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STUDY OF THERMAL EFFECTS ON THE COUPLING COEFFICIENT AND DIRECTIVITY OF MICROSTRIPLINE COUPLER

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ABSTRACT:- In the present paper, we minimize the losses & to reduce the size & cost new technology known as planar transmission line technology has been developed with the advent of microwave integrated circuits (MIC's). When two microstriplines are placed together in close proximity, natural coupling exit between them. Such coupling exits in stripline and slot lines also which are open in transverse direction. The coupling and directivity are the function of the width of the microstripline and the separation between the two striplines. Due to power flow through the structure energy dissipation occurs which results in thermal effect. This affects the coupling and directivity which is the aim of the present study.

KEYWORDS: Stripline Structure, Directivity, Coupling coefficients, Transmission Line

1. INTRODUCTION

The two parallel wire transmission lines (as shown in fig 1) are the simplest structure for microwave signal but these are very much loss in giga hertz range of frequency. To minimize the losses & to reduce the size & cost new technology known as planar transmission line technology has been developed with the advent of microwave integrated circuits (MIC's). There are various transmission structures which have been developed & designed by different pioneer of this field suitable for giga hertz range of frequency such as stripline, microstripline (as shown in fig.2.& 3), slot line, coplanar strips and coplanar wave guides (as shown in fig.4 & 5). When two microstriplines are placed together in close proximity, natural coupling exit between them. Such coupling exits in stripline and slot lines also which are open in transverse direction. A section of coupled lines is used in various microwave circuits like

(i) Directional coupler of given coupling coefficient and directivity
(ii) Filters
(iii) Impedance transformer
(iv) Circulators and Isolators.

Here we have to deal with the microstripline coupler, its directivity and coupling coefficient. We have to discuss also the factors affecting these parameters.

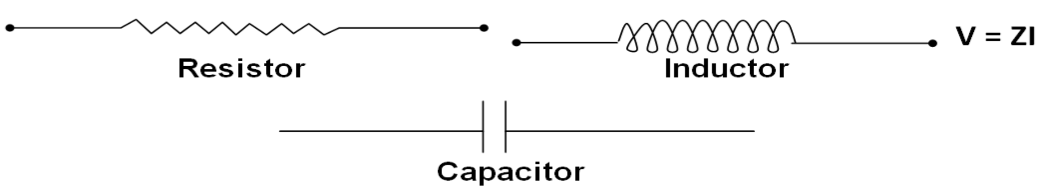


Fig 1. Dimensional transmission line

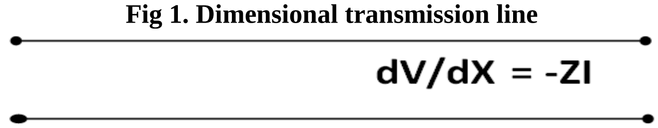


Fig 2: 1-Dimensional Transmission line

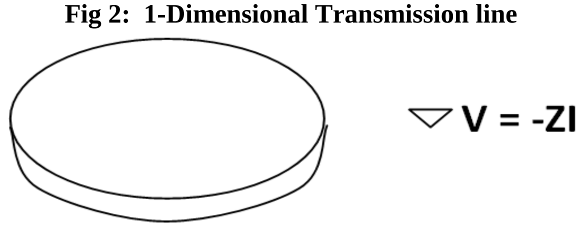


Fig 3: 2-Dimensional Planar transmission line

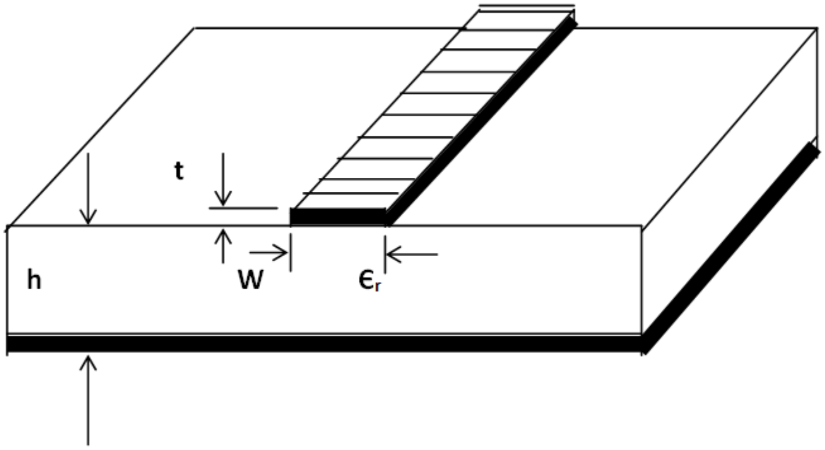


Fig 4: Microstripline structure

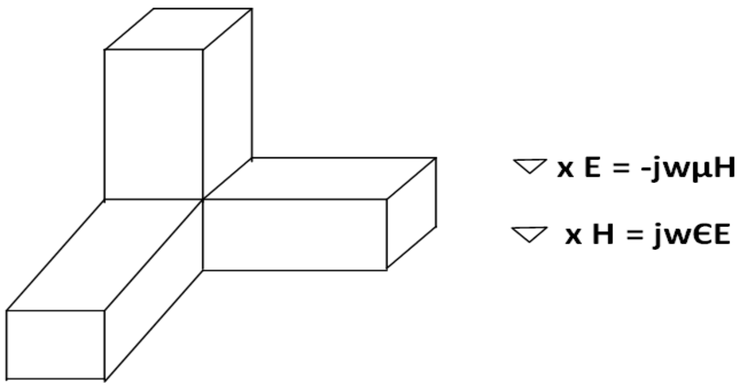


Fig 5: 3-Dimensional waveguide structure

2. 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.

$D = V_4/V_3$

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

For 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. 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)

3. 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

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

4. 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 and the results obtained are placed in tabular form for further study as given in following sections.

4.1. Study of directivity and its dependence on strip width

The directivity of microstripline coupler has been calculated for given spacing between two metal strip coupling coefficient and relative at given frequency 2 GHz. By changing the strip width for given spacing directivity has been obtained. The results have been placed in the table 1. 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.

4.2. Study of directivity and its dependence on spacing

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 in table 2 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.

4.3. Study of Directivity & its dependence on frequency

The directivity of the microstripline coupler with given stripwidth, spacing & dielectric substrate has been calculated at different frequencies & results were placed in table 3 With directivity on y-axis &frequency on x-axis graphs have been plotted shown in graph 3. This shows the marked variation of D with f with increasing of frequency directivity increases at moderate rate showing that the flow of power & its coupling to the neighboring line in forward direction is affected with increase of frequency.

Table 1:Variation of Directivity & coupling Coefficient with strip width

$t = 0.01$ mil, $h = 100$ mils, $f = 2$ GHz, $S = 10$ mils, $\epsilon_r = 9.6$

w	Z_{oe} Ω	Z_{oo} Ω	$Z_o = \frac{Z_{oe} + Z_{oo}}{2}$ Ω	D dB	C dB	ϵ_{ree}	ϵ_{reo}
10	164.50	58.85	96.96	26.0	6.0	6.37	5.62
30	119.00	40.60	79.80	21.5	6.2	6.70	5.38
50	97.10	36.10	66.60	19.0	6.8	7.01	5.30
70	82.75	32.80	57.77	17.0	7.2	7.20	5.28
90	72.50	30.50	51.50	16.0	8.0	7.35	5.30

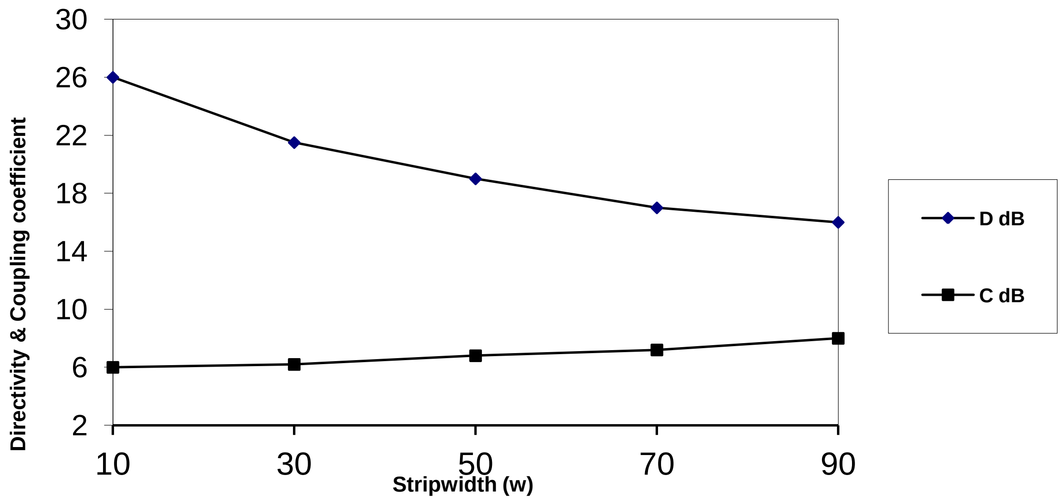
Table 2: Variation of directivity & coupling coefficient with spacing

S mils	Z_{oe} Ω	Z_{oo} Ω	$Z_o = \frac{Z_{oe} + Z_{oo}}{2}$ Ω	D dB	C dB	ϵ_{ree}	ϵ_{reo}
10	136.10	44.35	90.22	23.2	6.2	6.58	5.44
20	129.85	52.75	91.30	18.5	7.6	6.61	5.41
50	112.10	65.50	88.8	13.8	11.7	6.55	5.35
100	102.00	93.50	97.75	8.5	17.6	6.60	5.33

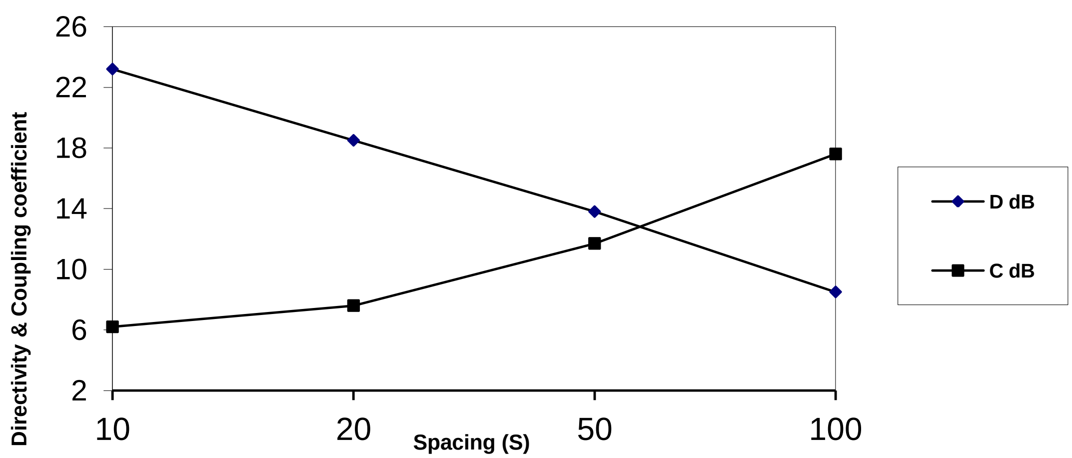
Table 3: Variation of directivity and coupling coefficient With frequency

f Ghz	Z_{oe} Ω	Z_{oo} Ω	$Z_o = \frac{Z_{oe} + Z_{oo}}{2}$ Ω	D dB	C dB	ϵ_{ree}	ϵ_{reo}
2	129.85	52.75	91.30	17.15	8.15	6.61	5.41
5	130.20	53.30	93.75	20.20	8.50	6.80	5.62
10	135.50	55.20	95.35	28.80	8.80	7.25	5.80
15	140.30	57.30	98.80	32.20	9.00	7.50	5.95
20	145.25	60.20	102.725	37.00	9.2	7.80	6.25

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

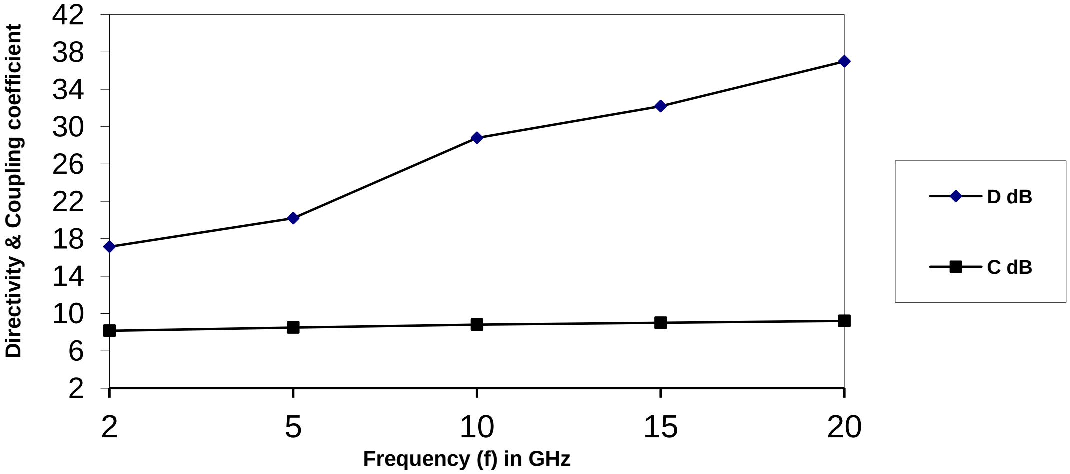


Graph 2: Variation of Directivity & coupling coefficient with spacing
t = 0.01 mils, h= 100 mils, f = 2GHz, w = 20 mils, ϵ_r = 9.6



Graph 3: Variation of Directivity & coupling coefficient with frequency

t = 0.01 mils, h= 100 mils, w = 20 mils, ϵ_r = 9.6 S = 20 mils



5. 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 microstripline 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. This also contains scope for future study.

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