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Analytical Study of Microstripline Coupler

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ABSTRACT

This paper presents the analytical study of microstripline coupler. A natural coupling exists when two microstriplines are placed parallel to each other in close proximity. In ideal microstripline directional coupler makes use of the basic feature that power flowing in one direction in the strip conductor induces a power flowing in second strip conductor either in same direction or in reverse direction. First case is called Forward coupling and second case is called reverse coupling. When a second strip conductor is placed close to the first coupled microstrip structure is formed and the electric and magnetic field lines get distorted. The coupling between the two lines is even and odd. In the even mode coupling power flow is in the same direction and in the odd mode power flow is in the reverse direction after coupling. An ideal microstrip coupler makes use of the basic features that power flowing in one direction in the main microstripline induces a power flow in the second line in the forward direction or in the reverse direction. The coupling characteristics & reflected waves depend on the microstrip width, spacing between two microstrip and operating frequency. In the coupler some power flowing in the system gets reflected back.

KEYWORDS: MSL, VSWR, MICROWAVE, COUPLERS.

I. INTRODUCTION

In the age of modern high technology our country is developing tremendously with the growth of microchips and software. The importance lies in the study of light weight, small size and lower cost planer transmission structure like stripline microstripline specially in the field of communication. It is justified to carry out researches in this field of communication in the range of gigahertz frequency. In the coupled system energy flow may occur in the same and reverse direction. For the study of coupling of energy between two lines even and odd mode technique developed by Akhatarjad, Rowbotham & Jones is employed. For the analytical study of microstripline coupler, we also study of voltage standing Wave Radio (VSWR) and the same power flowing in the system which gets regulated back. For the purpose mathematical formulation of the problem is done using CAD and necessary computation & calculation will be carried out by using computers and calculator as well.

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

$$Z_o = 1/V_P C_P \qquad \text{---------------} (1)$$

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

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

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

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

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

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

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

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

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 DEPENDENCE OF CHARACTERISTIC IMPEDANCES FOR EVEN AND ODD MODE ON DIELECTRIC CONSTANT

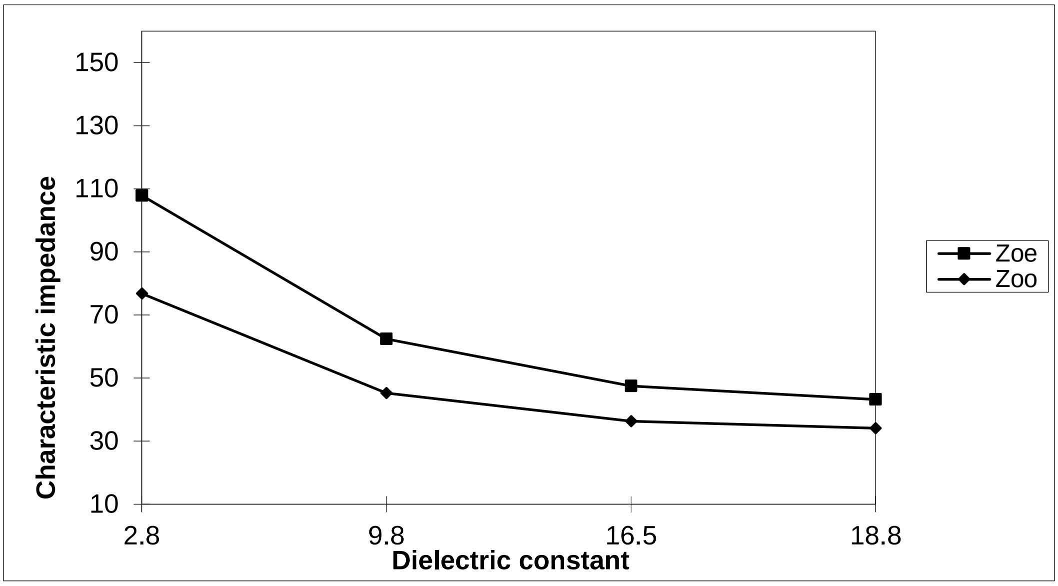
From the formulae it is evident that characteristic impedances for even and odd-modes also depend on dielectric constant of the substrate material used. Taking different substrate materials study has been performed for calculating these parameters for different dielectric constant keeping metal strip width and spacing between two metal strips fixed. The even and odd-mode characteristic impedances have been obtained and placed in the table 1 keeping dielectric constant on x-axis and characteristic impedances on y-axis graphs have been plotted as shown in graph 1. It is evident that both the impedances show decreasing trend with increase of dielectric constant for a given stripwidth and spacing. The rate of decrease in both the cases is almost the same.

Table No. 1: Dependence of characteristic impedances for even and odd mode on dielectric constant

w = 100 mils, h = 100 mils, t = 0.05 mils s = 100 mils, f = 3 GHz.

ϵ_r	Z_{oe}	Z_{oo}
3.8	107.92	76.81
9.8	62.42	45.51
16.5	47.52	36.51
18.8	43.22	34.51

Graph No. 1: Dependence of characteristic impedances on dielectric constant



IV. CONCLUSION

This concludes that more and more flux lines and power are concentrated in thicker metal strips when they are widely separated in case of even-mode of propagation. But in case of odd-mode of propagation lesser flux lines and power are concentrated when the strips are separated widely.

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