}).[1/ \{(w/h)[1+(1/3\sqrt{\epsilon_{reff}})]+(1/3\sqrt{\epsilon_{reff}}). (w/h) (1/ (w/s) + 1)\}]$
$= (\eta/\sqrt{\epsilon_{reff}}). [1/ \{(w/h) [1+ (1/3/\sqrt{\epsilon_{reff}})] + (1/3\sqrt{\epsilon_{reff}}) (1/(w/s)+1)\}$ -----11

4. STUDY OF HEAT LOSS IN COUPLED MICROSTRIPLINE

In case of coupled microstripline study of thermal effects has been performed for even and odd-modes of propagation for such study rise in temperature has been calculated with the aid of following equations:

(i) Even-mode-

Rise in temperature is written as

$\delta T = (0.23 h/K) \{ \alpha_c / w_e) + (\alpha_d / 2w_e)\} (^oC / watt)$ -------- 12

(ii) Odd-mode-

Rise in temperature is written as

$\delta T = (0.23 h/K) \{ \alpha_c / w_o) + (\alpha_d / 2w_o)\} (^oC / watt)$ -------- 13

Where, e' stands for even-mode and 'o' stands for odd-mode of propagation. On the basis of result obtained in calculations have been made for obtaining rise in temperature for even and odd-mode of propagation. Further by changing the strip geometry of coupled structure and relative permittivity rise in temperature has been calculated at different operating frequencies. Study has been performed in the following sections:

(i) Variation of rise in temperature with stripwidth;
(ii) Variation of rise in temperature with relative permittivity;
(iii) Variation of rise in temperature with operating frequency.

5. DISCUSSIONS AND CONCLUSIONS

This discussion of the result leads to the conclusion that thermal effects and rise of temperature are the functions of the geometry of the coupled structure, permittivity of the dielectric material and operating frequency. The thermal effects and rise in temperature can be controlled by changing these parameters. Results are shown in table and graph given below. These are very useful in designing the machine useful for heating. Microwave oven, diathermy machine and other appliances useful in preserving agriculture products are based on this fact. Among several heating process this is also mode of heat transfer. In this mode heat is produced directly at the locations where loss of power occurs.

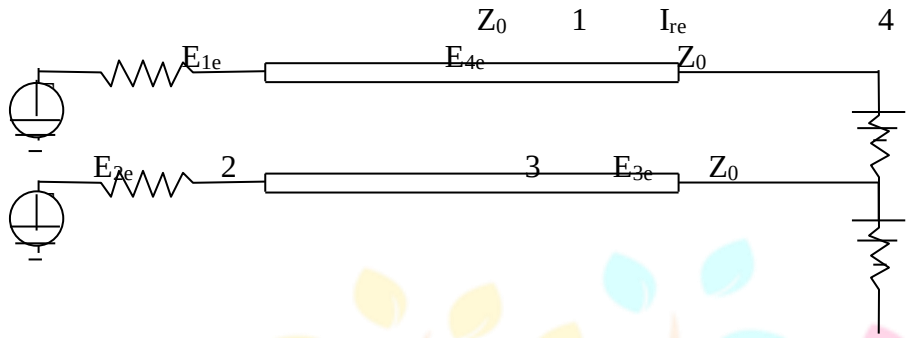


Fig 1. Coupled microstripline for Even-mode of excitation

Table No. 1: Variation of rise in temperature with stripwidth for even and odd-modes, h = 100 mils, s = 25 mils, t = 0.01 mils, f = 2 GHz, ϵ_r = 9.6

Stripwidth (w)	Even-mode			Ood-mode		
	α_d dB/m	α_c dB/m	ΔT °C	α_d dB/m	α_c dB/m	ΔT °C
10	8.76	0.58	6.31	7.39	0.92	7.90
50	9.34	0.60	6.63	7.70	0.98	8.37
100	9.56	0.67	7.14	7.81	1.01	8.76
150	9.81	0.72	7.52	7.95	1.21	10.15

Table No. 2: 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

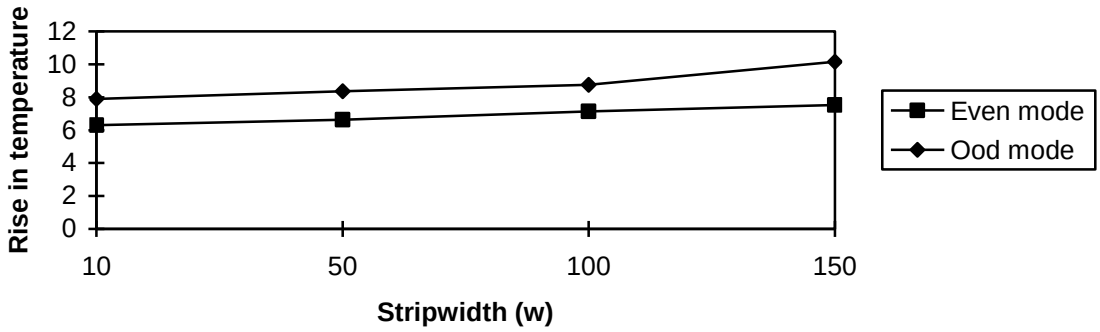
ϵ_r	Even-mode			Ood-mode		
	α_d dB/m	α_c dB/m	ΔT °C	α_d dB/m	α_c dB/m	ΔT °C
2.2	0.011	0.36	4.89	0.010	0.51	6.89
3.75	0.018	0.45	6.14	0.015	0.59	7.99
10.0	0.024	0.68	9.26	0.020	0.90	12.18
13	0.027	0.78	10.62	0.024	0.98	13.28

Table No. 3: Variation of rise in temperature with operating frequency for even and odd-modes, w = 100 mils, s = 100 mils, h = 100 milst = 0.01 mils

f (GHz)	Even-mode			Ood-mode		
	α_d dB/m	α_c dB/m	ΔT °C	α_d dB/m	α_c dB/m	ΔT °C
3	0.024	0.68	9.26	0.020	0.89	12.05
6	0.025	0.62	8.46	0.022	0.83	11.25
12	0.028	0.58	7.69	0.024	0.76	10.33
18	0.029	0.56	7.68	0.026	0.72	9.81
21	0.030	0.55	7.55	0.027	0.71	9.68

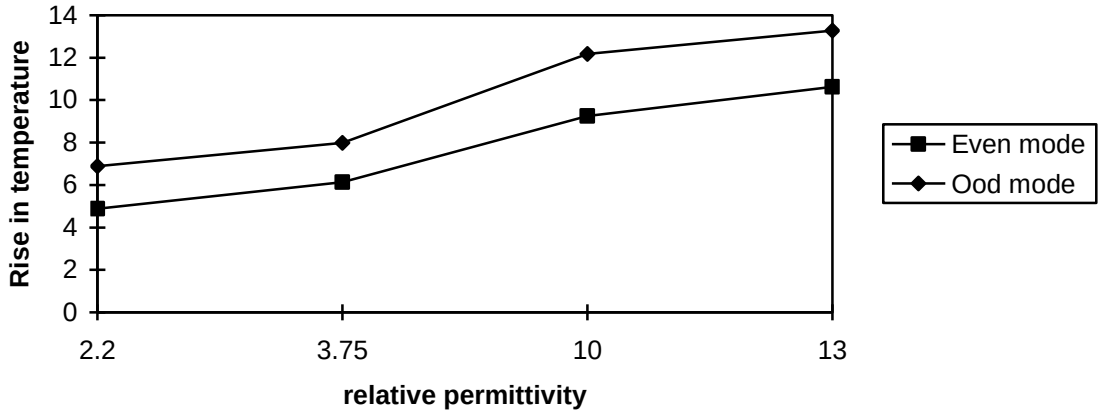
Graph No. 1: Variation of rise in temperature with stripwidth for even and odd-modes

h = 100 mils, s = 25 mils, t = 0.01 mils, f = 2 GHz, ϵ_r = 9.6



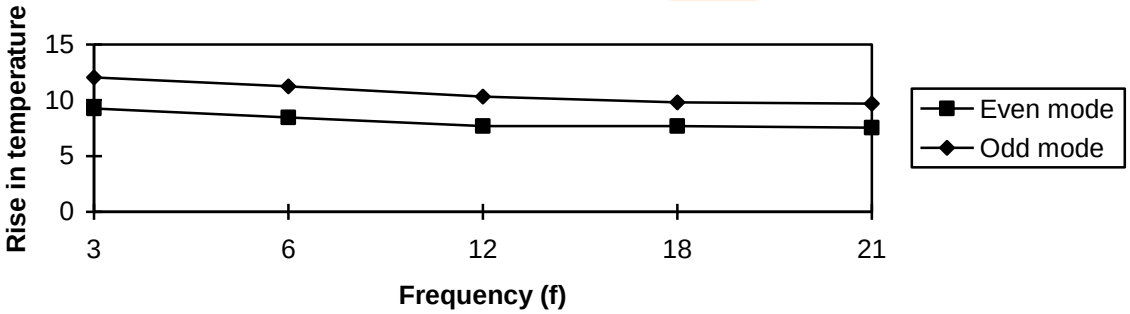
Graph No. 2: Variation of rise in temperature with relative permittivity for even and odd-modes

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



Graph No. 3: Variation of rise in temperature with operating frequency for even and odd-modes

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



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