STUDY OF VARIATION OF ATTENUATION AND SELECTIVITY OF COUPLED MICROSTRIP LINE STRIP WIDTH

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Abstract: *There are several advantages associated with the small wave length at microwave frequencies especially in giga hertz range. It is significant for communications owing to large bandwidth. Microwave communications are widely used for telephone networks, cell phones, internet and broadcast of television systems and for radar communication used in defense services. This is also suitable for space and satellite communications. Microwave techniques are now being used in extremely fast computer operations. The nano second pulses are useful in special purpose radars for docking the pre-collision sensing.*

Keywords: Microstripline, Coupler, Waveguide, Network, Microwave

1. INTRODUCTION

There are different transmission structures used for sending the message information, ideas and power (energy) from one place to another how far remote it is. For this purpose we need (i) Source (transmitter) (ii) Receiver (iii) Medium (bound and unbound). The unbound medium is open space atmosphere (ionosphere) which extends three dimensionally. The bound medium consists of Lumped circuit: 0-dimensional structure, example resistor, inductor & capacitor. Distributed transmission structures: Two parallel wire, Filter, and Coaxial line. one dimensional structure: transmission structure. Two dimensional structure: Stripline, Microstripline, Slotline, Coplanar stripline, Coplanar wave guide, Inverted stripline, Suspended stripline, Inverted microstripline, Suspended microstripline and different variants of these structure. Three dimensional structure: Waveguide, Rectangular, and Cylindrical. The two parallel wire transmission line structure, coaxial line,& wave guide have become absolate now-a-days due to their bulky size, heavy cost and power losses in gigahertz range of frequency. The planar transmission line (2-dimensional) technology has been developed due to advent of microwave integrated circuits (MIC's) owing to certain special features and characteristics such as: Miniaturized size, Reduced weight, Low cost, Minimum power consumption, Low dissipation of power, Easily replaceable, Easy to fabricate. In the giga hertz range of frequency stripline, microstripline and their variants have been proved to be significant in transmitting the signals. Among these, microstripline is simple and open structure. It is easy to fabricate and less lossy. Microstripline consists of a metal strip fixed on one side of a dielectric substrate whose other side is metalized to serve as ground plane. The substrate material should be of suitable permittivity having low loss tangent and the operating frequency ranges from 2 GHz–30 GHz. For maximum circuit size reduction, the dielectric substrate material has been selected having relative permittivity of the order of two or higher. But due to smaller loss tangent or low dissipation factor fused quartz like substrate is preferably used.

The presents paper aims at the study of attenuation constant and selectivity of the coupled microstrip line structure. As the study of selectivity of microstripline and coupled microstripline has not received much attention in recent years. This confines our attention to the study of variation of selectivity with the strip width, spacing between two strip lines and relative permittivity. This furnishes very useful information for the design of the single microstripline and coupled microstrip line of desired characteristic impedance, microstripline coupler and resonator of high selectivity and low attenuation.

2. ATTENUATION CONSTANT DUE TO DIELECTRICS SUBSTRATE (α_d)

Welch and Pratt have analyzed the case of dielectric losses in a non-magnetic mixed dielectric system. They have shown that their expressions account for most of the attenuation observed with a microstrip fabricated on a silicon substrate for which dielectric losses predominated. Following the approach of Wheeler in determining the filling factor for the dielectric constant, Welch & Pratt derived corresponding filling factor for the loss tangent (tanδ), or equivalently, the conductivity σ of the dielectric substrate and obtained the following results for the case when the upper dielectric is air assumed lossless.

$\alpha_d = 27.3\ (q_k / K_e)\ \tan\delta / \lambda_g$ (dB/cm) 1

or, $\alpha_d \approx 4.34\ (q_k / \sqrt{K_e})\ \sqrt{(\mu_0/\epsilon_0)}\sigma$ (dB/cm) 2

where the factor $8.68 = 20 \log_{10} e$ has been used to convert nepers to decibels. K denotes the dielectric constant (ϵ_r) of the substrate and

$K_e = 1 + q(\epsilon_r - 1) = \epsilon_{re}$ = effective substrate permittivity.

Where, q is the filling factor as defined by wheeler. μ_0 and ϵ_0 denote the permeability and permittivity of free space. Equation (1) is more convenient for non - conducting substrate where as equation (2) is appropriate for substrate in which the conduction loss is the predominant component of loss. Since the loss - tangent tanδ is frequency independent; the dielectric attenuation factor (per unit length of the structure) is also frequency independent. Further since "q" is a function of ϵ_r and w/h, the filling factor for the loss tangent, $q\epsilon_{re}/\epsilon_r$ and for the conductivity, $q/\sqrt{\epsilon_{re}}$ are also the functions of these quantities. The loss tangent filling factor is of the order of unity as $\epsilon_{re} \rightarrow \infty$. For most of the practical purposes, this factor can be approximated by unity. The conductivity filling factor exhibits only a mild dependence on w/h, which can be ignored in practice. For more convenience, the dielectric attenuation factor is expressed as [1-4].

$\alpha_d = (27.3 \tan\delta / \lambda_0)\ \{(\epsilon_r/\sqrt{\epsilon_{re}})\ ((\epsilon_{re} - 1)/(\epsilon_r - 1))\}$ 3

Where λ_0= free space wavelength

= 15 cm for f = 2 GHz.

ϵ_r = 10.5 = the average relative permittivity (ϵ_{re}) for sapphire anisotropic substrate used as isotropic material.

ϵ_{re}=effective dielectric constant of the substrate used.

3. ATTENUATION CONSTANT DUE TO METAL STRIP (α_c)

In a microstrip line structure over a low - loss dielectric substrate, the predominant sources of loss at microwave frequencies are the non - perfect conductors. The current density in the conductor is concentrated in a sheet nearby a skin depth deep inside the conductor surface exposed to the electric field. If the current distribution were known, the Ohmic attenuation factor has been computed as

$$\alpha_c = (Rs_1/2Z_0) \int_C (|J_1|^2 dx / |I|^2) + (Rs_1/2Z_0) \int_{-\infty}^{\infty} (|J_2|^2 dx / |I|^2) \quad 4$$

Here Z_0 denotes the characteristic impedance of the microstrip line structure. $Rs_1 = \sqrt{(\pi f \mu_1 \rho_1)}$ and $Rs_2 = \sqrt{(\pi f \mu_2 \rho_2)}$ the surface skin resistivity in ohm per square for the strip conductor and ground plane respectively, $J_1(x)$ & $J_2(x)$ the corresponding surface current densities & modulus of current |I| the magnitude of the total current per conductor, $\mu_{1,2}$ and $\rho_{1,2}$ represent the permeability & the bulk resistivity of the strip and ground conductor respectively. 'f' denotes the operating frequency.

The integral $\int_C$ implies the integration around all surfaces of the strip conductor. Both the strip conductor thickness (t) and the ground plane thickness are assumed to be at least three or four skin depth deep. The strip conductor contributes the major part of the skin loss. Because of mathematical complexity, exact expression for the current density for the practical case of a strip of non - zero thickness (t) have never been derived. Some workers have assumed [5-7] for simplicity that the current distribution is uniform and equal to I/w in both conductors, and confined to the region |x| <w/2. With this assumption, the conductor attenuation factor has been expressed as

α_c = $8.68\ Rs / Z_0 W$ 5

Where W = strip width

Rs = surface resistivity = $\sqrt{(\pi f \mu / \sigma_c)}$ 6

α_c = conductivity of strip conductor.

= $1/\rho$, ρ = 1.7 $\mu\Omega$/cm = resistivity
= 1.7 X 10^{-6} Ω/cm for copper conductor.

Putting $1/\rho$ for σ_c in eqn.(3)

Rs = $\sqrt{(\pi\mu f\rho)}$
Rs = 11.58 X 10^{-3} ohm per Sq. meter
μ = $\mu_0\,\mu_r$
μ_r = 1 for copper,
μ_0 = 15.57 X 10^{-7} H/m

For copper, the surface resistivity is

Rs = 8.26 X 10^{-3} $\sqrt{f}\Omega$

4. STUDY OF ATTENUATION AND SELECTIVITY FOR MICROSTRIP LINE COUPLER

For the study of total attenuation for coupled line in case of even and odd-modes the calculations of attenuation is based on the formula

$(\alpha_c)_e$ = 8.68 (R_s /Z_{oe} w) dB / unit length. 7

Where R_s = Surface resistivity
= $\sqrt{\pi\mu f/\sigma_c}$ Ω/m^2
= 11.58 x 10^3 Ω/m^2
f = operating frequency = 2 GH_Z
σ_c = 1.7 $\mu\Omega$ for Cu
μ = 15.57x10^7 H/m for Cu
Z_{oe} = even mode characteristic impedance

For odd-mode above equation is rewritten as

$(\alpha_c)_o$ = 8.68 (R_s /Z_{oo} w) dB / unit length. 8

putting different values of Z_{oe} & Z_{oo}, attenuation constant (α_c) can be calculated for even and odd-mode both.

Similarly attenuation due to dielectric substrate can be calculated for even and odd-modes both using the following equations:

For even-mode;

$(\alpha_d)_e$ = 27.3 (Tan δ/λ) (ϵ_r /$\sqrt{\epsilon_{ree}}$)(ϵ_{ree} -1/ ϵ_r -1) dB/ unit length 9

Where,

ϵ_{ree} = Even-mode effective permittivity

For odd-mode;

$(\alpha_d)_o$ = 27.3 (Tan δ/λ) (ϵ_r /$\sqrt{\epsilon_{reo}}$)(ϵ_{reo} -1/ ϵ_r -1) dB/ unit length 10

Where,

ϵ_{reo} = Odd-mode effective permittivity

Selectivity of the coupled microstrip line is for even-mode is expressed as:

For even-mode;

S_e = 27.3 / α_e λ_{ge} 11

Where,

λ_{ge} = guide wavelength of the microstripline for even-mode.

For odd-mode;

S_o = 27.3 / α_o λ_{go} 12

Where,

λ_{go} = guide wavelength of the microstripline for odd-mode

Computing attenuation and guide wavelengths selectivity can be studied for even and odd-modes of propagations. For the calculation of the selectivity and attenuation for single and coupled microstrip line have been calculated first using the values of characteristic impedances of the single and coupled microstripline structures and surface resistivity of the metal strip using different values of characteristic impedances for different relative permittivity of the substrate material. Thus using equations (11) & (12) the attenuation and selectivity (or figure of merit) of the structures have been calculated for different geometries of the structures and different relative permittivity. The results obtained have been placed in tabular forms. The exhaustive computations have been carried out using computer and manual calculation have been carried out with the help of calculators.

5. STUDY OF VARIATION OF ATTENUATION AND SELECTIVITY OF COUPLED MICROSTRIP LINE STRIP WIDTH

The exhaustive calculations have been carried out for the study of variation of the attenuation and selectivity of the single and coupled microstrip line structures both for even and odd-modes with strip width keeping frequency fixed. The results obtained have been placed in Table no. (1), and Table no. (2). The graphs have been plotted keeping strip width on x-axis and attenuation and selectivity on y-axis shown in Graph no. (1), and Graph no. (2). The result shows that selectivity increases with increase of metal strip and reverse is the case with attenuation constant. This shows that greater amount of power is flowing through wider metal strip and larger amount of power will be stored in the structure than the narrow metal strip.

Table No. 1: Variation of attenuation of coupled microstrip line with strip width

t = 0.01 mils, w = 100 mils, h = 100 mils, $\epsilon_r = 10$

W (mils)	Even-mode					Odd-mode				
	Z_{oe}	ϵ_{reff}	$\alpha_d \times 10^{-2}$ dB/m	α_c	$\alpha = \alpha_c + \alpha_d$	Z_{oo}	ϵ_{reff}	$\alpha_d \times 10^{-2}$ dB/m	α_c	$\alpha = \alpha_c + \alpha_d$
10	151.00	6.40	8.75	0.58	0.667	65.19	5.26	7.40	0.95	1.024
30	112.32	6.75	9.10	0.59	0.681	50.63	5.35	7.62	0.98	1.0562
50	92.81	7.10	9.35	0.60	0.693	43.80	5.38	7.75	1.00	1.0775
70	79.80	7.25	9.48	0.64	0.734	39.45	5.42	7.80	1.05	1.1280
100	67.37	7.45	9.60	0.67	0.766	34.80	5.47	7.85	1.10	1.1785

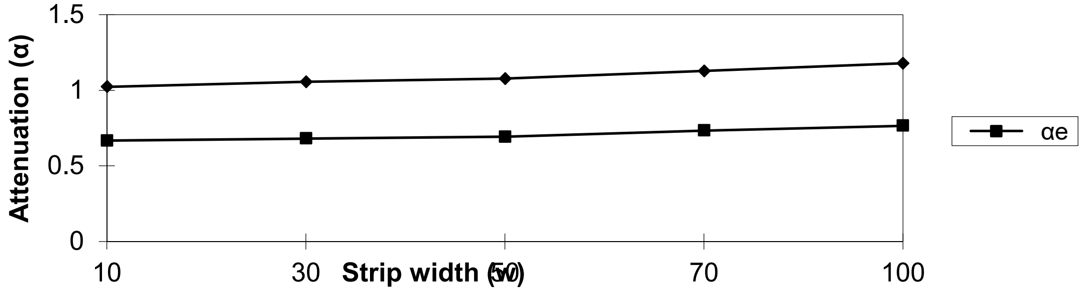
Table No. 2: Variation of Selectivity of coupled microstrip line with strip width

$\epsilon_r = 9.6$, h = 100 mils, f = 4 GHz

Strip width (w)	Even-mode			Odd-mode		
	α	λ_{ge}	S_e	α	λ_{go}	S_o
10	3.26	4.70	1.78	2.81	4.46	2.178
50	1.19	4.30	5.33	0.89	4.35	7.05
100	0.82	3.85	8.64	0.61	4.20	10.66

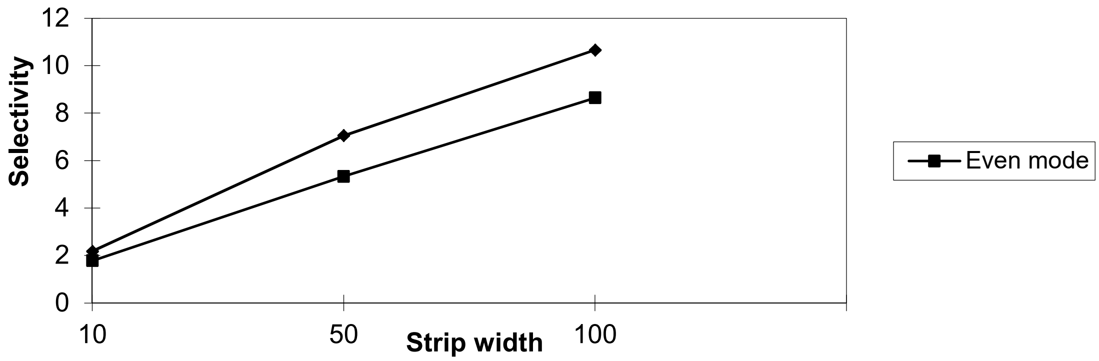
Graph No. 1: Variation of attenuation of coupled microstrip line with strip width

w = 100 mils, $\epsilon_r = 10$, h = 100 mils, t = 0.01 mils



Graph No. 2:Variation of Selectivity of coupled microstrip line with strip width

w = 100 mils, s = 100 mils, h = 100 mils, t = 0.01 mils



6. DISCUSSION AND CONCLUSION

The variation of total attenuation with metal strip width reveals that & with increase of strip width total loss 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 selectivity of microstripline shows a sharp increase in selectivity with increase of metal strip. Thus selectivity is smaller for narrower strip and larger for wide strip. This concludes that wider metal strip is more useful for larger flow of power through the structure with smaller dissipation. But dispersion effect is smaller in lower GHz frequency range than the higher GHz range of frequency. For higher selectivity or figure of merit and higher storing ability higher frequency, higher relative permittivity and wider metal strip are more useful. This study helps a designer to design and fabricate a practical microstrip transmission structure which will be used in coupler, filter, and oscillator and antenna circuits. This work has the scope for future work also. The study of selectivity using Cu strip and fused quartz substrate has been experimentally obtained by J. H. C. Van et al. Showing good agreement with present paper.

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