Analysis and Theoretical Calculation of 3 dB Hybrid Combiner

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Abstract---In this paper we discuss about 3 dB broadside coupled strip line coupler. A hybrid combiner is a passive device and used in radio and telecommunications. It is a directional coupler where input power is equally divided between two ports and gets combined power at output port. We calculate the design data for 3 dB hybrid combiner at 50MHz frequency.
Keywords: 3 dB; broadside; strip line; hybrid combiner

I. INTRODUCTION

Recently, the demand for high frequency and broadside transmission are increased. To achieve combining and splitting 3 dB broadside coupled stripline coupler is used. Directional couplers are an important category for passive microwave circuits. Directional couplers are used to divide or combine power. In principle of hybrid combiner or splitter is a 3 dB coupler having 4 ports. In case of splitter input power is given to one port and splits power in two equal parts. In case of combiner power is given to diagonally opposite ports and combined power appears at third port and remaining power goes to isolation port.

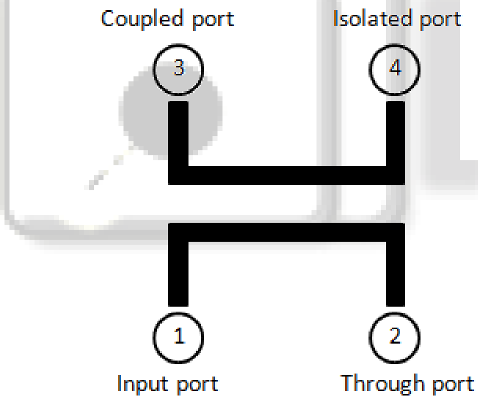

Fig. 1: Four port directional coupler.

Four port directional couplers are represented schematically by two single line representation of transmission lines with a crossed line between them to represent the coupling between lines can occur by providing an electrical connection between lines or by bringing together so that their magnetic and electric fields interact like shown in figure 2**.**

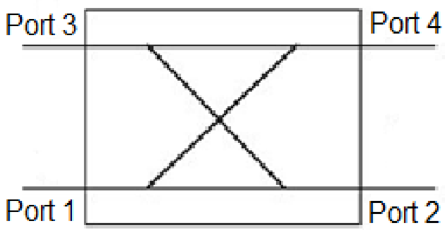

Fig. 2: Coupled line

II. BROADSIDE COUPLED STRIP LINE

Early microwave systems relied on waveguide and coaxial lines for transmission line. Waveguide has the advantage of high power handling capacity and low loss but it has one disadvantage of bulky and expensive. Coaxial line has very high bandwidth and convenient for test applications, but is a difficult medium in which to fabricate complex microwave components. Planar transmission lines provide an alternative, in form of strip line. Such transmission lines are compact, low cost and are capable of being easily integrated with diodes and transistors to form microwave integrated circuits. A conventional strip transmission line is balanced line in which a flat conducting strip is placed symmetrically between two large ground planes, with the space between the ground plane filled with a homogeneous dielectric.

Symmetric stripline, homogeneously filled with a dielectric material, is commonly used in the realization of passive microwave components such as filter, coupler and power dividers. In broadside coupled stripline a pair of strip conductors situated in homogeneous, lossless dielectric medium can support two fundamental TEM modes, called even mode and odd mode so there are two possible ways in which the electromagnetically coupled two conductor strip transmission lines can be excited. In even mode two strip conductors are excited in equal amplitude and in phase and in odd mode both strip conductors are excited in equal amplitude, but opposite phase means one is positive and the other is negative with respect to ground. In even mode both strips have positive voltage and in odd mode one strip is positive and another is negative. The electric field configurations and magnetic field configurations for two modes of excitation are illustrated schematically in figure.

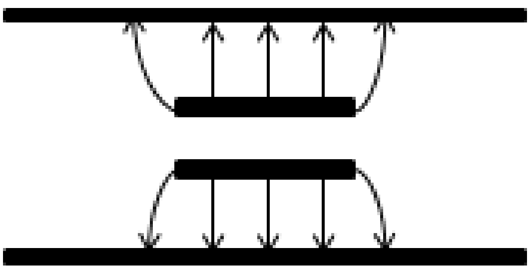

Fig. 3: Electric field for even mode.

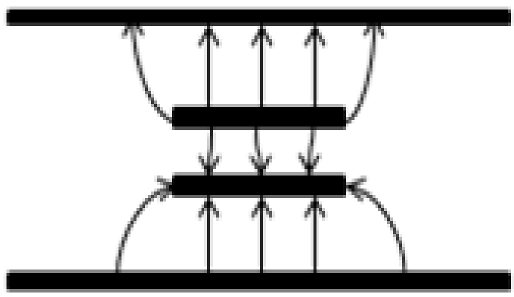

Fig. 4: Electric field for odd mode

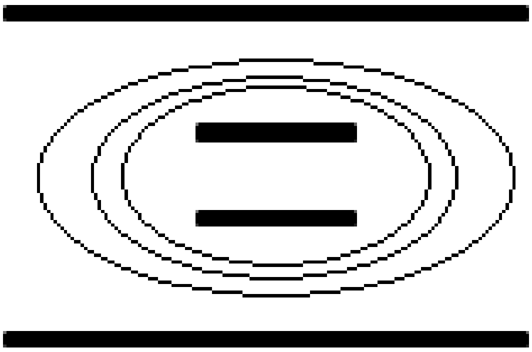

Fig. 5: Magnetic field for even mode

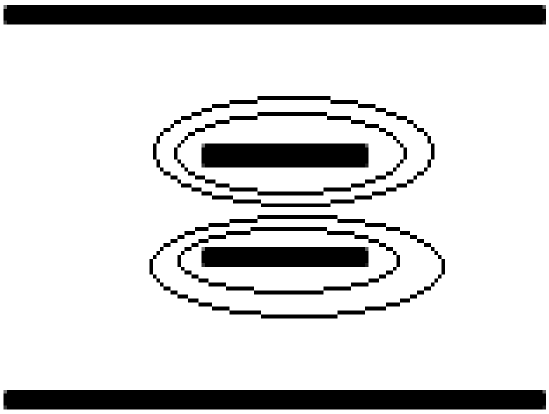

Fig. 6: Magnetic field for odd mode

At the plane of symmetry, normal component of the electric field is zero for even mode excitation whereas the tangential component is zero for odd mode excitation, where n̂ is the unit normal perpendicular to the plane of symmetry. The two modes have different characteristic impedances, but they propagate with the same phase velocity if the mode is pure TEM. If the medium is inhomogeneous, as would result when layered dielectrics with different dielectric constants are used, pure TEM mode cannot propagate. In such structure the two normal modes which are supported by a pair of coupled lines propagate with different phase velocities.

We designate the two characteristic impedances of the structure as Z_e and Z_o where the subscripts e and o represent the even and odd modes, respectively.

$$Z_e = Z_t \sqrt{\frac{1+C_v}{1-C_v}} \quad (1)$$

$$Z_o = Z_t \sqrt{\frac{1-C_v}{1+C_v}} \quad (2)$$

Where, C_v is voltage coupling coefficient and Z_e and Z_o represent the even and odd mode characteristic impedances.

In order that the coupler is perfectly matched to its terminating transmission line having a characteristic impedance Z_t , here characteristic impedance is 50 ohms. It is necessary that

$$Z_t = \sqrt{Z_e Z_o} \quad (3)$$

III. DIMENSIONAL PARAMETER OF BROADSIDE COUPLED STRIPLINE

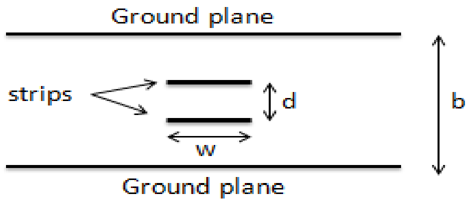

Fig. 7: Broadside coupled stripline

The even and odd mode characteristic impedances of broadside coupled homogeneous stripline by applying the Schwarz-Christoffel transformation method. These formulas are valid for w/d≥ 0.35. [6]

$$Z_e \sqrt{\varepsilon_r} = 59.952\pi \frac{K(\mathrm{k'})}{K(\mathrm{k})} \quad (4)$$

$$Z_o \sqrt{\varepsilon_r} = \frac{94.172\pi(\mathrm{d/b})}{\tanh^{-1} k} \quad (5)$$

K(k') and K(k) are complete elliptical integral of the first kind. The quantity [K(k')/K(k)] as a function of k has been tabulated in oberhettinger and magus[1]. The quantity [K(k')/K(k)] can also be expressed in simpler closed form formulas as follows.[6]

From equation, we have

$$\frac{K(\mathrm{k'})}{K(\mathrm{k})} = \frac{59.952\pi}{Z_t\sqrt{\varepsilon_r}}\left(\frac{1-C_v}{1+C_v}\right)^{1/2} \quad (6)$$

For $0.5 \le k^2 \le 1$; $1 \le K(k')/K(k) \le \infty$

$$\frac{K(\mathrm{k'})}{K(\mathrm{k})} \square \frac{1}{\pi}\ln\left(\frac{2(1+\sqrt{k})}{(1-\sqrt{k})}\right) \quad (7)$$

For $0 \le k^2 \le 0.5$; $0 \le K(k')/K(k) \le 1$

$$\frac{K(\mathrm{k'})}{K(\mathrm{k})} \square \frac{\pi}{\ln\left(\frac{2(1+\sqrt{k'})}{(1-\sqrt{k'})}\right)} \quad (8)$$

From and, k can be expressed as follows

$$k = \left(\frac{0.5\exp[\pi K(\mathrm{k})/\mathrm{K(k')}]-1}{0.5\exp[\pi K(\mathrm{k})/\mathrm{K(k')}]+1}\right)^2 \quad (9)$$

We have to find three important parameter which is width(w), gap between two strip(d) and total height of couple(b) for designing broadside coupled stripline coupler.

$$d/b = \frac{Z_t}{94.172\pi}\sqrt{\frac{1-C_v}{1+C_v}}\sqrt{\varepsilon_r}\,\tanh^{-1}(\mathrm{k}) \quad (10)$$

$$w/b = (2/\pi)\left[\tanh^{-1}\sqrt{\frac{k(\mathrm{k}-\frac{d}{b})}{(1-\mathrm{k}\frac{d}{b})}} - d/b\tanh^{-1}\sqrt{\frac{(\mathrm{k}-\frac{d}{b})}{k(1-\mathrm{k}\frac{d}{b})}}\right] \quad (11)$$

For a given coupling coefficient C_v, ε_r, and Z_t, the values of (d/b) and (w/b) can be obtained from equation 10 and 11 , respectively.

Name of parameter	Value(mm)
Length of strips(l)	1500
Gap between two strip(d)	37
Width of strip(w)	224
Distance between strip to ground plane(H1/H3)	118.8
Total height(b)	284.6
Thickness of strip(t)	5

Table 1: Design parameter for 3 dB broadside stripline coupler

In this work, the main purpose was to calculate parameter for broadside stripline coupler. Dielectric constant is 1, dielectric name is air.

IV. CONCLUSION

We have calculated design parameter for 3 dB broadside coupled stripline coupler at 50 MHz frequency. 3 dB broadside coupled stripline is used for combining and splitting power. In hybrid combiner half power is given to two ports and gets combined output power at coupled port.

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