STACKED RECTANGULAR MICROSTRIP ANTENNA WITH ELECTROMAGNETIC BAND GAP STRUCTURE

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ABSTRACT

In this work the stacking technique is studied with the Electromagnetic band gap structure to enhance the performance of the conventional rectangular microstrip antenna (RMSA). The proposed antennas are experimentally studied and the results are compared with the RMSA. By stacking technique multi bands are obtained and overall bandwidth is 130.8% when compared to the conventional rectangular microstrip antenna. This antenna is small size, low cost, compact, easy to fabricate, and gives good radiation characteristics with a reduction in side lobes. These antennas can have wide application in wireless Communication and X-band applications.

Keywords: Bandwidth, back lobes, Electromagnetic Band Gap (EBG) structures, microstrip antenna.

I. INTRODUCTION

Microstrip antenna is most common small sized antenna in which a metal patch is deposited on dielectric material. Microstrip patch antennas have been an attractive choice in mobile and radio wireless communication. They have advantages such as low profile, low cost and robust. However, at the same time they have disadvantages of low efficiency, narrow bandwidth and surface wave losses. Recently, considerable research effort in the electromagnetic band gap (EBG) structure for antenna application to suppress the surface wave losses and improve the radiation performance of the antenna [1-2]. Many new technologies have emerged in the modern antenna design arena and one exciting breakthrough is the discovery development of electromagnetic band gap (EBG) structures. The electromagnetic-band gap (EBG) structures are periodical cells composed of metallic or dielectric elements. The major characteristic of EBG structures is to exhibit band gap feature in the suppression of surface-wave propagation. This feature helps to improve antenna’s performance such
as increasing the antenna gain and reducing back radiation [3]. The substrate properties that are taken into consideration while selecting a dielectric include: dielectric constant and loss tangent and their variation with temperature and frequency, homogeneity, dimensional stability with processing and temperature, humidity and aging. Other physical properties such as resistance to chemicals, impact resistance, formability, bonding ability, Foil adhesion etc, are important in fabrication [4]. Small antenna design is always compromised between size, bandwidth and efficiency. The bandwidth can be increased with the use of stacked patch structure in a microstrip antenna (MSA) (Ollikainen, Fischer and Vainikainen, 1999). The radiation characteristics can be further improved by an electronic band gap structure on one side of the substrate. This reduces the surface waves induced in the antenna and also increases the radiation pattern (Gonzalo, Maagt, Sorolla, 1999). The use of the reflector plane is fed on the finite size ground plane at the rear end of the antenna to reduce the level of back radiations (Raghava and Ashok De, 2009). The use of Photonic Band Gap (PBG) structure is becoming attractive for many researchers in electromagnetic and antenna field. PBG had been used to improve the performance of various antennas such as patch antenna and resonant antenna. Microstrip patch antenna is promising to be a good candidate for future wireless technologies [5].

Surface waves are undesired because when a patch antenna radiates a portion of total available radiated power becomes trapped along the surface of the substrate. It reduces total available power for radiation to space waves, and there is harmonic frequency created. Recently there has been an increasing interest in studying the Microstrip patch antenna with various periodic structures including Electromagnetic Band Gap (EBG) [6-7]. This uniplanar compact EBG (UC-EBG) structure is realized with metal pads etched in the ground plane connected by narrow lines to form a distributed $LC$ network. A distinctive stop band over a wide range of frequency is observed and the measurement results agree with finite-difference time-domain (FDTD) simulations. Another unique feature of this new EBG structure is the realization of a slow-wave microstrip line with low insertion loss. Slow-wave mode propagation is of great interest for its use in reducing the dimension of distributed components in integrated circuits [8]. EBG always referred as high impedance surface that increase antenna surface efficiency by suppressing the unwanted surface wave current. Suppression of surface waves excitation helps to improve antenna’s performance such as it reduces backward radiation and increase antenna gain (Gonzalo et al., 1999) [9].

In this paper, stacking technique is studied with the rectangular microstrip antenna EBG structure to enhance the performance of the RMSA. The results of the proposed antennas are compared with the conventional microstrip antenna.

II. ANTENNA & EBG STRUCTURE

In this paper a conventional rectangular microstrip antenna (RMSA) has been designed for 6GHz. The antenna is designed on FR4 with dielectric constant $\varepsilon_r = 4.4$ and with the height of $h=1.6mm$ with the width of $W=15.24mm$ and the length $L=11.33mm$ respectively. The antenna is fed by stripline fed $L_{f50}=6.18mm$ & $W_{f50}=3.06mm$ to match the impedance and quarter wave transformer $L_t=4.92mm$ & $W_t=0.5mm$ is used and ground plane $L_g=40mm$ & $W_g=40mm$ is considered for the design. The geometry is as shown in Fig.1 (a) and the photographic view of the conventional RMSA antenna is shown in the Fig.1 (b).
Initially the study is carried out by keeping all the parameter of the RMSA radiating patch constant. The antenna is fed by stripline fed and the ground plane of the antenna is kept constant. For obtaining dual wide slits RMSA (DWS-RMSA), pair of wide slits are incorporated in one of the radiating edge of the rectangular microstrip antenna. The two wide slits are placed at equal distance from the centerline of the patch width. Is = 9mm and ws=1mm are the slits length and slits width respectively \( w_1 \) is the separation between these two slits. The geometry of the DWS-RMSA is as shown in the Fig.2 (a). The photographic view of the top and bottom of DWS-RMSA antenna is as shown in Fig.2 (b).

The study is carried by loading the swastika EBG structure on the ground plane of the RMSA. By keeping all the parameter of the radiating patch constant, the antenna is fed by stripline feed as in RMSA. The ground plane is replaced by the swastika EBG. The geometry of the DWS-swastikaEBG is as shown in the Fig 3(a). The 8x8mm EBG structure with length of the slot (sl) =4mm, width of the slot (sw) =1mm, the gap between swastika EBG is g=8mm, by connecting center swastika EBG four arms to the adjacent swastika EBG arms. The photographic view of the DWS-swastikaEBG is as shown in Fig3 (b). The swastika EBG structure prohibits propagation of electromagnetic waves in a certain frequency bands. This suppresses the surface waves and hence gives enhancement in the performance of the proposed antenna. Further the study is carried out by the stacking method, by keeping all the parameter of the radiating patch and the ground plane of the DWS-swastikaEBG constant. The geometry view of stacked-swastikaEBG is as shown in Fig.4 (a). Another rectangular patch of same size \( (\varepsilon r_2 = 4.4 \text{ and } h_2=1.6\text{mm}) \) has been stacked on this RMSA-swastikaEBG. The total height of this stacked swastikaEBG is \( h=3.2\text{mm} (h_1=1.6\text{mm}+h_2=1.6\text{mm}) \). The photographic view of stacked-swastikaEBG is as shown in Fig.4 (b). Fig.5 (a) shows the single
enlarged unit of swastika EBG. The final view of the stacked-swastikEBG is as shown in Fig.5 (b). The parameter of the swastikEBG is as shown in table 1.

Fig.3 (a) Geometry of top & bottom of DWS-swastikEBG

Fig.3 (b) Photographic view of top & bottom DWS-swastikEBG

Fig.4 (a) Geometry of top and bottom of stacked-swastikEBG

Fig.4(b) Photographic view of top and bottom stacked-swastikEBG

Fig.5 (a) The enlarged geometry swastikEBG

Fig.5 (a) The final view of stacked-swastikEBG
Further the study is carried out by stacking other type of EBG structure. All the parameter of the (DWS-RMSA) radiating patch constant. The antenna is fed by stripline feed by replacing the ground plane of the DWS-RMSA by a high impedance spiral EBG structure. The geometry of the DWS-spiralEBG is as shown in the Fig. 6(a). The ground plane is loaded with four arms metal strip connected to the spiral EBG structure below the radiating patch of the antenna with metal strip width w= 1mm and the gap between each metal strip g= 1mm is used to improve the impedance matching and reduce the antenna size. The photographic view of the DWS-spiralEBG is as shown in the Fig. 6(b). This spiral EBG is stacked with DWS-RMSA. The geometry of stacked-spiralEBG is as shown in Fig. 7 (a). Another rectangular patch of same size (\(\varepsilon_r = 4.4\) and \(h_2=1.6\text{mm}\)) has been stacked on this RMSA-swastikEBG. The total height of this stacked spiralEBG is \(h=3.2\text{mm}\) (\(h_1=1.6\text{mm}+h_2=1.6\text{mm}\)). The photographic view of stacked-spiralEBG is as shown in Fig. 7 (b).

### Table 1. Parameter of the proposed swastikEBG

<table>
<thead>
<tr>
<th>Antenna part</th>
<th>Parameters</th>
<th>Size in mm</th>
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<tbody>
<tr>
<td>Swastik EBG</td>
<td>Length(X)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Width(X)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Gap(G)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Length of the slot(SL)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Width of the slot(Sw)</td>
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Fig. 6(a) Geometry of DWS-spiralEBG

Fig. 6(b) Photographic view of top and bottom DWS-spiralEBG

Fig. 7(a) Geometry of stacked-spiralEBG
III. RESULTS AND DISCUSSIONS

Prototypes of the proposed antennas Conventional Microstrip Antenna RMSA were constructed and experimental results are studied. The antenna bandwidth over return loss less than -10 dB is tested experimentally on Vector Network Analyser (Rohde & Schwarz, Germany make ZVK model 1127.8651). The variation of return loss verses frequency of RMSA is as shown in fig.8 the antenna is resonating at 5.99GHz, the overall bandwidth of the RMSA is 4.18%. From this graph the experimental bandwidth (BW) is calculated using the equations,

\[
BW = \left[\frac{f_2 - f_1}{f_c}\right] \times 100\%
\]  

(1)

Where, \(f_2\) and \(f_1\) are the upper and lower cut off frequency of the resonated band when its return loss reaches -10 dB and \(f_c\) is a centre frequency between \(f_1\) and \(f_2\).

The variation of return loss versus frequency of DW-RMSA antenna is as shown in Fig.9, it gives three bands. The overall bandwidth of DW-RMSA antenna is 26.30% and increase in gain 13.70 dB, this is due to the dual slit in the radiating patch of the RMSA. The variation of return loss versus frequency of DWS-swastikEBG antenna is as shown in Fig.10, it gives a 05 bands. The overall bandwidth of DWS-swastikEBG antenna is 109.15% and a increase in gain of 15.95dB, virtual size reduction 65.55%. This is due to the dual slit in the radiating patch of the RMSA and the swastika EBG on the ground plane. Fig.11 shows the variation of return loss versus frequency of stacked-swastikEBG antenna. The overall bandwidth of the antenna is 118.90% and a increase in gain of 15.25dB virtual size reduction 65.21%, this is due to the stacking technique with swastikEBG.

The variation of return loss versus frequency of DWS-spiralEBG antenna is as shown in Fig.12, it gives a 05 bands. The overall bandwidth of DWS-spiralEBG antenna is 114.72% and a increase in gain of 10.87dB, virtual size reduction 34.60%. This is due to the dual slit in the radiating patch of the RMSA and the spiral EBG structure on the ground plane. Fig.13 shows the variation of return loss versus frequency of stacked-spiralEBG antenna. It gives 06 bands the overall bandwidth of the antenna is 130.8% and a increase in gain of 12.45dB virtual size reduction 56.81%. The results of the proposed antennas are as shown in table2.
Fig. 8 The return loss versus frequency of RMSA

Fig. 9 The return loss versus frequency of DW-RMSA

Fig. 10 The return loss versus frequency of DWS-swastikEBG
Fig. 11 The return loss versus frequency of stacked-swastikEBG

Fig. 12 The return loss versus frequency of DWS-spiralEBG

Fig. 13 The return loss versus frequency of stacked-spiralEBG
The radiation characteristics of all proposed antennas were studied. The radiation patterns are observed for all the cases. It is observed that there is reduction in back lobes of the DWS-swastikEBG and stacked-swastikEBG when compared to the RMSA and it is as shown in E-plane radiation pattern in Fig.14 (a). The typical radiation patterns for H-plane for the DWS-swastikEBG and the stacked-swastikEBG are compared with RMSA and it is as shown in the Fig.14 (b). The radiation pattern for DWS-spiralEBG and the stacked-spiralEBG is compared with the RMSA it is shown in Fig.15 (a). From that it is clear that the back lobes are reduced. The typical radiation patterns in the H-plane for the RMSA, DWS-spiralEBG and stacked-spiralEBG are as shown in the Fig.15 (b).

<table>
<thead>
<tr>
<th>Antenna</th>
<th>No. of bands</th>
<th>Resonating Freq. (GHz)</th>
<th>Return loss in dB</th>
<th>Bandwidth in MHz</th>
<th>Bandwidth in (%)age</th>
<th>Size reduction in (%)age</th>
<th>Gain in dB</th>
<th>Overall Bandwidth in (%)age</th>
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<tr>
<td>RMSA</td>
<td>01</td>
<td>5.99</td>
<td>-37.21</td>
<td>250</td>
<td>4.18</td>
<td>--</td>
<td>10.36</td>
<td>4.18</td>
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<tr>
<td>DW-RMSA</td>
<td>03</td>
<td>5.96</td>
<td>-13.50</td>
<td>22</td>
<td>3.69</td>
<td>--</td>
<td>13.70</td>
<td>26.30</td>
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<tr>
<td>DWS-swastikEBG</td>
<td>05</td>
<td>2.10</td>
<td>-34.52</td>
<td>19</td>
<td>9.04</td>
<td>65.55</td>
<td>15.95</td>
<td>109.15</td>
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<tr>
<td>Stacked-swastikEBG</td>
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<td>2.21</td>
<td>-21.15</td>
<td>43</td>
<td>19.72</td>
<td>65.21</td>
<td>15.20</td>
<td>118.90</td>
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<tr>
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<td>4.06</td>
<td>-16.08</td>
<td>56</td>
<td>13.79</td>
<td>34.60</td>
<td>10.87</td>
<td>114.72</td>
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<tr>
<td>Stacked-spiralEBG</td>
<td>06</td>
<td>2.66</td>
<td>-15.30</td>
<td>13</td>
<td>4.88</td>
<td>56.81</td>
<td>12.45</td>
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IV. CONCLUSION

In this the rectangular Microstrip antenna with EBG and stacking technique has been proposed. The two types of EBG structures i.e swastika and spiral structure have been embedded on the ground plane of the dual wide slit RMSA (DWS-RMSA) and the performance of the antennas has been studied. The experimental results shows that there is a improvement of bandwidth to 118.9% with swastika EBG and stacking. Also the spiral EBG and stacking gives enhancement in bandwidth to 130.85%. Then increase in gain and virtual size reduction of the antenna are also observed with EBG and stacking. The antenna with spiral EBG and stacking gives more bandwidth. The antenna with swastikaEBG and stacking gives more gain. But both configurations suppress the back lobes compared to conventional RMSA. This is the advantage of using EBG along with RMSA.
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REFERENCES