

Design and Optimization of a Microstrip Patch Antenna for Increased Bandwidth

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Abstract—With the ever-increasing need for wireless communication and the emergence of many systems, it is important to design broadband antennas to cover a wide frequency range. The aim of this paper is to design a broadband patch antenna, employing the three techniques of slotting, adding directly coupled parasitic elements, and fractal EBG structures. The bandwidth is improved from 9.32% to 23.77%. A wideband ranging from 4.15 GHz to 5.27 GHz is obtained. Also a comparative analysis of embedding EBG structures at different heights is also done. The composite effect of integrating these techniques in the design provides a simple and efficient method for obtaining low profile, broadband, high gain antenna. By the addition of parasitic elements the bandwidth was increased to only 18.04%. Later on by embedding EBG structures the bandwidth was increased up to 23.77%. The design is suitable for variety of wireless applications like WLAN and Radar Applications.

Keywords—Bandwidth, broadband, EBG structures, parasitic elements, Slotting.

I. INTRODUCTION

MICROSTRIP patch antennas have been designed and characterized extensively over the past many years because of their low profile structures, light weights, and low cost in fabrication [1]-[8] where various design techniques and fast solvers have been developed to enhance radiation performance (such as bandwidth and gain). These low profile antennas are useful in aircraft, satellite and missile applications where size, weight, cost, performance, ease of installation and aerodynamic profiles are strict constraints. In spite of many advantages, these antennas suffer from some disadvantages which include their low efficiency, low power, high Q, spurious feed radiation and very narrow bandwidth [9]-[14]. There have been considerable efforts made by researchers from all over the world towards increasing its bandwidth. A possible way for increasing the bandwidth is to either increase the height of the dielectric or decrease the dielectric constant. However the first approach would make it unsuitable for low profile structures while the latter approach will make the matching circuit to the patch difficult due to excessively wide feeding lines. Various other techniques [15]-[17] have been proposed to increase the bandwidth of a patch antenna. Bandwidth of small size microstrip antennas has been improved by the use of U slot and L probe [15], stacked microstrip patch antenna, aperture coupled, and impedance

matching network using filter design techniques [16], unbalanced structures [17].

Another way of increasing the bandwidth of the MPA is the use of additional resonators [18] either directly coupled or indirectly coupled to the patch antenna.

Use of EBG structures for improving the characteristics of MPA such as improving their radiation patterns, enhancing their gain, and minimizing the side and back lobe levels, etc. has attracted much attention among researchers in the microwave and antenna communities [19]. Various EBG structures have been proposed and they have found many applications in the microwave region [20]-[23]. Recently EBG structure on the feed line has also been studied to improve performance of a triple band slot antenna [24].

The main objective of this paper is to present a new antenna configuration with combined effect of slotting, use of directly coupled parasitic elements and fractal EBG structures to design a simple low profile broadband antenna. Firstly slotting was done by introducing four slits on all the four sides of a rectangular shaped patch antenna as shown in Fig. 1. Then four different radiating elements connected together and directly coupled to the slotted antenna as shown in Fig. 2 were added which shows improvement in bandwidth from 9.32% to 18.04%. Later on by embedding fractal EBG structures in the same antenna it was being observed that the bandwidth was increased up to 23.77%. A comparative analysis was also done at different heights of fractal EBG structures. The material used as the substrate is FR4 (glass epoxy, $\epsilon_r = 4.4$) and the type of feed used is coaxial probe feed. The simulation is done using HFSS which is based on Finite Element Method.

II. ANTENNA DESIGN

A. Slotted Rectangular Microstrip Patch Antenna

In this section a slotted patch antenna is designed. Fig. 1 depicts the geometry of the proposed patch antenna with its dimensions 36mm×28mm. The four slits as shown in Fig. 1 are created in its shape. The FR4 material is used as the substrate whose thickness is 3.2mm (h_1). The dimensions of the slits along the length are $L_1=4$ mm and $W_1=10$ mm and along the width are $W_2=4$ mm and $L_2=12$ mm. The feed is positioned 0.6mm along the x-axis and 4.3mm along the y-axis from the centre of the rectangular patch. The ground plane size is 100mm×100mm. The proposed antenna is simulated using HFSS which is based on FEM. Fig. 7 shows the simulated impedance bandwidth. The impedance bandwidth is found to be 9.32% ranging from 4.2GHz to 4.61GHz. It has been observed that by introducing the slits in

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the patch antenna the surface current path is increased leading to a broader bandwidth of 9.32% whereas the bandwidth of a normal patch antenna is generally about only 1%.

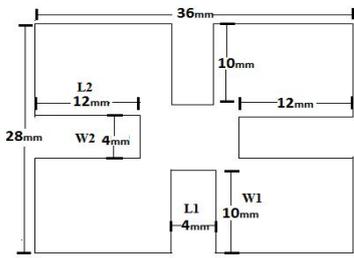


Fig. 1 Top view of Slotted Patch Antenna

B. Bandwidth Improvement by the use of Directly Coupled Parasitic Elements

The antenna designed in Section A still has narrow bandwidth by seeing the demand for overgrowing need of wireless communication. The second technique employed here to increase its bandwidth is the use of directly coupled parasitic elements. Fig. 2 shows the geometry of the proposed new modified slotted patch antenna with parasitic patches. These additional resonators generate the modes very close to the fundamental resonant frequency of the main patch resulting in broad bandwidth. As shown in the figure additional parasitic elements are directly coupled and inserted in the slits of the slotted patch antenna. All the dimensions of the parasitic elements are shown in the figure. This new antenna with parasitic elements has bandwidth of 18.04% which is twice that of the slotted patch antenna. This antenna operates in the range of 3.53GHz to 4.23GHz. The length and width of each element of these parasitic elements are optimized to get the broad bandwidth. The optimized feed location is found to be at 0.62mm along the x-axis and 4.3mm along the y-axis from the centre of the rectangular patch. The results are shown in Fig. 8.

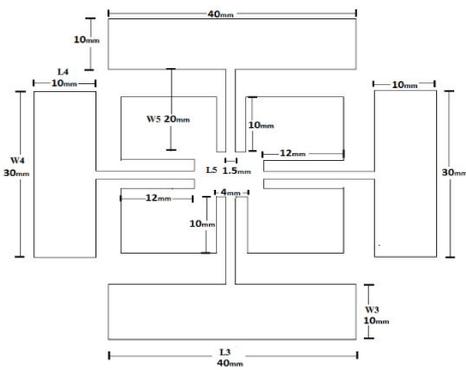


Fig. 2 Top view of Slotted Patch Antenna with directly coupled parasitic elements

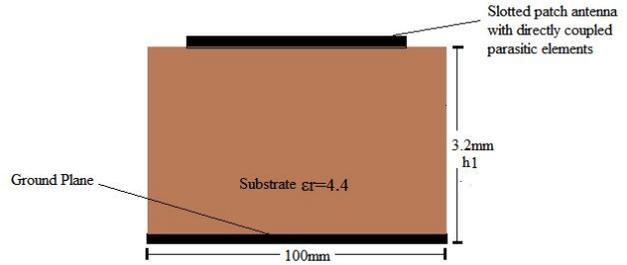


Fig. 3 Side view of Slotted Patch Antenna with directly coupled parasitic elements

C. New Modified Antenna Design using Fractal EBG Structures for Wide Bandwidth

In this section a third technique is employed to further improve the bandwidth of the antenna designed in Section B. By the use of EBG structures the characteristics of the patch antenna can further be enhanced. An EBG structure is a periodic structure that forbids the propagation of all Electromagnetic waves within a particular frequency band called the band gap. The performance improvement occurs due to the stop bands of these periodic structures. These structures provide a simple and effective solution to surface and leaky waves. Several types of microstrip based EBG structures have been analyzed for variety of applications.

Fig. 4 shows the geometry of the single element of the EBG structures. An array of 6×6 EBG structures is embedded at a height of 1.6mm (h2) as shown in Fig. 5. Each single array element has dimensions of L7=12mm and W7=12mm as shown in figure. The gap between the array elements, L5=4mm and W5=4mm is also shown in the figure. This new modified antenna design using ebg structures has a wide bandwidth of 23.77% ranging from 4.15GHz to 5.27GHz as shown in Fig. 9 in comparison to 18.04% of the antenna designed in Section B. The antenna is found to resonate at the frequency of 4.17GHz with -38.60dB return loss.

The side view of the new modified antenna design is shown in Fig. 6. The EBG structures were embedded at the height of 1.6mm (h2) from the ground plane in the antenna designed in section B. The modified feed location is found to be at 0.6mm along the x-axis and 4.6mm along the y-axis from the centre of the rectangular patch.

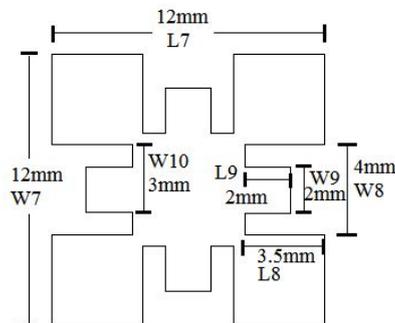


Fig. 4 Single Element of EBG Structures

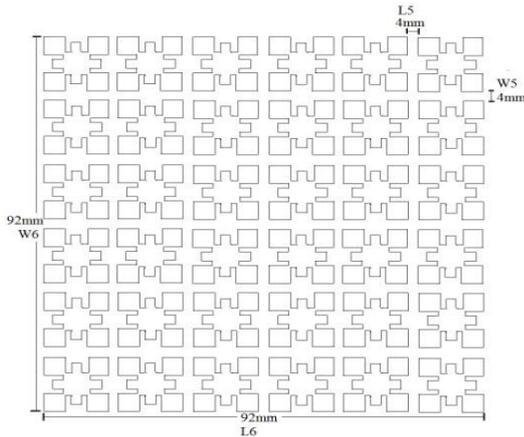


Fig. 5 6x6 array of EBG structures

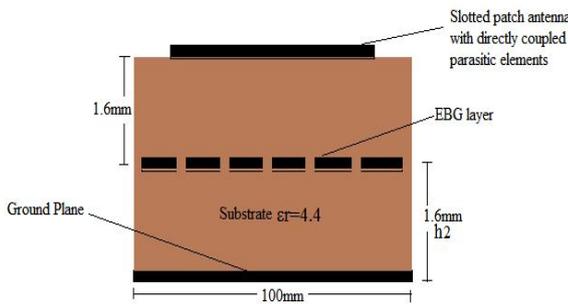


Fig. 6 Side view of the new modified antenna design with EBG structures

III. SIMULATED RESULTS AND DISCUSSION

A. Slotted Patch Antenna

Fig. 7 shows the return loss curve for the antenna designed in section A. The simulated results show that the resonant frequency locates at about 4.31GHz with the maximum return loss of -33.55dB. The -10dB impedance bandwidth is found to be 9.32% ranging from 4.2GHz to 4.61GHz which is comparable more than the normal rectangular shaped patch antenna having only 1% bandwidth.

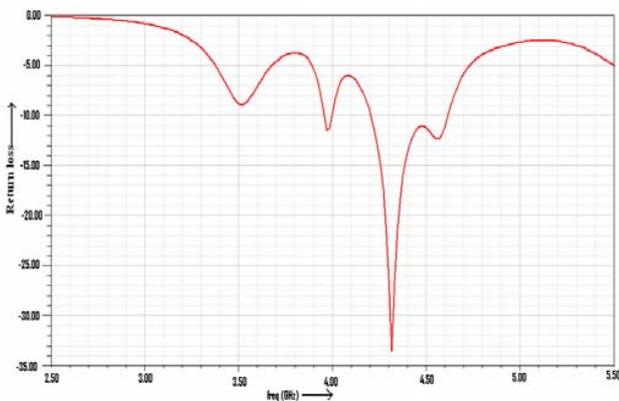


Fig. 7 Return Loss (in dB) vs freq (in GHz) for slotted patch antenna

B. Slotted Patch Antenna with Directly Coupled Parasitic Elements

The result in Section A shows only the limited bandwidth. To further enhance the bandwidth of the patch antenna designed in section A, the use of parasitic elements is made which increased the bandwidth to 18.04% ranging from 3.53GHz to 4.23GHz. Fig. 8 shows the return loss curve for the antenna designed in section B. The maximum return loss is found to be -29.12 dB located at the resonant frequency of 3.63GHz.

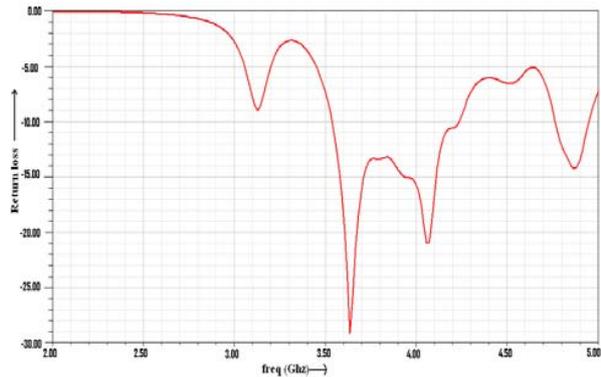


Fig. 8 Return Loss (in dB) vs. freq (in GHz) for slotted patch antenna with directly coupled parasitic elements

C. New Modified Antenna with Embedded Fractal EBG Structures

Fig. 9 shows the return loss curve for the antenna designed in section C. By embedding the fractal EBG structures the bandwidth was further improved to 23.77% ranging from 4.15GHz to 5.27GHz. It is being observed from the figure that by embedding EBG structures the bandwidth is drastically improved.

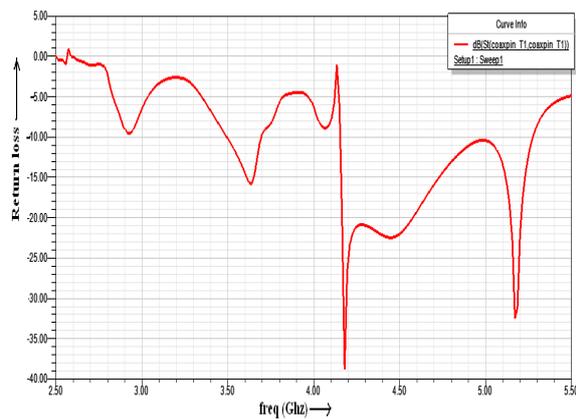


Fig. 9 Return Loss (in dB) vs. freq (in GHz) for slotted patch antenna with directly coupled parasitic elements and embedded fractal EBG structures

D. Effect of Embedding Fractal EBG Structures at Different Heights from Ground Plane

Fig. 10 shows the return loss curve of the new proposed antenna with EBG structures at different heights. The height from the ground plane of the EBG structures is optimized to get the broad bandwidth. The optimum result is found at height $h_2=1.6\text{mm}$ from the ground plane as can be seen from Fig. 6.

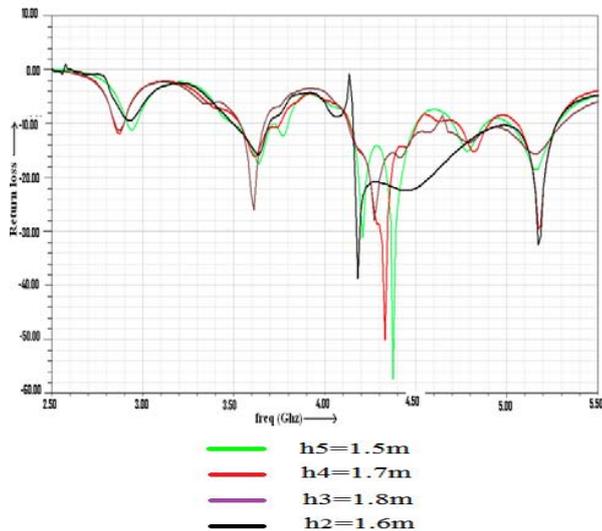


Fig. 10 Effect of fractal EBG structures at different heights from ground plane

IV. CONCLUSION

In this paper a very wideband patch antenna is designed, employing the three techniques of slotting, adding directly coupled parasitic elements and embedding fractal EBG structures. From the simulation result it is being observed that by adding slots in the normal rectangular shaped patch antenna the bandwidth is increased from 1% to 9.32%. This bandwidth is further improved to 18.04% by adding directly coupled parasitic elements which is just twice to that of the slotted antenna. To further increase the bandwidth the third feature is incorporated that is the use of 6×6 fractal EBG structures. These EBG structures are embedded in the modified patch to increase the bandwidth up to 23.77%. This antenna can be used to provide the wide band operation for WLAN and radar applications.

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