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Study of Dependence of Capacitance of Coupled Stripline on Stripwidth, Frequency and Spacing Between Two Striplines

Dheeraj Kumar Singh[1], K. B. Singh[2], Pramendra Ranjan Singh[3]
[1]Research Scholar, Department of Physics, J. P. University, Chapra, Bihar, India
[2]Department of Physics, L. S. College, Muzaffarpur, B. R. A. Bihar University, Muzaffarpur, Bihar, India
[3]Principal, Narayan College Goryakothi, Siwan, J. P. University, Chapra, Bihar, India

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ABSTRACT

In this present paper, we studied about the dependance of capacitance of coupled stripline on strip width, frequency and spacing between two striplines. Miniaturized microwave circuits fabricated by extension of integrated circuits (ICs) technology to microwave frequencies are known as Microwave Integrated Circuits (MICs). MICs promise a real revolution leading to both expansion of present markets of microwaves & opening of many new applications including host of non-military uses in India & abroad. With the advent of MICs planar Transmission Lines have been developed which have been proved to be very significant as regards the fabrication of various microwave-components such as: Directional Coupler, Filters, Isolator & Impedance transformers etc. The planar Transmission Lines are: Stripline, Microstripline, Slot line, Coplanar Striplines & their different variant forms such as inverted and suspended striplines & microstriplines etc. Among these microstripline is the most suited due to its open structure, low losses in gigaharz range of frequency, reduced size, improved reliability and eventual cost reduction in mass production. The microstrip transmission line consists of a narrow strip conductor separated from a conducting ground plane by an intervening supporting dielectric substrate as studied by Wheeler and others. The electromagnetic traveling through such structures suffers from some losses like: Conductor loss & Dielectric loss. There is a change of phase of the wave traveling through the structure also. This phase change (shift) depends on the width of metal strip, height of the dielectric substrate, permittivity of the substrate and operating frequency. The present study is devoted to this objective i.e. we have to study the variation of Phase-Shift of the wave within the structure with width of the stripline, height & effective permittivity of the structure & frequency.

Keywords: Phase Factor, MIC's, Filter, Transmission line, Stripline, Microstripline, Operating Frequency

I. INTRODUCTION

There are different structures for the propagation of electromagnetic powers in different modes. Also there are various devices for sending massage or signals from one place to another remote place. In the age of Moughal period pigeons were employed for sending massage. In addition different animals such as horses, donkeys, elephants, bullock, buffalos, asses etc were employed for the communication purposes. Now in the age of modern science & technology, radios, television, telegraphs, satellite, cell phones and mobiles are used for sending the message from one place to other places how far away these are. Lumped circuits, transmission lines, co-axial cables and waveguides are now the significant systems of communication. Microwave Integrated circuits (MIC'S) have changed these systems in the present days by replacing large scale waveguides and co-axial component arrays to small light weight assemblies. These introduced microwave striplines, microslotlines, coplanar strip lines and coplanar waveguide etc. The design system used for these circuits has also changed from the early "cut & try" methods, using "ruler and knife" to the computer aided design (CAD), photo-mechanical fabrication and optical fiber communication. The transmission lines, waveguide, co-axial cable, stripline and micro striplines are used for sending message signals from one place to another. Striplines and micro striplines are planer transmission structure having features as: Small in size, low cost, light weight, and easily replaceable are widely used these days. Microstripline is an open structure and used in microwaves integrated circuits. There are various parameters like characteristics impedance, phase velocity, guide wavelengths and propagation parameters. These parameters are very sensitive to the frequency in the microwave region. These also depend on the geometry of the structure. The aim of the present work is to concentrate on the study of the Phase Shift of the microstripline structure with frequency, width and height of the structures comprising its geometry.

II. Study of Microstripline

It is out of various planer transmission structures microstripline is an important open structure. It consists of a narrow conductor strip on one side of a dielectric substrate and the other side being completely metalized to serve as a ground plane. The microstrip structure may be derived from the stripline configuration by removing the top ground plane and upper laminate shown in fig 1 a. The electric and magnetic field configuration are shown in fig 1 b. Although the structure is

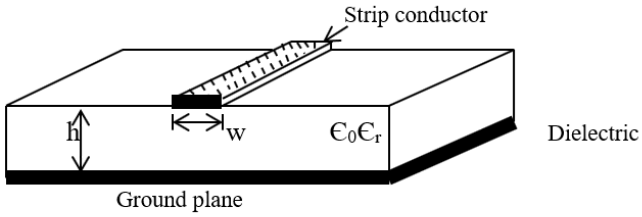


Fig 1a: Microstripline (QUASI-TEM Mode)

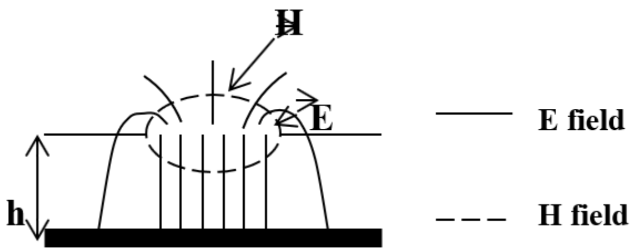


Fig 1b: Microstrip Field configuration

open, the radiation problem is avoided by using high dielectric constant substrate. Alumina (ϵ_r=9.6) and garnet etc are most commonly used substrate. In the present work we use garnet having dielectric constant ϵ_r=10.5.

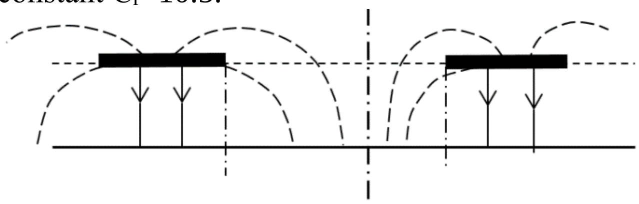


Fig 2. The even mode forward coupling

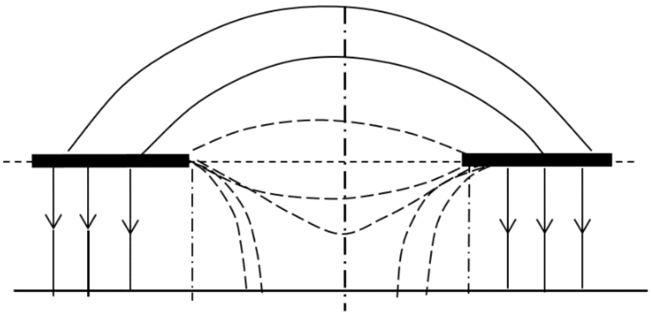


Fig 3. The odd mode reverse coupling

III. Formulation of characteristics impendence

The transmission structures like two parallel wire transmission line, co-axial cable, waveguide, stripline, microstripline, slotline and their different variants posses the different characteristics parameters like characterstics impedance, propagation constant, phase velocity and guide wavelength. All these parameters are the function of the width of the metal strips, height of the dielectric substrates and permittivity of these substrates. Here we concentrate only for the study of characteristics impedance and their variation with strip width, height and operating frequency of the wave to be propagated through the transmission structure.The characteristic impedance [59] of TEM transmission line like stripline and microstripline is given by

$Z_o = 1/V_P C_P$ -----1

Where, V_P= phase velocity of the wave traveling along the transmission structure.

C_P= capacitance per unit length of the structure.

C_P is given by the expression

$Cp= (\epsilon re / C\eta)(w/h) + (2/3)(\epsilon re / C\eta)(w/h)(\epsilon re / C\eta).(2.7/Log4h/t)$ ------2

and Characteristics Impedance is giver by

$Z_o=(\eta/\sqrt{\epsilon_{re}})[1/[(w/h)+(2w/3h)+(2.7/Log4h/t)]]$ ------3

Were w= width of microstripline, h= height of dielectric substrate, t= thickness of stripline and Єr=permittivity of the dielectric substrate.

IV. Study of dependence of capacitance for even and odd modes

For the study of a dependence of capacitances for even and odd modes exhaustive calculations have been carried out for different values of strip width capacitance have been calculated for even and odd modes of propagation. The results obtained have placed in table 1. The graphs have been plotted keeping strip width (w) along x-axis and capacitances for even and odd modes on y-axis. It is evident from the graph shown in graph figure1 that have keeping spacing fixed, the capacitance increases with increase of strip width in case of both even and odd modes. But capacitance for even mode is less than the capacitance in odd mode. This means more and more energy is stored in the coupled micro strip line transmission structure as strip width becomes wider and wider. Also, greater energy is stored in odd mode than that in even mode.

V. Study of dependence of capacitance for even and odd modes with spacing between two coupled microstriplines

For this purpose, exhaustive calculations have been carried out for the study of variation of capacitances in even and odd modes (Ce & Co respectively) with spacing (s) keeping strip width fixed. The computed results have been placed in table 2. Keeping spacing on x-axis and Ce and Co on y-axis graphs have been plotted as shown in graph figure 2. From the results it is evident that with increase of spacing Zoe decreases and Zoo increases which causes capacitance for even mode increases with increase of spacing. Whereas capacitance decreases with increase of spacing in odd mode propagation. It means as spacing increases more energy can be stored in even mode propagation and less energy can be stored in odd mode propagation. This idea is more useful for the design of the microstripline coupler.

VI. Study of dependence of capacitances for even and odd modes (Ce & Co) with relative permittivity of the substrate

For this purpose, both for even and odd modes characteristics Impedances and phase velocity have been calculated for different values of relative permittivity of the substrate and then capacitances have been obtained. In case of even and odd modes propagation of energy through the coupled transmission structure. The results obtained have been placed in table 3. Keeping relative permittivity on x-axis and capacitances on y-axis graphs have been plotted as shown in graph fig. 3. As it is evident from the graph both Zoe and Zoo decrease with increase of relative permittivity as a result of which capacitances increase with increase of relative permittivity in case of both even and odd modes showing greater concentration of electric flux within the coupled structure and greater storage of energy. Thus, study furnishes very useful information for designing of a coupler.

Table 1: Dependence of Ce and Co with stripwidth (w) t = 0.01 mils, f= 2Ghz, s= 10 mils, h= 100 mils, Єr= 9.6

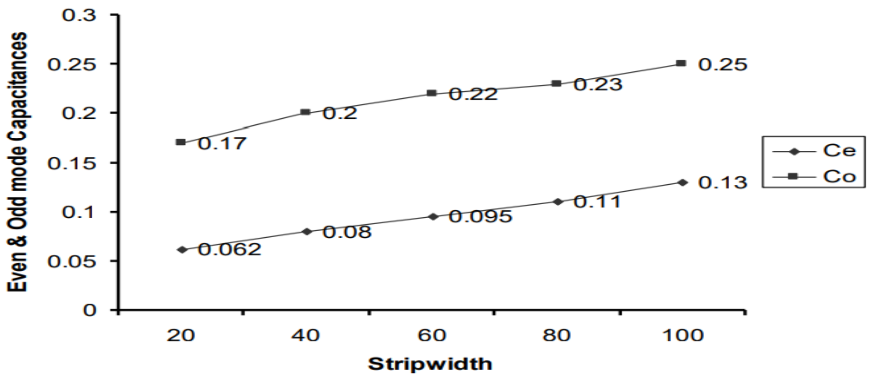
Stripwidth W (mils)	Capacitance (even mode) = C_e (pf)				Capacitance (odd mode) = C_o (pf)			
	Z_{oe}	$V_{pe}x10^{10}$ cm/sec	ϵ_e	$C_e = 1/V_{pe}Z_{oe}$	Z_{oo}	$V_{po}x\ 10^{10}$ cm/sec	ϵo	$C_o = 1/V_{po}Z_{oo}$
20	135.20	1.20	6.60	0.062	45.50	1.24	5.45	0.170
40	105.60	1.18	6.90	0.080	38.90	1.26	5.40	0.200
60	90.20	1.16	7.10	0.095	35.10	1.28	5.35	0.220
80	76.25	1.14	7.30	0.110	32.25	1.30	5.32	0.230
100	67.30	1.12	7.40	0.130	30.30	1.32	5.28	0.250

Table 2: Dependence of Ce and Co with spacing between two microstriplines F=2Gha, t= 0.01mils, w= 20mils, h= 100mils, Єr = 9.6

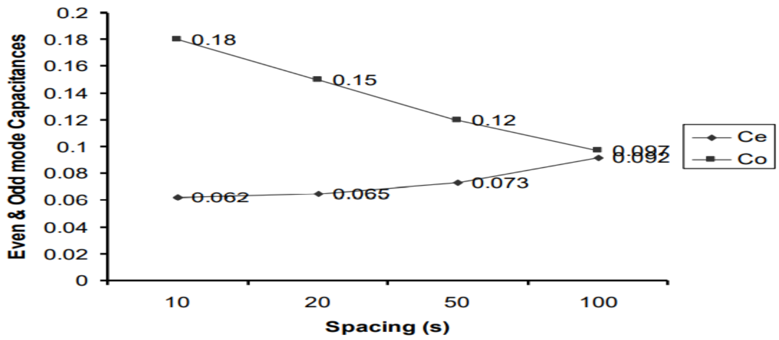
Stripwidth (mils)	Capacitance (even mode) = C_e (pf)				Capacitance (odd mode) = C_o (pf)			
	Z_{oe}	$V_{pe}x10^{10}$ cm/sec	$Є_e$	$C_e= 1/V_{pe}Z_{oe}$	Z_{oo}	$V_{po}x\ 10^{10}$ cm/sec	Єo	$C_o= 1/V_{po}Z_{oo}$
10	135.10	1.20	6.55	0.062	44.15	1.26	5.40	0.180
20	130.20	1.16	6.65	0.065	53.10	1.29	5.42	0.150
50	112.10	1.14	6.70	0.073	65.50	1.30	5.45	0.120
100	102.20	1.12	6.75	0.092	78.10	1.32	5.2	0.097

Table 5.3 Dependence of Ce and Co with Єr S= 10 mils, w=10 mils, f= 2Ghz, t= 0.01mils

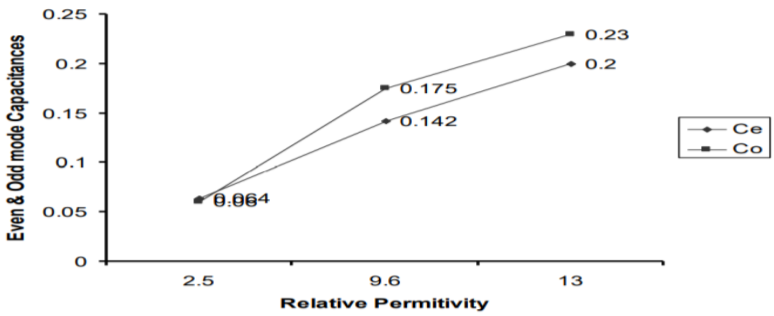
$Є_r$	Capacitance (even mode) = C_e (pf)				Capacitance (odd mode) = C_o (pf)			
	$Є_e$	V_{pe}	Z_{oe}	C_e	$Є_o$	V_{po}	Z_{oo}	C_o
2.5	1.98	1.41	107.10	0.064	1.84	2.21	75.25	0.060
9.6	7.31	1.11	60.20	0.142	5.67	1.26	45.15	0.175
13.0	9.90	0.98	51.20	0.200	7.49	1.10	38.75	0.230



Graph 1: Dependence of Even – Odd mode Capacitances with Strip width.



Graph 2: Dependence of Even and Odd mode capacitances with spacing between two microstriplines



Graph 3: Dependence of Even Odd mode Capacitances with relative permittivity.

VII. Discussion and conclusion

For above study various results have been obtained by changing strip widths, spacing and relative permittivity and these are placed in tabular forms and graphs have been plotted. These results provide a useful information and greater insight regarding the analysis and synthesis of various microwave strip line circuits such as directional coupler, circulator isolator filter etc operating at different Ghz frequencies. From this study for designing of coupler of desired coupling we can obtain suitable design data. Desired power can be stored or coupled or flown. This depends on the different parameters. Thus, this study furnishes a useful chart for designer. This study helps in designing and fabricates a practical microstrip transmission structure which will be useful in design and fabricating microstripline coupler, filter, oscillator, and resonator and in antenna circuits. This work also posses the scope for future work.

VIII. RESULTS AND DISCUSSION

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IX. CONCLUSION

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