International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 07 Issue 06 June 2024
DOI: 10.47191/ijcsrr/V7-i6-69, Impact Factor: 7.943
IJCSRR @ 2024
www.ijcsrr.org

A Study on Dispersion Characteristics for Inverted Microstrip Lines

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ABSTRACT: Inverted microstrip lines are studied for their dispersion characteristics for three different values of permittivity of the substrate using Galerkin Technique in Spectral Domain. This structure is very much useful as the current strip is attached at the lower surface of the dielectric substrate. Therefore it is rarely exposed to the outer medium results no effect due to external hazards and almost zero possibility to expose to electro- magnetic interference. Basis functions for the unknown strip current are chosen according to the ones specified in [1]. Basis functions in [1] were for slot magnetic currents and consequently they are modified for the particular problem by considering the modified boundary conditions for Maxwell's field equations for this structure. For the theoretical development the Fourier transformation of the basis functions from space domain to spectral domain are considered. Variation of effective permittivity with available dielectric thickness has also been studied and the result shows a saturating tendency with increase in dielectric thickness.

KEYWORDS: Dispersion, Galerkin technique, Microstrip, Spectral domain.

I. INTRODUCTION

Much work has been reported in the literature on analysis of microstrip lines [2] and some of its variants like suspened microstrip lines and others [3,4]. But to the best of our knowledge and information, little has been reported about the analysis of inverted microstrip lines so far. However, this is an important category of transmission lines which may find lots of usage in applications like radar systems especially in the middle and higher microwave frequency range. Here we present an analytical study for variation of its effective dielectric constant using the spectral domain approach.

II. THEORY

The geometry of the structure under investigation is shown in Figure1

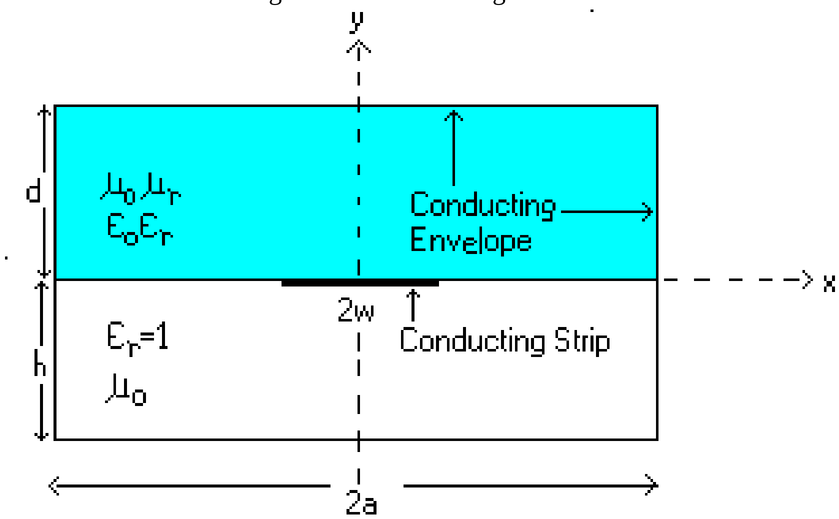

Figure 1

The basis functions whose weighted sum represents the unknown strip current[5], as chosen by us, are

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$$Jxn(x)=\begin{cases}(\mathrm{Sin}\,2\pi nx/w)\Big/\sqrt{(w/2)^2-x^2}, & |x|\langle w/2\\ 0 & ,\text{otherwise}\end{cases}$$

$$Jzn(x)=\begin{cases}\mathrm{Cos}[2\pi(n-1)x/w]\Big/\sqrt{(w/2)^2-x^2}, & |x|\langle w/2\\ 0 & ,\text{otherwise}\end{cases}$$

whose Fourier transforms are obtained as

$$\tilde{J}xn(\alpha)=\frac{\pi}{2j}[J_0(\alpha w/2+n\pi)-J_0(\alpha w/2-n\pi)]$$

$$\tilde{J}zn(\alpha)=\frac{\pi}{2}[J_0\{\alpha w/2+(n-1)\pi\}+J_0\{\alpha w/2-(n-1)\pi\}]$$

Then for all values of m (m=1, 2,……….. , N), taking the inner products of the field expressions in terms of the spectral domain Green's functions with respect to $\tilde{J}zm(\alpha)$ and using Perseval's theorem [6] ,we get a set of linear equations as

$$\sum_{n=1}^{M} K_{mn}^{(1,1)} c_n + \sum_{n=1}^{N} K_{mn}^{(1,2)} d_n = 0; m=1,2,....,N \quad (1)$$

$$\sum_{n=1}^{M} K_{mn}^{(2,1)} c_n + \sum_{n=1}^{N} K_{mn}^{(2,2)} d_n = 0; m=1,2,....,M \quad (2)$$

Where c_n and d_n are the unknown amplitude coefficients for the n-th current basis function. These are to be evaluated for complete knowledge of the strip currents and hence to solve for the fields. Since equations (1) and (2) are linearly independent, for a nontrivial solution set, the determinant of the coefficient matrix should be set equal to zero[7] i.e.

$$\Delta=\begin{vmatrix}\sum_{n=1}^{M} K_{mn}^{(1,1)} & \sum_{n=1}^{N} K_{mn}^{(1,2)}\\ \sum_{n=1}^{M} K_{mn}^{(2,1)} & \sum_{n=1}^{N} K_{mn}^{(2,2)}\end{vmatrix}=0$$

The above equation forms the characteristic equation for the system solving which we get the propagation constant and there from the unknown strip current and consequently the fields. The line studied is etched over a dielectric substrate placed within wave guide housing. Variations in effective dielectric constant with frequency over the X-band are studied for different values of substrate permittivity. Results indicate a saturating trend with frequency after an initial rise for all cases. We also studied the dependence of effective permittivity with substrate thickness for different dielectric substrates. Again a saturating trend for higher values of substrate thickness is observed i.e. the effective dielectric constant for the structure shows very little change with increasing substrate thickness after an initial rise for all dielectric substrates.

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III. RESULTS

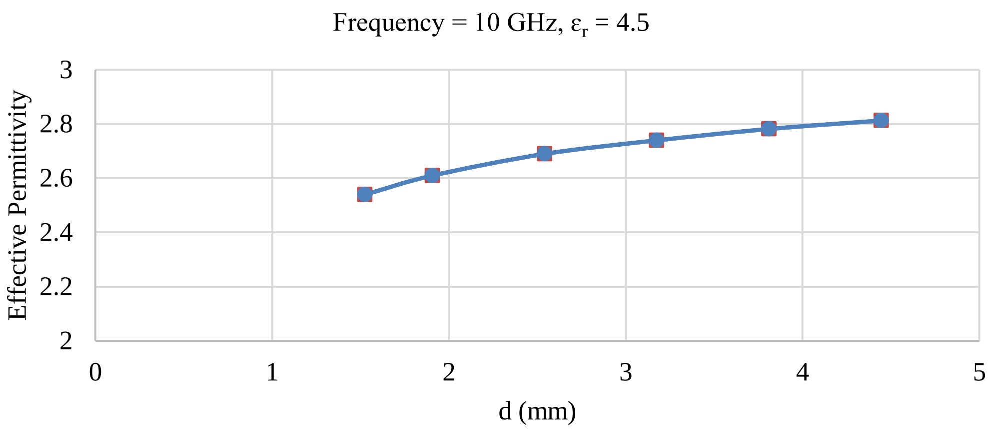

Figure 2

Figure 2 gives the variation of effective permittivity with the substrate thickness for the relative permittivity $\varepsilon_r = 4.5$

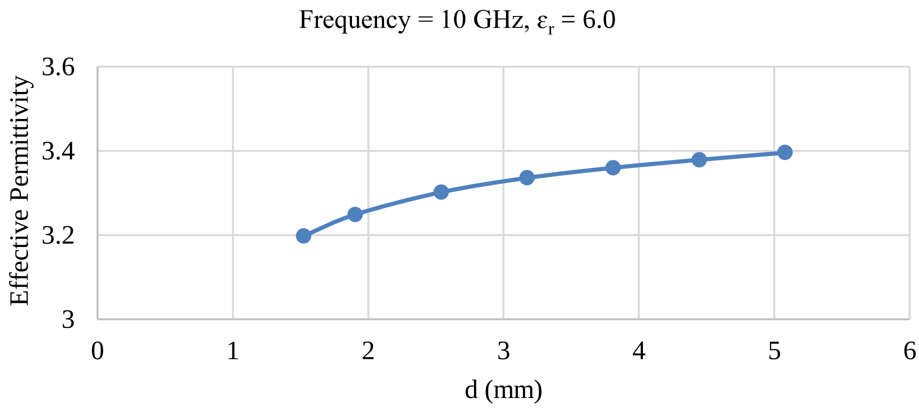

Figure 3

Figure 3 gives the variation of effective permittivity with the substrate thickness for the relative permittivity $\varepsilon_r = 6.0$

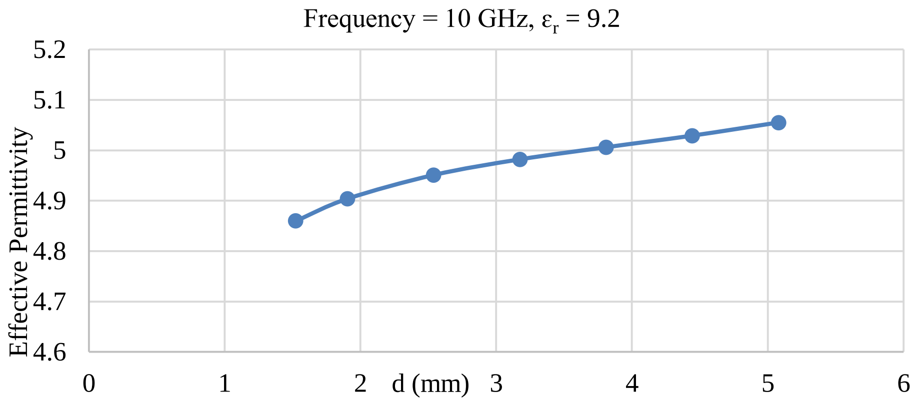

Figure 4

Figure 4 gives the variation of effective permittivity with the substrate thickness for the relative permittivity $\varepsilon_r = 9.2$

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Above figures (Figure 2,3,4) give the variation of effective permittivity with the dielectric thickness for different values of dielectric substrates and these shows a similar type of saturating tendency of effective permittivity for the structure.

Dispersion characteristics are obtained for an inverted microstrip structure with strip width w=3.17mm, substrate thickness d=3.04mm, side wall separation a=22w and top wall separation h=7.12mm in X-band region.

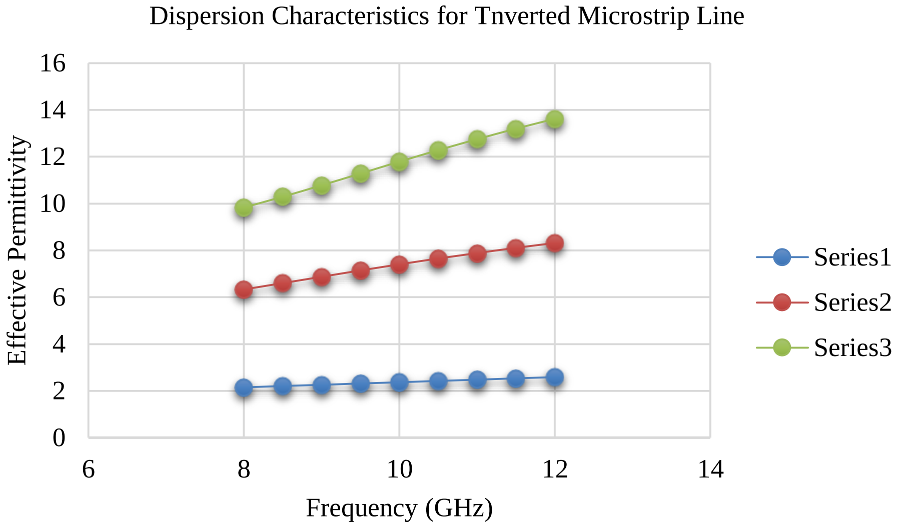

Figure 5

Figure 5 shows dispersion characteristics of the structure for different values of relative permittivity (Series1 for $\varepsilon_r = 4.0$, Series2 for $\varepsilon_r = 11.7$, Series3 for $\varepsilon_r = 20.0$) of the dielectric substance and it shows that effective permittivity tends to saturate for higher frequency.

IV. CONCLUSIONS

Results obtained are significant in respect of radar systems since inverted microstrip lines form a very useful category of transmission structures from mid microwave to the millimeter wave region of spectrum. Especially in view of the low losses and good EMI rejection, these lines should find widespread application in radar systems. Their dispersion analysis, as presented in this paper, should thus be very helpful to the radar engineers who would like to make use of the inverted microstrip transmission lines.

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Cite this Article: Kuntal Biswas, Lakshman Dhal, Bidyut Haldar (2024). A Study on Dispersion Characteristics for Inverted Microstrip Lines. International Journal of Current Science Research and Review, 7(6), 4186-4189