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Analytical Study of Phase of Microstripline and its Variation with Different Characteristic Parameters

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Abstract:

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

1. 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 structures 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.

2. 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

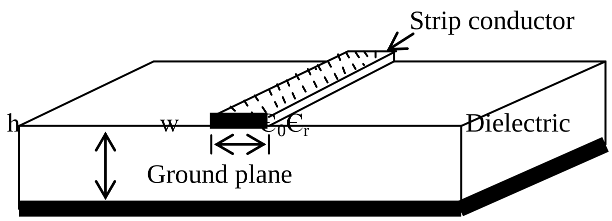


Fig 1a Microstripline (QUASI-TEM Mode)

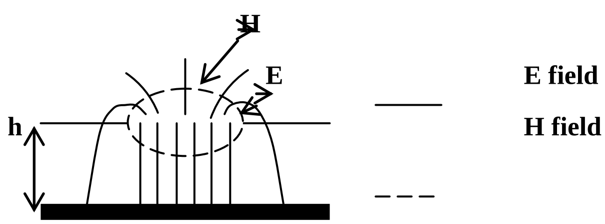


Fig 1b Microstrip Field configuration

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.

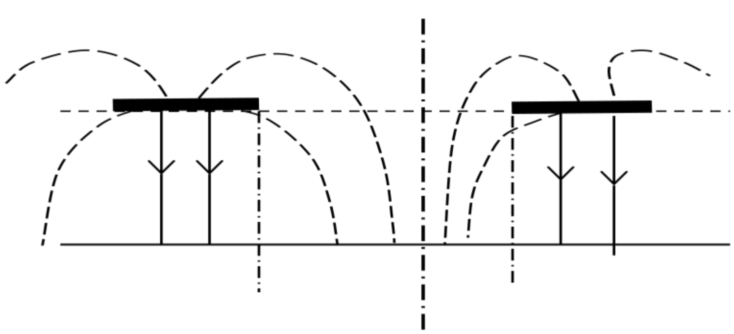


Fig 2. The even mode forward coupling

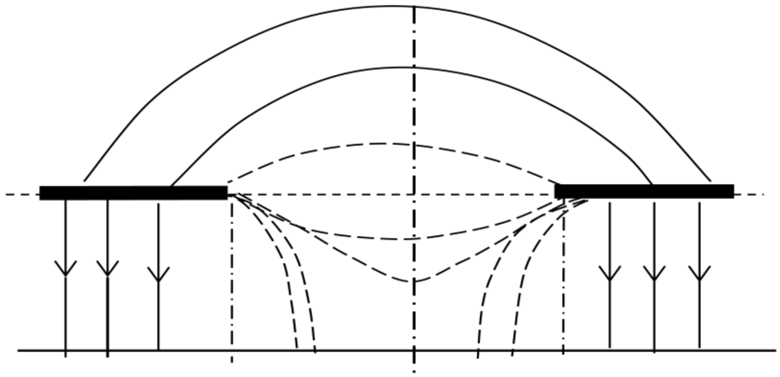


Fig 3. The odd mode reverse coupling

3. **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 ϵr=permittivity of the dielectric substrate.

4. **Formulation of phase velocity and guide wavelength**

When a microwave source is connected to the stripline wave starts flowing. The velocity with which the wave propagates is called phase velocity which is the function of geometry of the stripline, height of the dielectric substrate and effective permittivity. The relation between phase velocity and effective permittivity is given for TEM mode as

$Vp = c/\sqrt{\epsilon re}$ -------4

Where, c = velocity of the wave in free space= 3 x 10^8 m/sec

If λ_o is free space wavelength and λ_g is the Guide wavelength than If λ_g is given by the relation

$\lambda_g = \lambda_o/\sqrt{\epsilon_{re}}$

Where $\sqrt{\epsilon_{re}}$ is the effective permittivity of the dielectric substrate used in the microstripline structure.

5. Study of phase shift (β)

The Phase shift of a microstripline structure is important characteristic that indicate the phase change of the wave traveling through the microstripline structure. It is denoted by Phase factor

$$\beta = 2\pi/\lambda g \qquad \text{------5}$$

6. Analytical study of phase factor

It is important to study the phase factor for the design of the microstrip transmission line, stripline couplers, oscillators, circulator, resonators and coupled cavities of high value. The losses in this structure are as: Dielectric loss, Metallic loss, Surface wave loss and Radiation loss. For the calculation of Phase factor we first study the characteristics impedance, phase velocity and guide wavelength and there variation with strip geometry substrate height and frequency various computational work have been performed and results obtained are placed in table 1, 2, 3. Also various graphs have been plotted by putting the variables w, h and f on x-axis and phase factor on y axis as shown in graphs accordingly.

Table1: Variation of Phase factor with frequency (f)

h = 100 mils, t = 0.01 mils, W = 50 mils

f (GH_Z)	□$_r$ = 10.5		
	Z_0 (□)	λ_gx10^{-2}m	$\beta=2\pi/\lambda_g$ degree
2	62.50	5.56	112.98
5	65.70	5.40	116.33
10	70.29	4.90	128.20
15	72.40	4.60	136.50
20	73.50	4.45	141.10

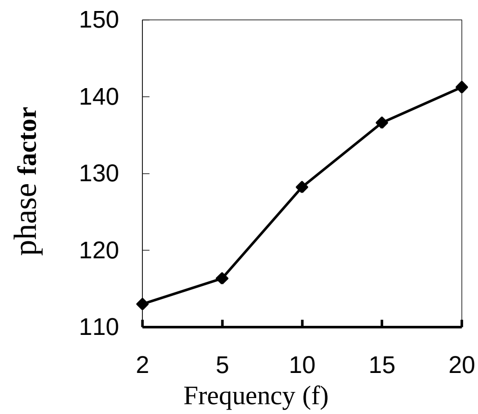


Table2: Variation of Phase factor with stripwidth (w)

h = 100 mils, t = 0.01 mils, f = 2 GHz

W (mils)	□$_r$ = 10.5		
	Z_0 (□)	λ_gx10^{-2}m	$\beta=2\pi/\lambda_g$ degree
50	62.30	5.56	112.98
100	46.10	5.45	113.39
150	39.20	5.30	118.52
200	31.95	5.20	1120.80
250	27.75	5.15	121.98

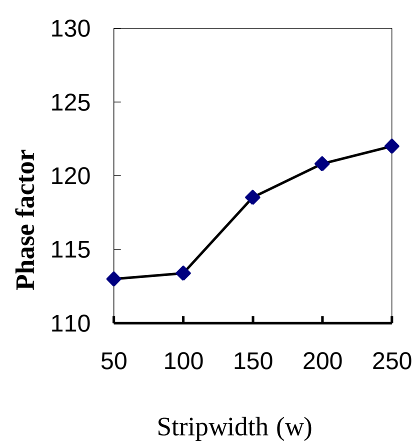
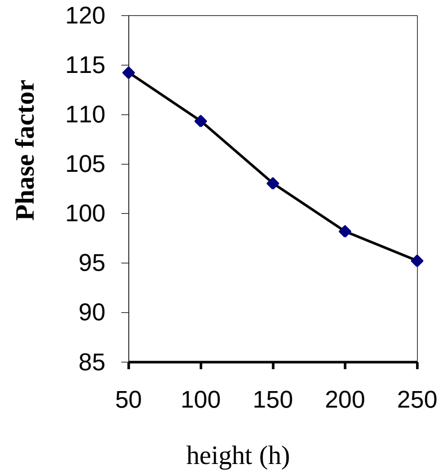


Table 3: Variation of Phase factor with height (h)

w = 100 mils, t = 0.01 mils, f = 2 GHz

h (mils)	□$_r$ = 10.5		
	Z_0 (□)	$\lambda_g x10^{-2}$m	$\beta=2\pi/\lambda_g$ degree
50	48.10	5.50	114.22
100	62.30	5.75	109.25
150	75.20	6.10	103.00
200	90.15	6.40	98.15
250	110.25	6.60	95.18



7. Discussion and conclusion

The variation of Phase factor with metal strip width reveals that with increase of strip width phase factor decreases sharply showing concentration of more & more energy below the strip in the dielectric medium. Also guide wave length shows a slight decrease with increase of strip width. Further variation of phase factor and propagation parameter of microstripline shows an increase with stripwidth and frequency. The rate of increase of propagation parameter with frequency is larger than the rate of increase of stripwidth. Thus propagation parameter is smaller for narrower strip and larger for wider strip. This concludes that phase factor is more useful for larger flow of power through the structure with smaller dissipation of power. But dispersion effect is smaller in lower GHz frequency range than the higher GHz range of frequency. 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.

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