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STUDY OF COUPLING COEFFICIENT & DIRECTIVITY OF THE MICROSTRIPLINE COUPLER

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ABSTRACT: The coupling coefficient, directivity and the attenuation constant etc. are to be studied in this present paper. The microstrip directional coupler and its characteristic parameters have also been analytically studied. An ideal microstrip directional coupler makes use of the basic feature that power flowing in one direction in the main transmission line induces a power flow in only one direction in the secondary line.

1. INTRODUCTION

When two transmission lines are placed parallel to each other inclose proximity a natural coupling exists. Such coupling exists for the structure like (i) striplines, (ii) microstriplines, (iii) slotlines etc. which are open in the transverse direction. As is known sections of coupled lines are used in various microwave circuits, like (i) directional couplers (ii) filters (iii) impedance transformers (iv) circulators and (v) isolators etc.The design of a quarter wave parallel coupled microstripline coupler is the topic of the present work. For this type of coupler, the coupling coefficient and directivity are the functions of the width of the microstripline, the separation between them and the length of the coupling coefficient, directivity and the attenuation constant etc. are to be studied, for any particular design.

2. DIRECTIONAL COUPLER

Directional couplers are used to sample the part of energy passing through the main waveguide. They are also used to check the signal passing through two arms in phase as well as amplitude. The directional coupler is four port device. There are no reflections at the junctions of these four ports. When the power is incident from port(1) then it is passed to port (2)and port(4) but it is not passing to port(3), thus the port(3) is uncoupled. Similarly when the power is incident from port(3) then this is coupled to port(2) and port(4) but it is not coupled to port(1).
The performance of directional coupler depends on the following four parameters:-
(i) Coupling factor,(ii) Directivity,(iii) Insertion loss,(iv) Isolation
But here we will discuss only two & their variation with strip width and spacing between two striplines only..

Coupling coefficient

Coupling coefficient is always given in decibels. It is defined as the logarithmic ratio of incident power to the power output from auxiliary arm. It is denoted by 'C'

$$C = 10 \log_{10} P_{in} / P_{out}$$

Where, P_{in} = Incident power
P_{out} = Power coming out from auxiliary arm.

Directivity

Directivity is defined as the ratio of power coupled in the forward to power coupled in the backward direction in the auxiliary arm. All other arms which are not used should be terminated with the matched load. It is denoted by 'D'. It is given in decibels.

$$D = 10 \log_{10} P_{aux(forward)} / P_{aux(backward)}$$

Where,
$P_{aux(forward)}$ = Power coupled in the auxiliary arm due to power in forward direction.
$P_{aux(backward)}$ = Power coupled in the auxiliary arm due to power in backward direction.

Thus if the value of directivity is more it indicates the leakage of power in the auxiliary arm is less. Generally D is in between 30 to 35 dB.

3. FORMULATION OF THE DIRECTIVITY OF THE MICROSTRIPLINE COUPLER

It is the measure of discrimination of a directional coupler between forward and backward waves and is defined as the ratio of the voltage coupled to the desired port and of the voltage coupled to the undesired port, i.e.

$$D = V_4/V_3$$

$$D(dB) = -20 \text{ Log } V_4/V_3 \quad \text{--------------------(1)}$$

or an ideal forward directional coupler directivity is infinity, i.e. voltage at port 3 should be ideally zero. The signal is coupled only to port 4, ports (2) and (4) being perfectly matched. [1-3]

With microstrip the differing field pattern associated with the odd and even modes, give rise to different phase velocities. This results in some coupling to the unwanted port as well. The greater difference in the phase velocities of the even and odd modes makes the coupling tighter. This parallel microstrip directional coupler may not give a wide band width performance for tight coupling. Further the directivity depends on microstrip geometry and substrate property ϵ_r. An approximate but simpler mathematical expression for the directivity of the coupled microstrip coupler is given as

$D = [4|\xi| / \Delta\pi(1-|\xi^2|)]^{-2}$

$D = [\lambda\pi(1-|\xi^2|) / 4|\xi|]^2$ --------------------- (2)

Where,

$\Delta = [\lambda_{go} / \lambda_{ge}] - 1$ ---------------------(3)

λ_{ge} and λ_{go} are the guide wavelengths of the coupled lines for even and odd modes respectively and expressed by equation and

$\xi = [\rho_e / 1- \rho_e^2] - [\rho_o / 1+ \rho_o^2]$ ---------------- (4)

Where,

ρ_e = Reflection coefficient for even mode.

$= Z_{oe} - Z_o / Z_{oe} + Z_{oo}$ --------------- -------(5)

and ρ_o = Reflection coefficient for odd mode.

$= Z_{oo} - Z_o / Z_{oe} + Z_{oo}$ --------------- --------(6)

4. FORMULATION OF THE COUPLING COEFFICIENT

For the purpose of calculating the coupling coefficient in terms of characteristic impedance for even and odd modes formula used is written as

$C = Z_{oe} - Z_{oo} / Z_{oe} + Z_{oo}$

5. CALCULATION OF THE DIRECTIVITY AND COUPLING COEFFICIENT

The coupling coefficient and directivity can be calculated manually using calculators by measuring the values of characteristic impedance for even and odd-modes and guide wavelengths for further study as given in following sections.

5.1 STUDY OF DIRECTIVITY AND ITS DEPENDENCE ON STRIP WIDTH

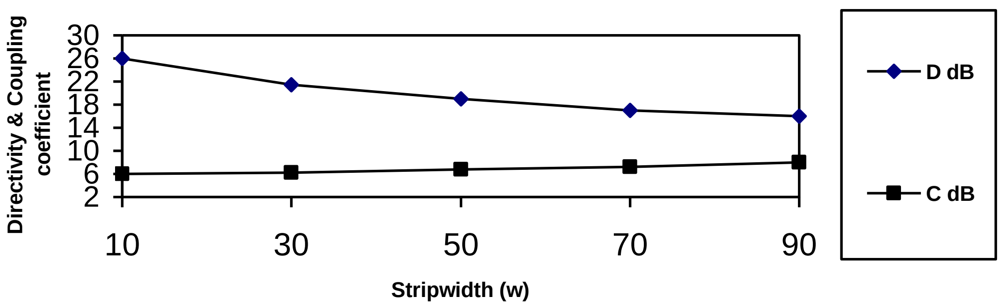
The directivity of microstripline coupler has been calculated for given spacing between two metal strips coupling coefficient and permittivity at given frequency 2 GHz. By changing the strip width for given spacing directivity has been obtained. The results have been placed. The graphs with strip width on x- axis and directivity on y-axis have been plotted for different spacing shown in graph 1.The results shows the dependence of directivity on strip width keeping other parameter fixed. As the strip width increases directivity decreases at moderate rate showing the greater amount of power coupled to the neighboring microstripline in forward direction which can result in greater coupling coefficient.

5.2 STUDY OF DIRECTIVITY AND ITS DEPENDENCE ON SPACING BETWEEN TWO METAL STRIPS

The directivity of the microstripline coupler with given strip width and dielectric substrate has been calculated for different spacing at given frequency of 2GHz. The results have been placed with spacing (S) on x-axis and directivity (D) on y-axis graphs have been plotted shown in graph 2. The result shows the dependence of directivity on spacing between two metal strips. The directivity decreases with increase of spacing between two strips with relatively larger rate than that of variation of directivity with strip width. This shows that spacing between two strip lines affects the flow of power its coupling to the neighboring line in forward direction.

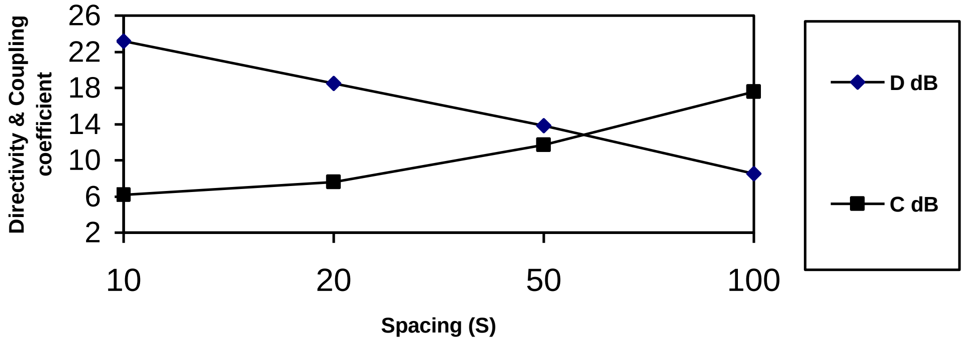
Graph 1: Variation of Directivity & coupling coefficient with stripwidth

t = 0.01 mils, h= 100 mils, f = 2GHz, S = 10 mils, ϵ_r = 9.6



Graph 2: Variation of Directivity & coupling coefficient with spacing

t = 0.01 mils, h= 100 mils, f = 2GHz, w = 20 mils, $\epsilon_r = 9.6$



6. CONCLUSIONS

From the above discussion of the results in different sections it can be concluded that coupling coefficient and directivity of the microstripline coupler are the functions of geometry of the structures along with spacing between two strips. These parameters are also the functions if guide wavelength, effective relative permittivity and frequency. Further these parameters are also the functions of different attenuations occurring within the structures due to propagation of waves in even and odd-modes both. Thus the coupling coefficient is dependent on thermal effects or rise in temperature of the structure as seen in the above discussion. The coupling coefficient has direct relation with rise in temperature where as directivity has inverse relation with it. These parameters are very important for the study of design of a microstripine coupler, directional coupler, isolators, resonators and filters as well. Regarding the development of planer transmission line in milimetric and sub milimetric wave length range, this study is more useful.

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