STUDY OF DESIGN SYNTHESIS & FABRICATION OF A MICROSTRIPLINE COUPLER

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ABSTRACT

In this paper, we discussed the analytical study of the characteristic impedance of microstripline couplers and their variation with geometry and frequency using Alumina substrates for the design synthesis of the microstripline coupler. 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 property which always results in 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

INTRODUCTION

Several authors have developed various methods for the study of characteristics of single & coupled microstriplines. Using a brief account of some methods we deals this paper with the analytical study of the characteristic impedance of microstripline couplers and their variation with geometry and frequency using Alumina substrates for the design synthesis of the microstripline coupler which is the aim of the present work. 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_{oe}). For the study of the characteristics 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 the results design synthesis techniue is used to obtain the geometrical parameters of a coupler of given parameters. 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 Schwarmann. 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 singe and coupled strips. Following this 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.

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. (2). These are : C_{PP} = parallel plate capacitance between lower surface of the microstrip and the ground plane and is given by

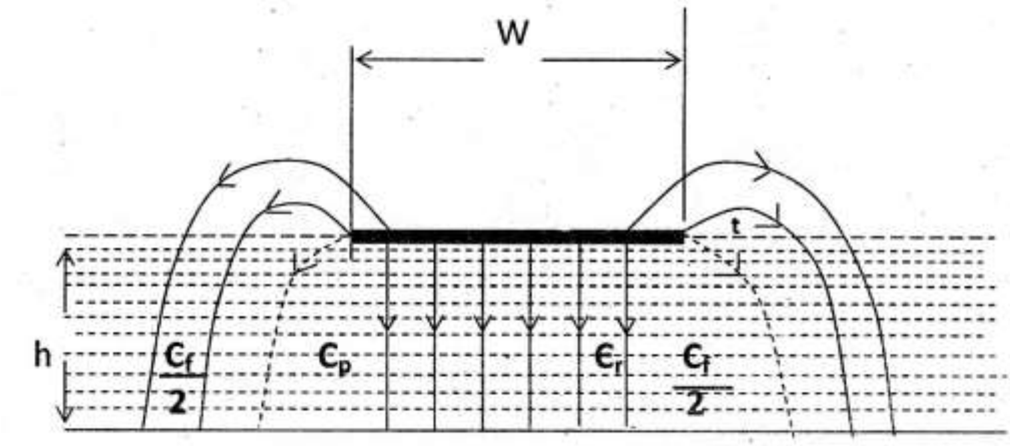


Fig. (1) : Electric field configuration in a microstrip (Isolated)

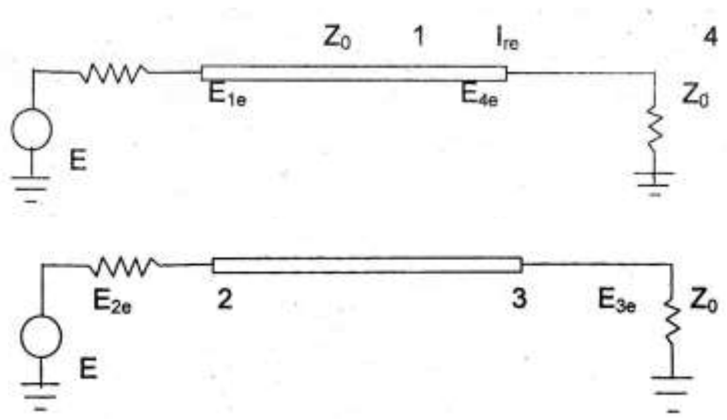


Fig. (2) : Coupled microstripline for Even-mode excitation

$$C_{PP} = \left[\in_{reff} / c.\eta_{\varepsilon}\right].\left(w/h\right) \qquad \text{.................. [1]}$$

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

$$C_{PPU} = (2/3)\left[\in_{reff} / c.\eta_{\varepsilon}\right].\left(w/h\right) \qquad \text{.................. [2]}$$

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

$$C_F = \left[\in_{reff} / c.\eta_{\varepsilon\varepsilon}\right].\left(2.7/Log4h/t\right) \qquad \text{.................. [3]}$$

Where, w = microstrip width, $\in_{reff}$ = 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 × 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

$$C_P = \left(\in_{reff} / c.\eta\right)\left(w/h\right) + \left(2/3\right)\left(\in_{reff} / c.\eta\right)\left(w/h\right)\left(\in_{reff} / c.\eta\right)\left(2.7/Log4h/t\right) \text{................. [4]}$$

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

$$V_P = c/\sqrt{\in_{reff}} \qquad \text{.................. [5]}$$

For wide strip $\in_{reff} \approx \varepsilon_r$, and for narrow strip, $\in_{reff} \approx \left(\in_r + 1\right)/2$

where, $\in_r$ = relative dielectric constant. From equations (1), (2) and (3), we get

$$Z_o = \left(\eta/\sqrt{\in_{reff}}\right).\left[1/\left(w/h\right) + \left(2w/3h\right) + \left(2.7/Log4h/t\right)\right] \qquad \text{.................. [6]}$$

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

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.

$$\left(2\in_{reff}/3c.\eta\right).\left(w/h\right).\left(1/\left[\left(w/s\right)+1\right]\right) \quad \text{..................} [7]$$

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

C_F = Fringe capacitance between two edges of the microstriplines.

$$\left(\in_r/c.\eta\right)\left(2.7/\log(4h/t)\right).\left(1/\left[\left(w/s\right)+1\right]\right) \quad \text{..................} [8]$$

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

$$C_{PE}=C_{PPE}+\left(1/2\right)C_{PPU}+\left(1/2\right)C_F+\left(1/2\right)C'_{PPU}+\left(1/2\right)C'_F \quad \text{................} [9]$$

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

$$Z_{oe}=\left(\eta/\sqrt{\in_{reff}}\right).\left[1/\left(w/h\right)+\left(w/3h\right)+\left(1.35/Log4h/t\right)+(2/3h)\right.$$

$$\left.\left(1/\left[\left(w/s\right)+1\right]+1.35/\log(4h/t\right).\left(1/\left[\left(w/s\right)+1\right]\right)\right] \quad \text{..................} [10]$$

and for $t = 0$

$$Z_{oe}=\left(\eta/\sqrt{\in_{reff}}\right).\left[1/\left\{\left(w/h\right)\left[1+\left(1/3\sqrt{\in_{reff}}\right)\right]+\left(1/3\sqrt{\in_{reff}}\right).(w/h)(1/(w/s)+1\right\}\right]$$

$$=\left(\eta/\sqrt{\in_{reff}}\right).\left[1/\left\{\left(w/h\right)\left[1+\left(1/3\sqrt{\in_{reff}}\right)\right]+\left(1/3\sqrt{\in_{reff}}\right)(1/(w/s)+1\right\}\right] \text{..........} [11]$$

ODD-MODE CHARACTERISTIC IMPEDANCE (Z_{OO})

In the case of odd-mode coupled lines, the total capacitance (C_{PO}) is determined in terms of the following components : C''_{PPU} = capacitance between strip conductor and the ground plane space enclosed between the two microstripline.

$$(8/3).\left(\sqrt{\in_{reff}}/c.\eta\right) \quad \text{..................} [12]$$

C''_F = Fringe capacitance between edges of the microstriplines and is given as

$$\left(\in_{reff}/c.\eta\right)[2.7/\log(4h/s)/\pi t)] \quad \text{..................} [13]$$

The total capacitance of the odd-mode coupled lines is thus expressed as

$$C_{PO} = C_{PP} + (1/2)\, C_{PPU} + (1/2)\, C''_{PPU} + (1/2)\, C_F + (1/2)C''_F \text{..................} [14]$$

And the odd-mode characteristic impedance (Z_{OO}) is given as

$$Z_{oo} = \left(\eta / \sqrt{\in_{reff}}\right).\Big[1/\Big\{(w/h) + \left(w/3h\sqrt{\in_{reff}}\right) + \left(1.35/\log(4h/t)\right)\left(4/3\sqrt{\in_{reff}}\right)$$

$$\left(1/(s/w)+1\right) + \left(1.35/\log(4s\tan(4h/s)/\pi t\Big\}\Big] \quad \text{..................} \; [15]$$

When, t = 0

$$Z_{oo} = \left(\eta / \sqrt{\in_{reff}}\right).\Big[1/\Big\{(w/h)[1 + \left(1/3\sqrt{\in_{reff}}\right) + \left(4/3\sqrt{\in_{reff}}\right)\left(1/(s/w)+1\right)\Big\}\Big] \text{....} \; [16]$$

STUDY OF DEPENDENCE OF CHARACTERISTIC IMPEDANCES FOR EVEN AND ODD-MODES WITH STRIPWIDTH

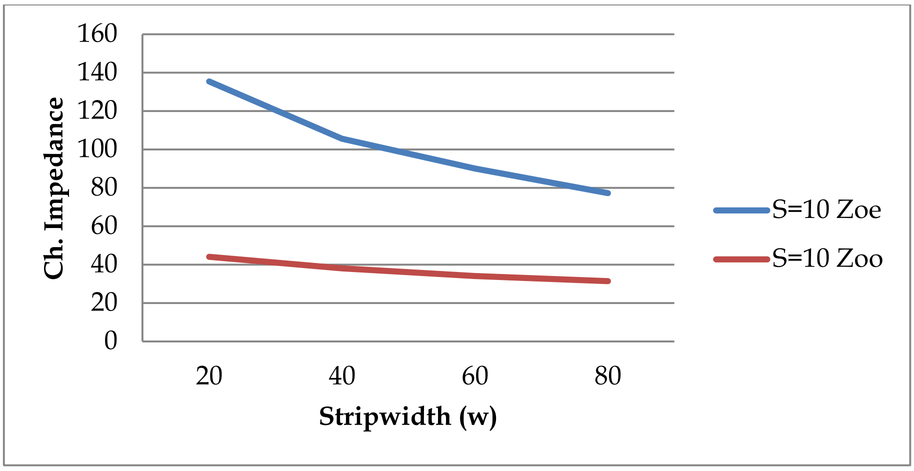
The alumina as dielectric substrate has been used for the present study. From the calculation, it is clear that for wider microstrip line (w/h>>1), the equivalent permittivity is very close to the value of relative permittivity ($\in_r$) and for narrower microstrip line (w/h<<1), the equivalent permittivity decreases to ($\in_r$ +1)/2. After exhaustive computations results for different metal stripwidth have been obtained. These results have been shown in Table 1. These computational works have been performed using computer Pentium-IV. Keeping frequency, relative and substrate height fixed and varying the width of metal strips characteristic impedance for even and odd-modes have been obtained for different spacing between metal strips. Further keeping width on x-axis and characteristic impedances for even and odd-modes on y-axis graphs have been plotted shown in graph 1.

Table-1

Dependence of characteristic impedance of coupled microstripline for even & odd-modes on strip width h = 100 mils, t = 0.01 mils, f = 2 GHz, $\in_r$ = 9.6, 1 mils = 10^{-3} inch = 2.54 µm

Stripwidth	**S=10 mils**				**S=20mils**			
W (mils)	$Z_{oe}\Omega$	$Z_{oo}\Omega$	$(\in_{reff})_e$	$(\in_{reff})_o$	$Z_{oe}\Omega$	$Z_{oo}\Omega$	$(\in_{reff})_e$	$(\in_{reff})_o$
20	135.50	44.20	6.52	5.42	130.20	53.10	6.65	5.40
40	105.60	38.12	6.80	5.40	103.12	44.50	6.92	5.35
60	90.10	34.20	7.12	5.39	86.90	40.20	7.15	5.32
80	77.25	31.50	7.28	5.35	75.50	36.40	7.35	5.28

Graph-1



STUDY OF DEPENDENCE OF CHARACTERISTIC IMPEDANCE FOR EVEN AND ODD-MODES ON SPACING BETWEEN TWO METAL STRIPS

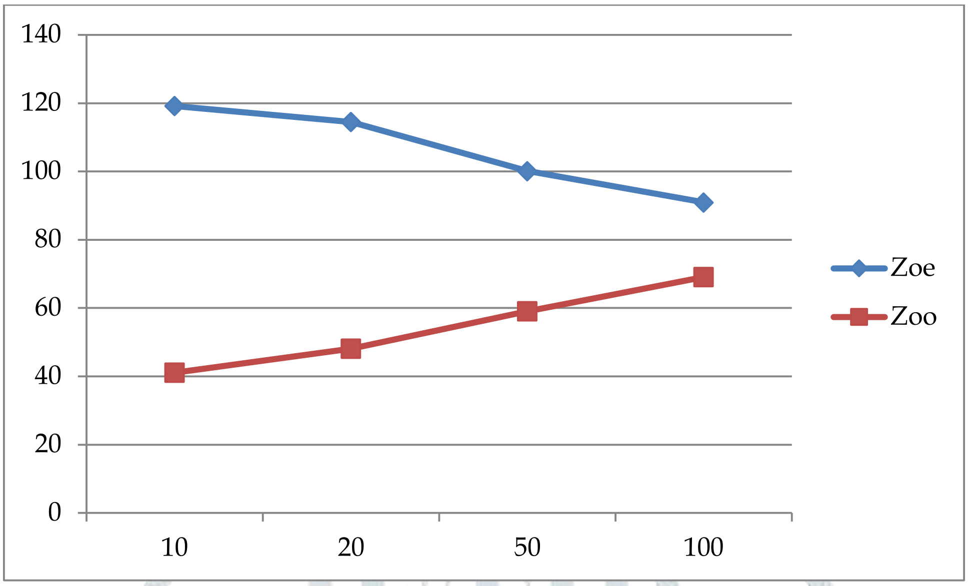
For this study characteristic impedance for even and odd-modes have been computed by putting the values of relative permittivity, substrate height, frequency and strip thickness and by changing the spacing between two metal strips. These results have been placed in table 2. Keeping spacing on x-asis and characteristic impedances on y-axis graph have been plotted both for even and odd-modes as shown in graph 2. These results show that with increase of spacing between two metal strips, characteristic impedances for even-mode decreases but for odd-mode increases.

Table-2

Dependence of characteristic impedance for even and odd-modes on spacing between two metal strips h = 100 mils, t = 0.01 mils, f = 2 GHz, $\in_r$ = 9.6, 1 mils = 10^{-3} inch = 2.54 µm, w=30 mils

Spacing (s) mils	$Z_{oe}\Omega$	$Z_{oo}\Omega$	$(\in_{reff})_e$	$(\in_{reff})_o$
10	119.20	41.10	6.78	5.40
20	114.50	48.12	6.72	5.35
50	100.12	59.10	6.65	5.32
100	90.95	69.12	6.62	5.30

Graph-2



DISCUSSIONS AND CONCLUSIONS

From the study of dependence of characteristic impedance of the microstripline directional coupler for even and odd-modes with strip width, spacing between two striplines, we draw useful information for design of directional couplers of different coupling coefficient and feed line characteristic impedance. These results obtained in the synthesis process are also reasonable agreement with those obtained in analysis process. So, this provides an important and necessary tool for the designer to fabricate directional coupler of desired coupling coefficient and directivity.

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