STUDY OF EBG STRUCTURES USING TRANSMISSION LINE

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Abstract : Most EBG structure used in microwave filtering applications consists of two conductors in which one is the reference conductor also acting as a shield. In PDNs and multilayer circuits, we generally encounter at least three conductor layers. The main focus of our problem is on the two metal layer structures. For this, we apply the modeled using conventional transmission line circuit.

***IndexTerms* - Conventional, Microwave, Transmission line, Encounter.**

I. INTRODUCTION

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The geometry of these EBG structures can be altered in order to obtain the bandgap in the desired frequency region. In simplified cases an EBG structure can be approximated with a surface impedance. This enables prediction of the bandgap using analytical approaches.

In this article, only patterned EBG geometries have been analyzed. The stepped impedance structure of Fig. 1.1 (g) and the structure of metal patches connected by meander lines shown in fig. 1.1 (h) serve as the basis for the EBG geometries structure.

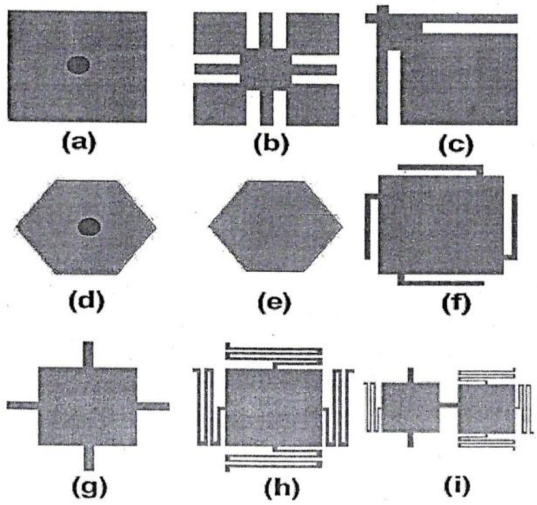

Fig. 1.1

Maxwell's equations hinges on the idea that light is an electromagnetic wave and they provide one of the most effective and succinct ways to correlate the electric and magnetic fields associated with the wave to their sources such as charge density and current density. Although deceptively simple to look at these equations epitomize a high level of mathematical sophistication.

II. THE PERIODIC GEOMETRIES OF EBG

In solid state physics, Felix Bloch applied the theorem to periodic boundary conditions and generalized it to three dimensions. This came to be known as Bloch's theorem. Bloch's work dealing with quantum mechanical structure of electrons in crystal lattices which are periodic geometries has been discussed in detail in [1], [2]. Hence in analysis of periodic structures in microwave engineering often the terminology Bloch-Floquet Theorem is used. According to this theorem, there exists a correlation between the fields at a point in an infinite periodic structure and the fields at a point period a away and they are found to differ from each other by a propagation factor $e^{\gamma a}$, where γ is the propagation constant in the direction of propagation.

Based on this theorem, for the structure shown in Figure 2.1 depicting a one dimensional periodic structure with a period *d*, the voltage and current relationships are given by

$$V_{n+1} = V_n e^{-\gamma d} \quad \text{............ (1)}$$

$$I_{n+1} = I_n e^{-\gamma d} \quad \text{............ (2)}$$

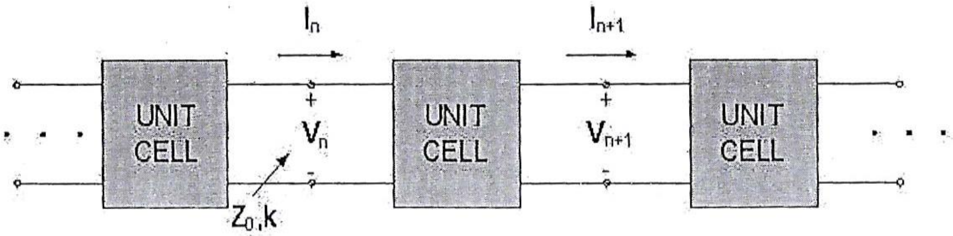

Fig. 2.1 : One dimensional representation of a periodic structure

III. The Planar EBG Structure

In the case of planar EBG structures, the sheet or effective capacitance arises not only because of the fringing fields between adjacent plates, but also due to the parasitic capacitance that comes into play due the substrate and the proximity between the patterned plane and the ground plane. The sheet or effective inductance results from the per unit length inductance of the transmission line sections as well as any meander structure that may be included in the planar design. Hence, often the EBG structure is crudely modeled as a resonant LC circuit. In [5] a planar EBG structure is investigated and the following formula is given to calculate the approximate bandwidth when the effective inductance and capacitance model is used.

$$BW = \frac{\Delta\omega}{\omega_o} = \frac{1}{\eta}\sqrt{\frac{L}{C}}$$

IV. Analysis of a Single Microstrip Line

Microstrip lines are widely used as interconnects of choice due to their ease of fabrication. A microstrip line consists of a conductor placed over a grounded dielectric substrate. The important geometrical parameters in the design of the microstrip line are its width (*W*), length (*L*), distance from the ground plane (*b*) and the relative permittivity of the dielectric medium (ε_r). The fundamental characteristics of the microstrip line, Z_o and β, depend upon the width of the microstrip line and the relative permittivity of the substrate. This can observed from the expressions discussed later under this section.

Since the electromagnetic wave supported by a microstrip line is exposed to two different dielectric media, the microstrip line supports a quasi-TEM wave.

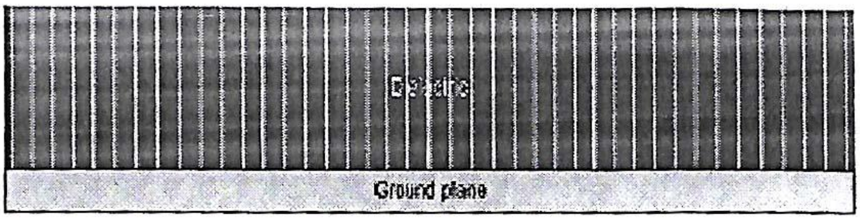

Fig. 4.1 : Cross section of a microstrip line configuration

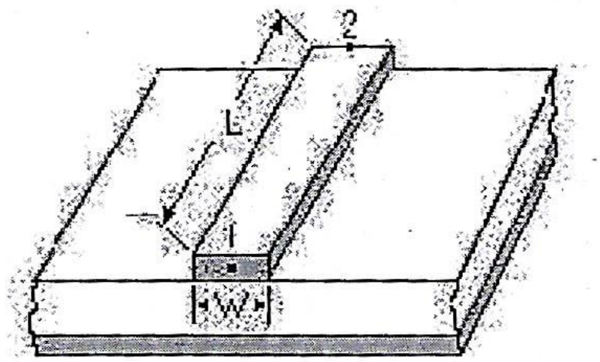

Fig. 4.2 : Important parameters and port definition for the analysis of a microstrip line.

Based on [4], [6] references, the effective dielectric constant of a microstrip line is given by

$$\varepsilon_e = \begin{cases} \dfrac{\varepsilon_r+1}{2} + \dfrac{\varepsilon_r-1}{2}\dfrac{1}{\sqrt{1+12\dfrac{b}{w}}} & \text{for } \dfrac{W}{b} > 1 \\ \dfrac{\varepsilon_r+1}{2} + \dfrac{\varepsilon_r-1}{2}\left[\dfrac{1}{\sqrt{1+12\dfrac{b}{w}}} 0.04\left(1-\dfrac{W}{b}\right)^2\right] & \text{for } \dfrac{W}{b} \le 1 \end{cases} \quad \text{............... (4.1)}$$

Same references provide the following formulas for the characteristic impedance of the microstrip line

$$\begin{cases} \dfrac{60}{\sqrt{\varepsilon_e}} In\left(8\dfrac{b}{w}+\dfrac{1W}{1b}\right) \; for \dfrac{W}{b} \le 1 \\ \dfrac{}{\sqrt{\varepsilon_e}\left[\dfrac{W}{b}+1.393+0.667\, In\left(\dfrac{W}{b}+1.444\right)\right]} \; for \dfrac{W}{b} > 1 \end{cases} \quad \text{............... (4.2)}$$

To verify the closed-form formulas, the microstrip line is analyzed using ADS Linecalc. The dimensions of the simulated microstrip line being analyzed are provided in Table-1. FR4 is the dielectric substrate. For these design parameters, $\frac{W}{b} > 1$ and Equations (4.1) and (4.2) yield the DC effective dielectric constant of $\varepsilon_{eff,0} = 3.3426$ F/m and a characteristic impedance, $Z_0 = 48.89\Omega$. The frequency dependent characteristic impedance of a microstrip line as provided in [7] is given by

$$Z_0, F = Z_0\left(\frac{\varepsilon_{eff,0}}{\varepsilon_{eff,F}}\right)^{0.5}\left(\frac{\varepsilon_{eff,F^{-1}}}{\varepsilon_{eff,0^{-1}}}\right) \quad \text{............... (4.3)}$$

where $\varepsilon_{eff,F}$ is the frequency dependent effective dielectric constant.

Table - 1 : Microstrip Line Parameters

Parameter	Value	Units
Width of the Microstrip line *W*	10	Mil
Thickness of the Microstrip line *t*	1.3	Mil
Distance from the ground plane *b*	5	Mil
Permittivity of the medium ε_r	4.4	None
Length of the Microstrip line *L*	100	Mil

Modifying (4.4) in order to calculate $\varepsilon_{eff,F}$ yields

$$\varepsilon_{eff,F} = \frac{-b \pm \sqrt{b^2-4ac}}{2a} \quad \text{............... (4.4)}$$

where $a = 1$

$$b = \left(\frac{-2\varepsilon_{eff,0} - k^2\varepsilon_{eff,0}^2 - k^2\varepsilon_{eff,0}k^2}{\varepsilon_{eff,0}}\right)$$

$c = 1$

$$k = \frac{Z_{0,F}}{Z_0}$$

Choosing only the addition in the numerator of the RHS of Equation (4.4), the frequency dependent $\varepsilon_{eff,F}$ can be calculated. The most accurate way to find characteristic impedance and permittivity of a microstrip line is by conducting full-wave simulations which provide these parameters as functions of frequency. Hence, the microstrip described in Table-1 was simulated using two main microwave circuit simulators; Ansoft's High Frequency Structure Simulator (HFSS) and Agilent's Advanced Design Systems (ADS). ADS is a 2.5-D it is meant that only 2D planar layouts and particular vertical conductor structures like vias can be simulated. This allows for stacking up of one layer above another but not a structure with 3D complexities. ADS is widely used to analyze planar circuits like microstrip or stripline-based geometries. HFSS is a 3D field solver operating based on the finite element method (FEM) for the numerical analysis. It is a robust and accurate software that enables the analysis of complex 3D geometries. FR4 was used as the dielectric substrate.

One of the most important steps in the design process using HFSS is the definition of the ports. A wave port is commonly chosen for the excitation. HFSS generates a solution by exciting each wave port individually. Each mode incident on a port contains one Watt of time-averaged power. Care has to be taken in defining the ports as wrong field excitation at the port can lead to incorrect results. In the conducted simulations, the height of the port is chosen to be approximately ten times the height of the substrate and the width was chosen to be approximately fifty percent of the dielectric width. This definition is in accordance with the recommended guidelines of the simulator. Another important feature is the definition of the radiation boundary. Since most of the designs discussed in this paper are open boundary problems and hence radiation boundaries are used to emulate a wave radiating infinitely far into space. It does so by essentially absorbing the wave at the radiation boundary thereby distending the boundary to theoretical infinity.

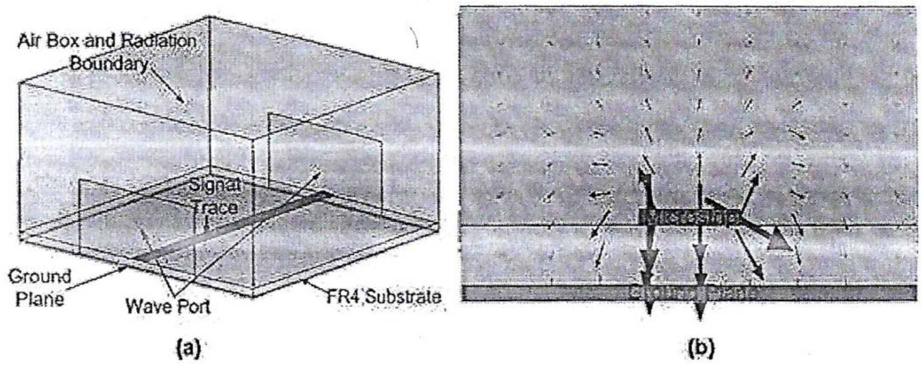

Fig. 4.3 (a) : Shows the layout of a microstrip line in HFSS.

Figure 4.3(b) shows the field distribution when a waveport is used for excitation. It clearly depicts the quasi-TEM nature of the wave supported by the microstrip line.

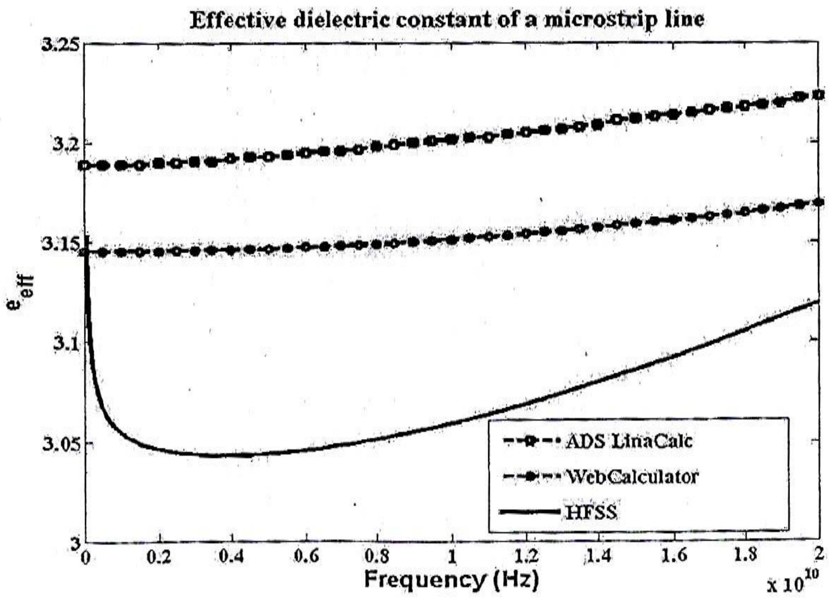

Fig. 4.4 (a)

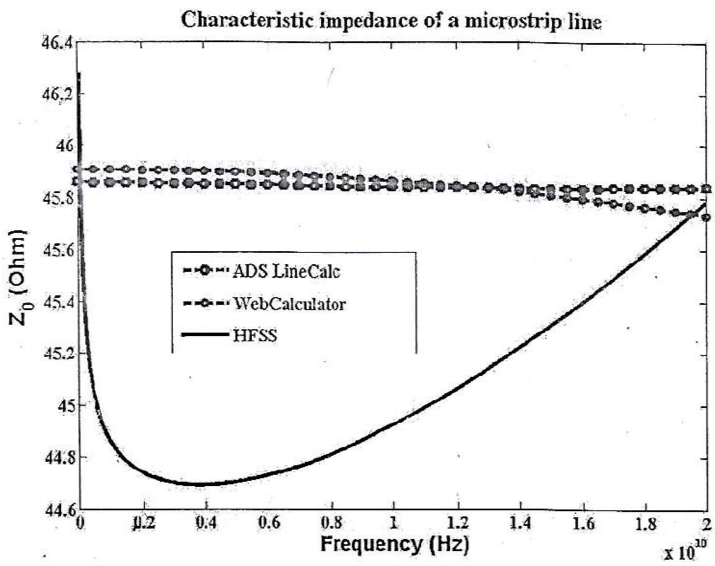

Fig. 4.4 (b) depicts the frequency dependent effective relative permittivity and

Fig. 4.4 (a) depicts the frequency dependent effective relative permittivity and Fig. 4.4 (b) shows the plot of the characteristic impedance of the microstrip line and its variation with frequency. Three methods are used to derive the results of Figure 4.4; HFSS, ADS Momentum and the web calculator from [6].

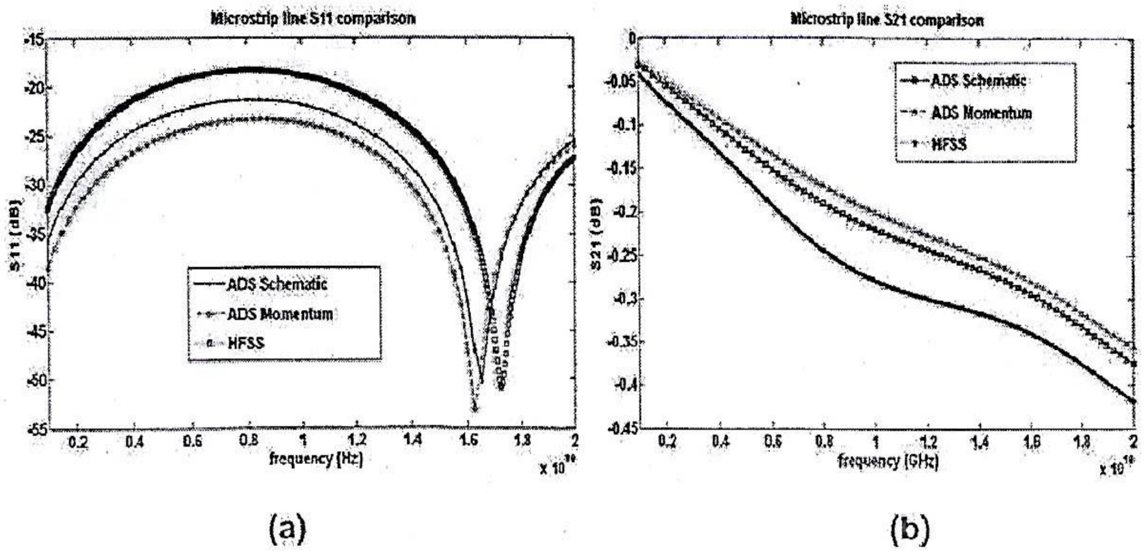

Fig. 4.5 : Shows the return loss and insertion loss of the studied.

Microstrip line found from three methods, HFSS, ADS Momentum, ADS Schematic window simulations which uses library models for the transmission lines as opposed to full-wave simulations.

V. Conclusion

It is observed at low frequencies, the microstrip line transmits almost all the power from the source to the load. This behaviour changes with the increases in frequency; the power at the load end is always lesser than the power at the source end. This is attributed to the radiation, conductor and dielectric losses.

Radiated power or electromagnetic interference at high frequencies can be serious problem as it can affect the performance of the circuit as well as those of the adjacent circuits [3].

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