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Study of Variation of Self- Inductance with Operating Frequency

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ABSTRACT

In this paper, I present about the study of variation of self-inductance with operating frequency. The proposed scheme aims at the study of variation of self-inductance of single stripline with operating frequency with different substrate which are useful in designing of coupler & filters. The recent advances in thick film ink have allowed microwave circuits to be produced using porous substrate which have resulted in more economical & easier exploitation of the concept.
KEYWORDS: Self- Inductance, Microwave, Microstripline Couplers.

I. INTRODUCTION

The proposed scheme aims at the study of variation of self-inductance of single stripline with operating frequency with different substrate which are useful in designing of coupler & filters. The recent advances in thick film ink have allowed microwave circuits to be produced using porous substrate which have resulted in more economical & easier exploitation of the concept. The importance of the present works lies in the fact that radio astronomers use these frequencies to study electromagnetic radiation originating from stars & others celestial objects. Also, this property makes microwave suitable for satellite communication & space communication. Using this virtue of microwave in the field of entertainment viz. T.V. programmes are transmitted from coast to coast via a trans-continental microwave network, intercity communication local transmission of T.V. between studios and remote transmitters. The recent installations of microwave links all over the country by post and telegraphs Department, Government of India have added great significance to such waves in the field of Microwave technology. This justifies the study of present work. The parameters which characterize the various types of circuits are the characteristics impedance, phase velocities, guide wavelength & capacitance. The study of frequency dependence of the capacitance & other parameters with strip geometry is of great significance for the design purpose. The present work involves the mathematical formulation of the problem and related computation of the results along with the discussion of the result and conclusion.

II. FORMULATION OF SELF INDUCTANCE OF SINGLE STRIPLINE

Since the microwave strip line involves and abrupt dielectric interface between the substrate and the air above it. Any transmission line which is filled with a uniform dielectric can support a single, well-defined mode of propagation over a wide range of frequency that is (i) TEM for co-axial line, stripline and microstripline, (ii) TE/TM-mode for waveguide, and (iii) non-TEM for slot line. Transmission line having not such uniform dielectric filling cannot support a single mode of propagation. Microstripline is within this category. Although it is true that bulk of energy is transmitted along the microstripline with field distribution closely resembling TEM-mode. It is usually referred to as a quasi-TEM mode. The field distribution is quite complicated. The electric field (E) and magnetic field (H). The fields have been analysed by several workers using various static technique in the analysis process characteristic impedance and phase velocity are computed which are further employed in calculating the self-inductance. Basically, the characteristic impedance is related with primary and secondary line constants and expressed as

$$Z_0 = \sqrt{\frac{R + j\,\omega L}{G + j\,\omega C}} \qquad \text{------------ 1}$$

At microwave frequency and for low loss

$$Z_0 = \sqrt{\frac{L}{C}} \qquad \text{-------------- 2}$$

Where,

C = Capacitance of the stripline transmission structure

L = Self-inductance for low loss stripline transmission structure.

Alternate expression for characteristic impedance for such structure is given as

$Z_0 = V_P \,.\, L$ --------------- 3

Also, $Z_0 = 1 / V_P \,.C$ --------------- 4

Where,

$V_P = 1 / \sqrt{LC}$

= Phase velocity of the wave travelling through the structure.

From equation 3.3

$L = Z_0 / V_P$

Knowing the value of characteristic impedance of the microstripline transmission structure and phase velocity of the wave passing through the structure, Self-inductance of the structure can be determined. This property of the structure is due to change of magnetic flux linked with the structure which is owing to the presence of magnetic flux and energy flowing through it.

III. COMPUTATION OF THE SELF INDUCTANCE

The exhaustive computations had been carried out for the characteristic impedance and phase velocity in chapter-4. Also, the variation of characteristic impedance and phase velocity had been discussed analytically there. These results are useful for the determination of self-inductance of single stripline. The self-inductance is the function of the frequency, width of the metal stripline and height of the dielectric substrate. The variation of self-inductance with frequency, strip width and height of the substrate will be discussed analytically in the following sections. For this purpose, calculations of self-inductance & its dependence will be performed manually.

IV. STUDY OF VARIATION OF SELF-INDUCTANCE WITH OPERATING FREQUENCY

Variation of self-inductance with frequency has been studied by computing the results at different operating frequency. The result shows that the self-inductance is the function of frequency. With increase of frequency the field distribution decreases below the strip within the dielectric material which shows the decrease of power flow through stripline which further causes increase of self-inductance with increase of frequency. Due to this reason the study of variation of self-inductance with operating frequency (f) is very important because it helps in designing in microstripline. The result obtained has been placed in table 1 and related graph shown in graph no. 1. The graph shows the rate of increase of L is larger for narrow strip than that for wider strip. Further it is also evident in lower Giga hertz range of frequency (up to 12 Giga hertz) rate of variation of L with frequency is slow and almost same for wider strip. This result leads to conclude that dispersion effect is negligible in smaller frequency range and becomes more significant in higher frequency range. Similar result has been studied by Getsinger using different technique. This also marks an important conclusion that TEM mode of wave propagation is effective only lower frequency range and in higher frequency range certain correction is needed. This fact must be taken into account by a designer while fabricating the microstrip line. These results are useful for studying the selectivity of the structure and attenuation of power traveling through the microstripline.

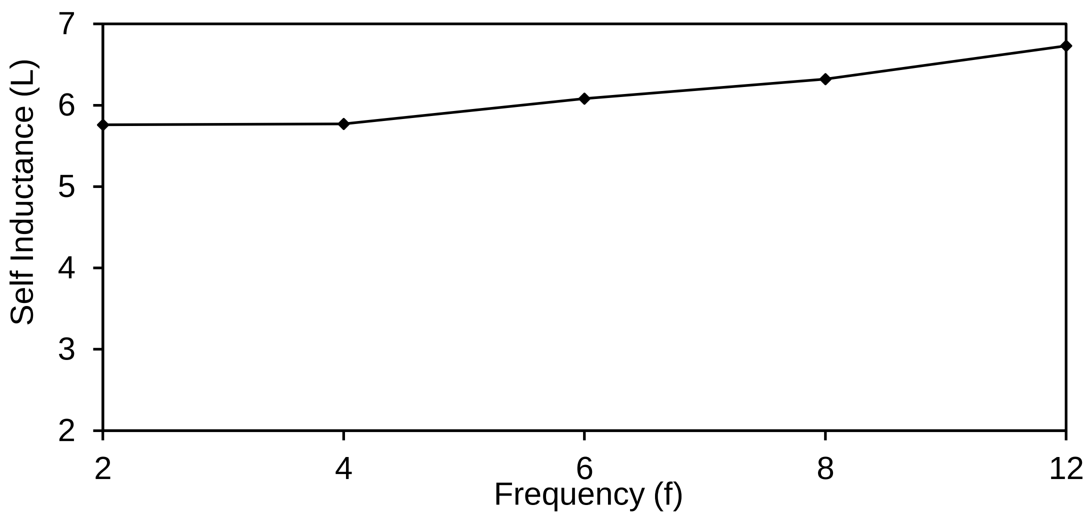
Table No. 1: Study of variation of self-inductance with operating Frequency

w = 60 mils, h = 100 mils, t = 0.02 mils, ϵ_r = 3.78(fused quartz), c = 3 x 10^8 m/sec 1 mil = 2.54 x 10^{-5} meter.

Frequency f (GHz)	Characteristic Impedance Z_0 (Ω)	Phase velocity V_p x 10^8 m/sec	Self Inductance (L) x 10^{-7} H
2	105.11	1.84	5.77
4	105.16	1.83	5.78
6	109.51	1.82	6.09
8	111.21	1.78	6.33
12	116.41	1.77	6.74

Graph No. 1: Study of variation of self-inductance with operating Frequency

w = 60 mils, h = 100 mils, t = 0.02 mils, ϵ_r = 3.78(fused quartz), c = 3 x 10^8 m/sec 1 mil = 2.54 x 10^{-5} meter.



V. CONCLUSION

The graph shows the rate of increase of L is larger for narrow strip than that for wider strip. Further it is also evident in lower Giga hertz range of frequency (up to 12 Giga hertz) rate of variation of L with frequency is slow and almost same for wider strip. This result leads to conclude that dispersion effect is negligible in smaller frequency range and becomes more significant in higher frequency range.

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