Study of Control of High Frequency over Voltage Standing Wave Ratio

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ABSTRACT

After World War-II, the microwave engineering and technology have been developed a lot and opened several tremendous dimensions and scopes for the advancement in the field of Defence, microwave & Digital Communications, Satellite Communication, Computer & Information technologies. Microwave is an important component of Medical Science, Industrial and Defence growth of the country. For fast working of weapons, Defence needs Radar, Missiles and many other areas like Microwave Antenna, Microwave Ovens, Microwave Cellular Phones and Remote Sensing etc. All such activities are being pushed at a great speed. With the growth of Microwave Integrated Circuits (MICs) new technique has been developed with the emergence of computer science, engineering and technology with the recent advances in microwave communication system. High frequency signals can be sent to any corner of the universe. With the growth of digital communication our country moving very fast, new techniques are being designed where high frequency signal can be employed to control the propagation of waves through planar transmission line technology such as stripline, microstripline, coplanar waveguides and their variants. The most useful structure is micro stripline where metal strip conductor is separated from a ground plane by a layer of dielectric substrate. It is useful to convey high frequency signal of giga hertz range. It is also useful in high-speed digital printed circuit board designs. When two microstripline structures are placed parallel to each other in close proximity, a natural coupling exists between them forming a microstripline coupler. The characteristic impedance, propagation constant and coupling coefficients are the important characteristic parameters of this structure which are useful for the study of Directivity of the coupler, Reflection coefficient and Voltage Standing Wave Ratio (VSWR). The flow of energy in these two lines in the same direction constitutes even-mode and odd-mode when flow is in opposite direction. These parameters of the coupler are the functions of geometry of the structure and operating frequency. The incident and reflected parts of the waves form the Standing Waves having several maxima and minima. The ratio of maximum voltage to the minimum voltage constitutes the VSWR. The VSWR is related with characteristic impedance and reflection coefficients for even and odd-modes of wave propagation. These parameters of the coupler are the functions of geometry of the structure and frequency of the signal. The present paper aims at the study of VSWR and frequency control over it. The frequency of the signal plays significant role in the design of the directional coupler, Filters, resonators etc in the Giga Hertz range of frequency.

Keywords: MIC's, Characteristic Impedance, Phase velocity, Reflection coefficient, VSWR etc.

I INTRODUCTION

The Microwave Integrated Circuits (MIC's) have changed the large-scale transmission structures to a small, lightweight and cheap assembly with introduction of stripline and microstripline. The two parallel wire transmission lines are the simplest structure for microwave signals 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 MIC's. There are various transmission structures which have been designed by different pioneers of this field suitable for Giga Hertz range of frequency such as stripline and microstripline. The microstripline is an open structure and modified version of stripline structure. It consists of a strip conductor patched on dielectric substrate supported by a conducting plate which serves as a ground plane.

When two microstriplines are placed together in close proximity, natural coupling exits between them forming the microstripline coupler as shown in figure-1. The field configurations for even and odd-modes are shown in figures-2 a & b. When the transmission structure is not terminated with characteristic impedance wave travelling through the structure gets reflected back and combines with incident wave to form standing wave. VSWR is the ratio of maximum voltage to the minimum voltage. It determines the efficiency of a signa from a power source and transmitted through the structure to the load. Present paper deals with the VSWR of microstripline coupler and its variation with geometry and frequency of the signal.

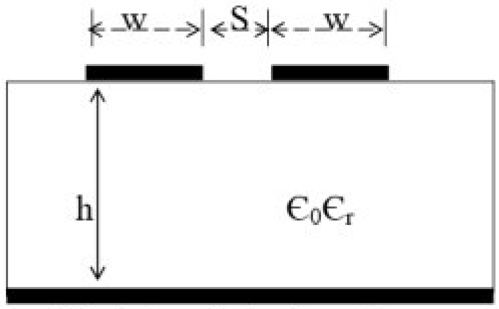


Fig-1 Coupled microstrip

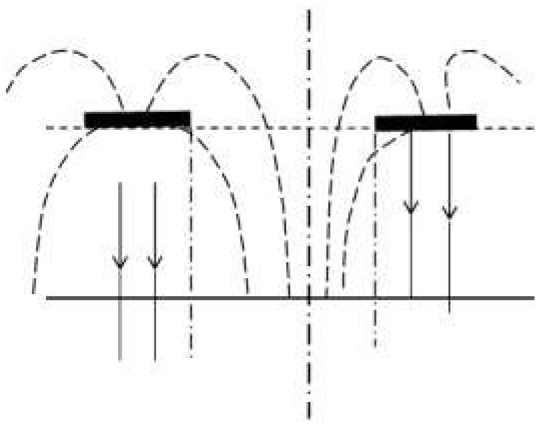


Fig-2 a. The Even-mode forward coupling

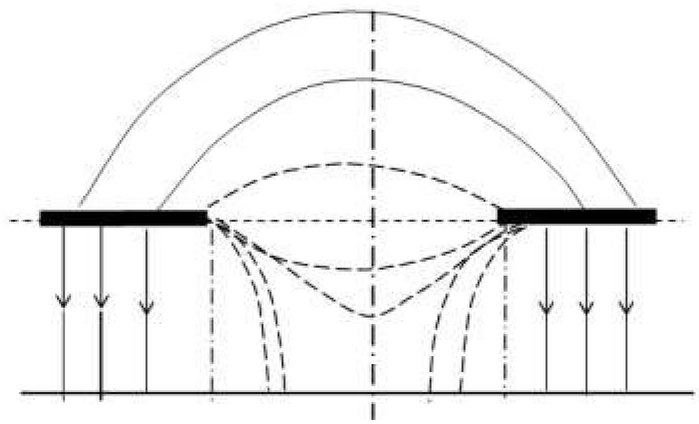


Fig-2 b. The odd mode reverse coupling

II CHARACTERISTIC IMPEDANCE FOR EVEN AND ODD MODES OF PROPAGATION THROUGH COUPLED MICROSTRIPLINE

The characteristic impedance of coupled microstriplines can be described in terms of geometry of the conductor strips, geometry of dielectric substrates and its constants and spacing between two strips for both even and odd-mode of wave propagation. The even-mode characteristic impedance (Z_{oe}) is the impedance measured from one strip to ground where the strips are at the same potential and have equal currents in the same direction and expressed as

$$Z_{oe} = (30\pi/\sqrt{\epsilon}) . \{K.K'_e / KK_e\} \text{ ohms} \qquad \text{------------- 1}$$

Where K is a complete elliptic integral of the first kind and

$$K_e = \tan h(\pi w / 2h). \tan h\{(\pi/2).((w+s)/h)\}$$

$$K'_e = \sqrt{(1 - K_e^2)}$$

Where, ϵ is the dielectric constant, w is the conductor strip width, h is the height of the substrate and s is the spacing between two strips as shown in figure-1.

The odd mode characteristic impedance (Z_{oo}) is defined as impedance from each strip to ground when the strip–potentials are opposite and the currents are in opposite directions and expressed as

$$Z_{oo} = (30\pi/\sqrt{\epsilon}) . \{K.K'_o / KK_o\} \qquad \text{------------- 2}$$

Where

$$K_o = \tan h(\pi w / 2h). \cot h\{(\pi/2).((w+s)/h)\}$$

$$K'_o = \sqrt{(1 - K_o^2)}$$

These relations show that the characteristic impedances will be different for each mode and that the even- mode will always be higher. Because of the difficulty of evaluating the complete elliptic integrals, it is frequently desirable to express Z_{oe} and Z_{oo} in terms of the fringing capacities, which is applicable for the zero thickness strips. The characteristic impedance for even-mode propagation is

$$Z_{oe} = (94.15 / (\sqrt{\epsilon}\,[w / h) + (\epsilon/2)\,(C'_{f}(o) + C'_{fe}(o).(s/h)]\ \text{ohms} \quad \text{----- 3}$$

and the characteristic Impedance for odd-mode propagation is

$$Z_{oo} = (94.15 / (\sqrt{\epsilon}\,[w /2\,h) + (\epsilon/2)\,(C'_{f}(o) + C'_{fo}(o).(s/h)]\ \text{ohms} \quad \text{---- 4}$$

This will hold good accuracy where w/h is greater than or equal to 0.35. Where,

$$C'_{f}(0) / \epsilon = (2/\pi)\log_e 2 = 0.4407$$

$$C'_{fe}(0,s/h)/\epsilon = (2/\pi)\log_e(1 + \tanh(\pi s/2h))$$

$$C'_{fo}(0,s/h)/\epsilon = (2/\pi)\log_e(1 + \coth(\pi s/2h))$$

III VOLTAGE STANDING WAVE RATIO (VSWR) OF A MICROSTRIPLINE COUPLER

The SWR is designated by "S" & It is expressed as

S = Maximum voltage or current / Minimum voltage or current

$$= \left|\frac{V_{max}}{V_{min}}\right|$$

$$= \left|\frac{I_{max}}{I_{min}}\right| \quad \text{--------------- 5}$$

As the standing wave is formed by superposition of incident and reflected parts of wave, which is not accepted by the load. VSWR (S) is also defined in terms of reflection coefficient (ρ) by the relation.

$$S = \left|\frac{1+\rho}{1-\rho}\right| \quad \text{--------------- 6}$$

If ρ_e stands for reflection coefficient for even-mode and Z_o is the characteristic impedance of the single microstripline[6], then

$$\rho_e = \frac{Z_{oe} - Z_o}{Z_{oe} + Z_o}$$

Similarly, For odd-mode of propagation of wave, the reflection coefficient is defined as the

$$\rho_o = \frac{Z_{oo} - Z_o}{Z_{oo} + Z_o}$$

Using above equations, VSWR is expressed both for even & odd-mode as

$$S_e = \left|\frac{1+\rho_e}{1-\rho_e}\right|$$

$$= [1 + \{(Z_{oe} - Z_o) / (Z_{oe} + Z_o)\}] / [1- \{(Z_{oe} - Z_o) / (Z_{oe} + Z_o)\}] \quad \text{----------- 7}$$

And, $S_o = \left|1 + \rho_o / 1 - \rho_o\right|$

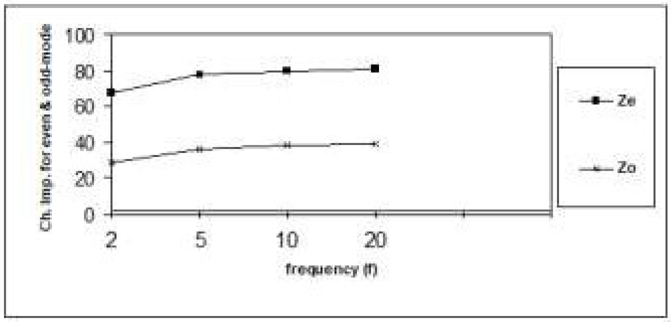
$$= [1 + \{Z_{oo} - Z_o / Z_{oo} + Z_o\}] / [1- \{Z_{oo} - Z_o / Z_{oo} + Z_o\}] \quad \text{----------- 8}$$

As it is evident, the VSWR must be the function of stripwidth, separation between two microstripline and the frequency of the signal which will be studied in the subsequent sections:

(i) Study of variation of even and odd mode characteristic impedances with frequency
(ii) Study of variation of even and odd mode VSWR with frequency

IV STUDY OF VARIATION OF EVEN AND ODD MODE CHARACTERISTIC IMPEDANCES WITH FREQUENCY

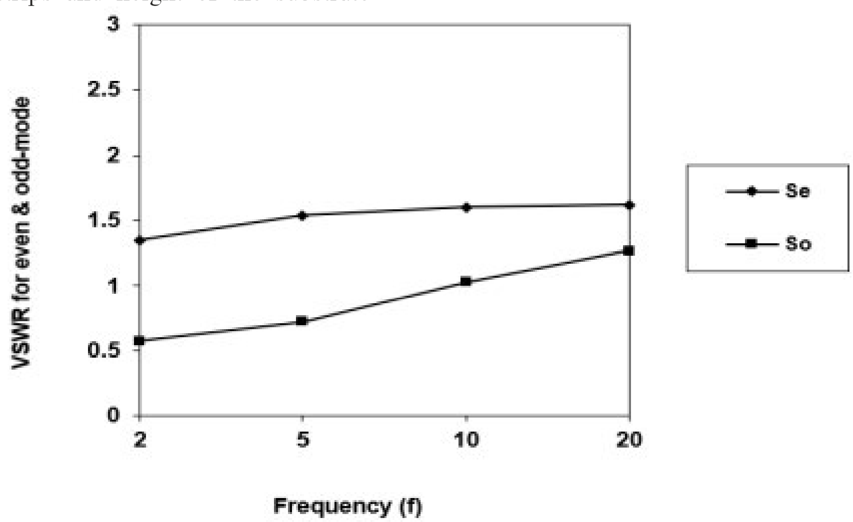
Computational works for the characteristic impedances have been carried out for different frequencies keeping strip width and spacing between two strips fixed. The even and odd-mode characteristic impedances have been obtained. Keeping frequency on x-axis and characteristic impedances on y-axis graph has been plotted as shown in graph-1. It is evident that both the impedances show increasing trend with increase of frequency for a given strip width and spacing. The even mode characteristic impedance is ever higher than the odd mode. This shows that flow of energy is smaller for even more than that in odd mode of wave propagation.



Graph-1: Variation of even and odd-modes characteristic impedances with frequency
(w=200 mils, h = 200 mils, t = 0.01mils, ϵ_r = 9.6, s = 20mils)

V STUDY OF CONTROL OF FREQUENCY OVER VSWR

For study of control of frequency over VSWR various calculations have been carried out. Keeping strip width, spacing between two strips and height of the substrate fixed characteristic impedances for even and odd-modes have been obtained for different operating frequencies. From these data VSWR have been computed for even and odd-modes of propagation.



Graph 2: VSWR with frequency
(h =100 mils, w = 20 mils, t = 0.01mils, s = 200 mils, ϵ_r = 9.6)

The results obtained have been plotted keeping frequency along x-axis and VSWR for even and odd-mode along y-axis as shown in graph-2. From such study it is clear that VSWR for both even and odd-modes increases with increase of frequency. The graph also shows that even mode VSWR is higher than that of odd mode.

VI DISCUSSION AND CONCLUSION

From the study of VSWR it is clear that the two traveling waves components add in phase in case of forward coupling and subtract in case of reverse coupling. VSWR is the ratio of maximum voltage to the minimum voltage. It is also expressed in terms of reflection coefficients for even and odd mode wave propagation. The distance between two successive maxima or minima is $\lambda/2$. VSWR denotes what amount of the incident wave gets reflected back If the VSWR is unity, it means no reflection of the wave occurs. Since the reflection coefficient is less than unity, so VSWR is a positive real number & should be greater than unity. From the results obtained above the VSWR for even-mode is actually practical value. If the reflection coefficient tends to zero, total incident wave energy gets absorbed and VSWR tends to unity. When reflection coefficient tends to unity, VSWR tends to infinity. High value of VSWR is always undesirable, because it results in the reduction of maximum power that can be transmitted through the transmission structure. The negative value of reflection coefficient shows the reflected wave with reverse polarity. Higher VSWR depicts a larger mismatch between the source and load impedances. So, for practical designs lower value of

VSWR is ever desirable. This can be done only by the frequency control. Thus, study of VSWR is very much useful for designing the coupled transmission structure. This will be further useful for determining the condition for impedance matching & obtaining the maximum power from the coupled microstripline structure.

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