ANALYSIS OF PHOTONIC BAND GAP STRUCTURE MICROSTRIP FILTERS USING ANN

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ABSTRACT: *This paper is only based on computational analysis. We first analyse the characteristics of microstrip filter and design methods of periodic structure, and then design the Photonic Band Gap (PBG) microstrip filter with various filling factor (2, 3, 4, 5 and 5.5) by using given references and formula and then its simulate with 3D EM simulator IE3D which based on MOM method, and compute all data from IE3D in an ANN model and compared stop bans and pass band with their filling factor. The substrate used for filter design is RT-Duroid 6010 board which has relative permittivity 10.2, thickness of substrate 0.635 mm and tangent loss 0.0005. After 8 epoch ANN model gives mean square error 10^{-18} and best training performance is $4.2433*10^{-18}$.*

***Keywords:* ANN, PBG structure.**

I INTRODUCTION

The function of a filter is to allow a certain range of frequencies to pass while to attenuate the others. Thus clearly there is a pass-band and a stop-band. Ideally in the pass-band there should be no attenuation while in the stop-band there should be maximum attenuation. However, with real components, such as inductors, capacitors, transmission lines and waveguides that is not the case. Contrary to the ideal case in the pass-band there is some attenuation, which can be controlled by improving the design and by proper choice of components. Similarly in the stop-band the attenuation can be controlled. Filters can be low-pass, high-pass, band-pass, and band-reject type. Filters are one of the most widely used components for radio frequency as well as for microwave communications [1]. An infinite transmission line or waveguide periodically loaded with reactive elements is referred to as a periodic structure. Periodic structure can take various forms, depending on the transmission line media being used. Often the loading element is formed as discontinuities in the line, but in any case they can be modelled as lumped reactance across a transmission line. Periodic structure support slow-wave propagation and has pass band and stop bands characteristics similar to those of filters. Recently, there has been an increasing interest in studying microstrip lines with various periodic structures that prohibit wave propagation in certain frequency bands, including photonic band gap (PBG), electromagnetic band gap (EBG) and defected ground structures (DGS). Each periodic structure has its own properties and advantages. For example, DGS can be simply realized by etching only a few areas on the ground plane under the microstrip line. The frequency behaviour of the EBG is better than the DGS, but the manufacturing process of EBG is very complex. Electromagnetic band-gap (EBG) materials are periodic structures that exhibit wide band-pass and band rejection properties at microwave frequencies. Introducing periodic perturbations such as dielectric rods, holes and patterns in waveguides and PCB substrates forms photonic band-gap (PBG) materials [2-5]. Artificial Neural Networks (ANNs) are suitable models for microwave circuit optimization and statistical design. Neuro-models are computationally much more efficient than EM models. Once they are trained with reliable learning data obtained from a "fine" model by either EM simulation or measurement, the Neuro models can be used for efficient and accurate optimization and design within the region of training. The Artificial neural networks (ANNs) provide fast and accurate models for microwave modelling, simulation and optimization. The past decades has seen a phenomenon growth in the development of new tools for microwave CAD. ANN application to the field of microwaves is very recent. ANN also finds application in filter yield prediction and optimization so the results from different work demonstrate that ANN technique can reduce the cost of computation significantly and thus can produce fast and accurate result compared to the conventional electromagnetic (EM) method [6-8].

II MICROSTRIP FILTER AND THEIR CHARACTERISTICS

Microwave filter is a two port network used to control the frequency response at a certain point in a microwave system by providing transmission at frequencies within the pass band of the filter and attenuation in the stop band of the filter. In microwave frequencies lumped element inductors and capacitors cannot be used and thus transmission line sections are used which behave as inductors and capacitors. Minimizing the losses in the pass band of a filter is extremely important since it is not only reduces the overall losses for a transistor but also improves the noise figure when used with a receiver. There are many kinds of filters used in microwave receivers, so it is impossible to cover all of them. If a filter is needed on the output of a jammer, it is desirable to place it approximately half way between the jammer and antenna vs. adjacent to either. The transmission line attenuation improves the VSWR of the filter at the transmitter. This may allow use of a less expensive filter or use of reflective filter vs. an absorptive filter.

III PHOTONIC BAND GAP (PBG) STRUCTURE

Photonic band gap (PBG) structures are periodic structures in which propagation of certain bands of frequencies is prohibited. Original PBG research was done in the optical region, but PBG properties are scalable and applicable to a wide range of frequencies. PBG structure can be achieved by using metallic, dielectric, ferromagnetic, or ferroelectric implants. Dielectric PBG structures have been used for microstrip circuits. PBG depends on the diffraction, reflection, and refraction. PBG materials can be used to affect and control the movement of electromagnetic waves. Photonic crystals are not a new material; in fact they exist in nature and have been studied for more than 100 years. By imitating the periodicity of photonic crystals one can tailor the specific band gap of a structure. This is done in PBG structures by defining a pattern with repeating regions which alternates between materials with high and low dielectric constant. Diffraction is the underlying physical mechanism describing how periodic changes in the dielectric constant can result in forbidden transmission bands. Since diffraction is the cause of the band formation, the placement of the band gap is defined by the characteristic length scale of the pattern periodicity. By defining the periodicity of the pattern one can therefore limit which specific photon frequencies are allowed to pass and which are not. The size of the band gap is determined by the difference in dielectric constant between the materials used. PBG structures in the optical regime have many applications and can be used in optical devices such as: low-loss waveguides, resonant cavities, optical switches, filters and beam shaping for LEDs.

IV DESIGN ANALYSIS

For the designing of the filter some parameters are taken as, design frequency = 10 GHz, dielectric constant ε_r (RT/Duroid 6010) = 10.2, thickness of substrate board h = 0.635 mm and loss tangent = 0.0005. From using equation we find length and width of microstrip ground plate 11.4 x 17.1 mm^2. The length and width of microstrip line is determine on 50Ω matching impedance and 90^0 electrical component with help of linegauge section of IE3D microstrip is 0.6096 x 17.1 mm^2 shown in Fig.1.

$$Kp = n\pi \qquad (1)$$

Where 'p' is the period of slots, n= number of slots, the value of K is find by equation (2) as

$$K = \frac{2\pi f_r}{c}\sqrt{\varepsilon_{eff}} \qquad (2)$$

The effective dielectric constant ε_{eff} is found with the help of dielectric constant ε_r and width (W) of filter and thickness of substrate by equation (3).

$$\varepsilon_{eff} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r + 1)}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \qquad (3)$$

The width (W) of filter is determined by equation (4) where c is the velocity of light, f_r design frequency.

$$W = \frac{c}{f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (4)$$

$$d_n = \begin{cases} (n-1)p & for\ odd\ n \\ \frac{2n-1}{2}p & for\ even\ n \end{cases} \qquad (5)$$

Equation (5) shows the numbers of slot are even or odd, where d_n is defined by the help of Bragg equation as

$$\lambda = 2d\sin\theta \qquad (6)$$

Where θ is vertical electrical component so it has 90^0. So, $\lambda = 2d$ (7)

For even slot taken n = 4, we get P = 5.7 mm, and $\varepsilon_{eff} = 6.8520$.

V SIMULATION ANALYSIS

When all the dimension of the filter had been investigated, the design and simulation process can be done. The IE3D (3D EM simulator version 14.00) have been used for the simulation of the structure. All dimensions are in mm. This EM Simulator software (IE3D) is very useful. By using this software, the design process can be done regularly to see to get an optimum result. This software helps to reduce the fabrication's cost because only the filter with the best performance will be fabricated first the parameters for the microstrip filter are calculated by using the equation before and applied to the schematic diagram. After that from the schematic diagram, the layouts of these filters were generated. The designs can also being done through the layout diagram without using the schematic diagram. After setting all parameters in the software, run the simulation.

5.1 Filling Factor

Filling factor is the ratio of slot width (w_s) to period (P) of slot. Here filling factor (FF) is vary as 2, 3, 4, 5, and 5.5. On the different filling factor find out different slot width (w_s) and period (P) of slots and simulate on basis of this parameter and give the data of S_{11} and S_{21}, data of S_{11} are plot by Microsoft excel for finding optimisation shown in Fig. 6, and the data of S_{21} are feed in ANN model and find optimise.

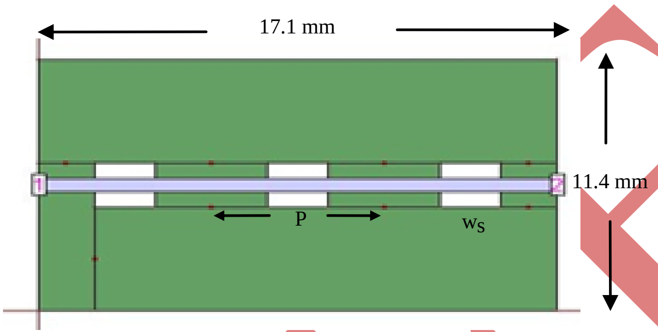


Figure.1 Microstrip filter with PBG structure by IE3D

5.2 ANN Model

ANN model based on L-M algorithm has three inputs and two outputs in the input side fill factor (FF), Centre frequency (f_c) and reflection coefficient at port 2 (S_{21}), and output side FF, Band rejection (BR) is shown in the Fig.2. After the simulation of proposed filter on Ie3d we taken data in terms of S_{21} and frequency according to different filling factor like as 2, 3, 4, 5, 5.5 and design a ANN model according to figure 5.1 and simulate by ANN tool we get mean square error very low 10^{-18} approx. on 8 epoch and gets best training performance is $4.2433*10^{-18}$. The performance, training and validation plot are shown in the Fig.3 to 5.

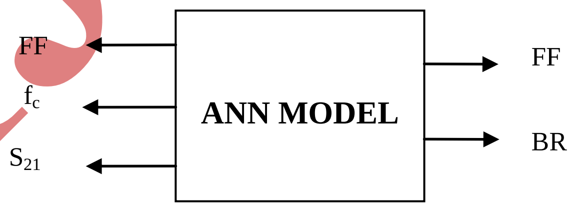
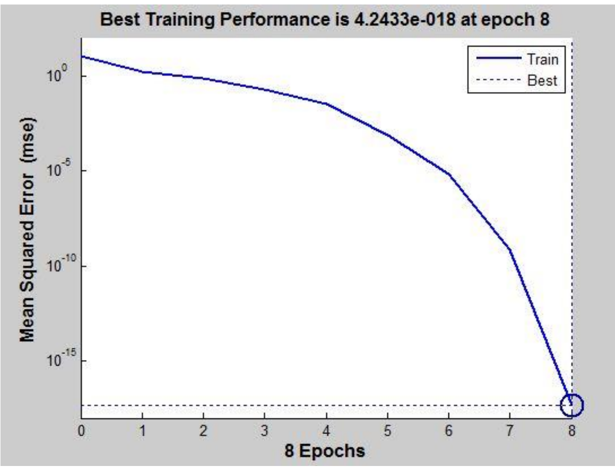


Figure.2. ANN model



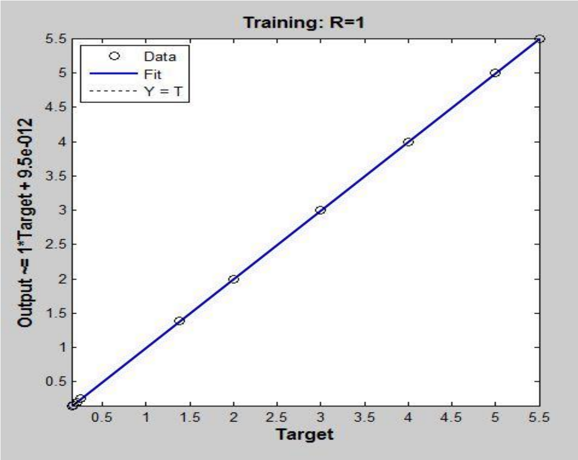


Figure: 3. Performance plot

Figure.4 Training plot

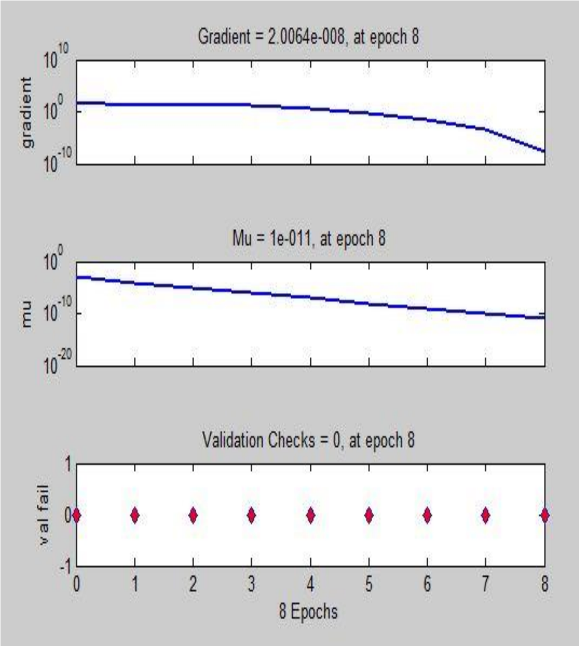


Figure.5.Validation plot

VI RESULTS ANALYSIS

The results of microstrip filter designs such as the return loss is obtained by using the EM Simulator IE3D software, and optimize results with their filling factor as 2, 3, 4, 5 and 5.5 using excel plot and again taking data in terms of reflection coefficient and band rejection at port 2 and optimize result using ANN model based on L-M algorithm.

6.1 Return Loss Analysis Of Filter Using IE3D

After the simulation of Ie3d in terms of their fill factor we get the pass band of the proposed filter is high with respect to high fill factor and return loss after -10dB is so high on at fill factor 3 in comparison other taken fill factor. The comparison diagram of return loss with their fill factor is shown in Fig. 6.

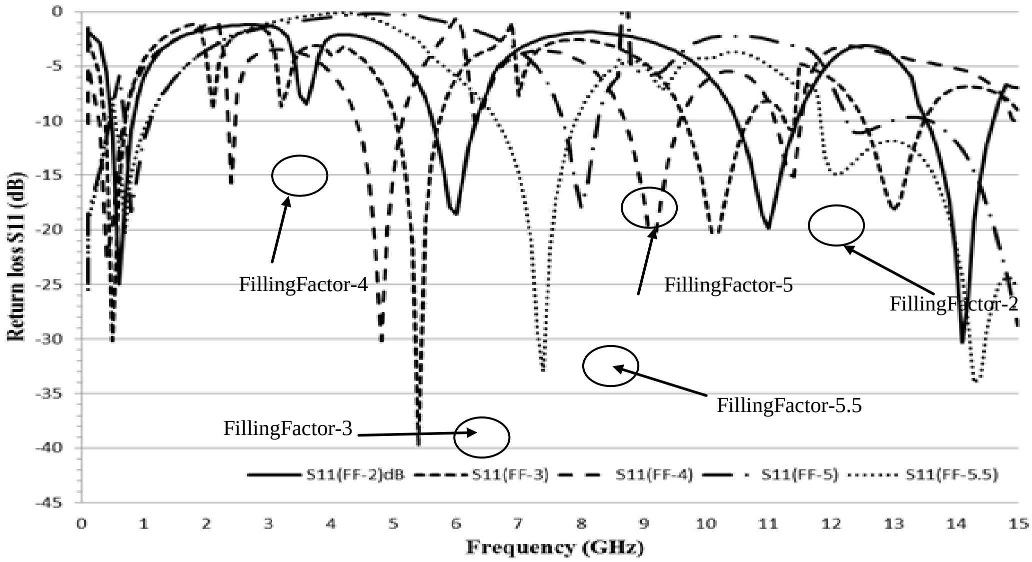


Figure.6. Return loss vs. frequency plot

6.2 Result Analysis Of Proposed Filter Using ANN

After simulation of IE3D according to their fill factor we find out result is near about 99.98% is same as the result of ANN Model simulation as Table1.

TABLE1. COMPARISON OF IE3D AND ANN

IE3D		ANN	Error (%)
Fill factor	Band reject(GHz)	Band reject(GHz)	
2	0.203	0.2030	0.0000
3	0.14763	0.1476	0.0200
4	0.16609	0.1661	0.0060
5	0.25145	0.2515	0.0190
5.5	1.38409	1.3841	0.0007

VII CONCLUSION

Various fill factors PBG Structure filters are design a standard 50-ohm transmission line and simulate IE3D with parameter and again to yield improved filter properties using ANN model based on L-M algorithm. The band reject of filter on different filling factors (FF) shown in Table1. For increasing FF up to 2 to 3 decrease band rejection and up to 5.5 increase. From Fig6, shows that the proposed filter can be used for dual band operation. This novel design provides impressive BPF properties. The wider stop band can be used to mitigate the surface wave problem and to suppress the unwanted transmission. This structure can also found potential application in RF front-ends to isolate transmitters from receiver modules.

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