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DIAMOND SHAPED SYMMETRICAL SLOTTED MINIATURIZED MICROSTRIP PATCH ANTENNA FOR WIRELESS APPLICATIONS

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ABSTRACT

A reduced ground plane diamond shaped multiband microstrip slot antenna is proposed. The antenna is designed with two symmetrical slots to form the diamond shape and the patch is fed with a microstripline. The slots make the antenna to have multiple resonances to operate in the frequency bands of 2.15 GHz to 7.8 GHz with a peak gain of 6.09 dB at 6.83 GHz and above 2 dB in all operating bands achieving a maximum impedance bandwidth of 16.38 % in the satellite operating band. The antenna has good radiation characteristics and operates in the C-Band and military X-band making it suitable for Wi-Max, WLAN and Satellite applications.

Keywords: *Patch, Reduced Ground Plane, Symmetrical Slot, Microstrip, Multiband.*

1. INTRODUCTION

As the concept of convergence multifunctional electronic device packs more functions that have increased the demand for multiband antennas. The Microstrip Patch Antennas are dominating the major segments of the wireless applications because of their small size, low cost and ease of fabrication [1-2]. Among the different miniaturization techniques such as cutting slots in the patch [3], using a shorting wall [4] or a shorting pin [5], and folding the microstrip patch to create a three-dimensional structure [6], the slot antenna with various shapes and structures becomes a potential candidate [7-11]. The effect of reduced ground plane and defected ground structure (DGS) improve antenna radiation characteristics and they are used for effective antenna matching for better control on the radiation pattern for optimum performance [12-16]. The use of slots and symmetrical slits on radiating patch are useful to achieve dual band with good isolation between bands [17]. Various antennas are designed with specific shaped slots for covering the different ranges of wireless applications [18].

This paper presents a novel antenna design with symmetrical slots on patch to have a diamond shaped structure with reduced ground plane to achieve miniaturization for multiband operation.

2. BASIC MICROSTRIP ANTENNA DESIGN

A simple rectangular patch structure is designed to operate at a single frequency using the formulas [19]. The basic microstrip fed patch antenna is designed with a dimension of 70 mm x 75 mm placed over a FR4 dielectric substrate. The antenna ground plane is reduced from 83 mm x 94 mm to a dimension of 10 mm x 90 mm as shown in Figure 1.

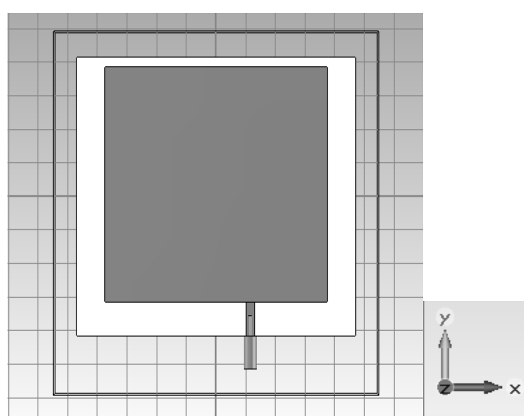

Figure 1. Basic Structure Of MSA Without Slots

This reduced ground plane makes the antenna to have controlled radiation characteristics. The basic antenna operates with a dual band characteristics

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resonating at 1.12 GHz and 1.9 GHz with S_{11} values of -16 dB and -24.5 dB as shown in Figure 2. It influences to limit the surface waves and activates the fringing fields at the radiating edges of the patch increasing the radiation efficiency. The antenna is simulated using a CST Microwave Studio, which employs the finite-integration time–domain technique.

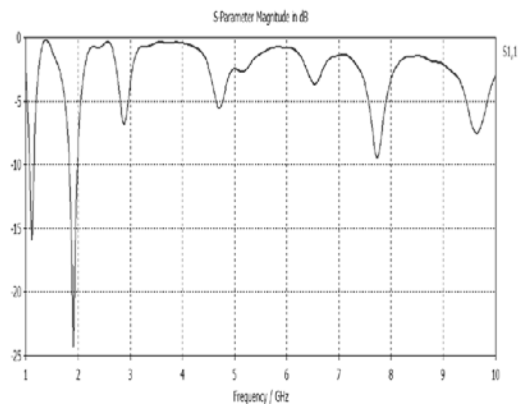

Figure 2. Frequency Versus S_{11}(Db) For Basic Structure

The radiating patch is introduced with symmetrical slots to form the diamond shape with thin radiating edges surrounding it as shown in figure 3.

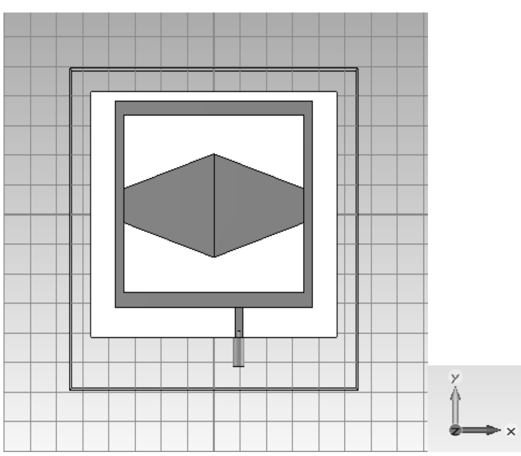

Figure 3. Diamond Shaped MSA With Symmetrical Slots

The antenna is fed with a microstrip feed matched with a 50 Ω SMA connector. The symmetrical slots on the patch increase the length of current path in the thin edges surrounding the diamond patch and converge to the middle patch. The symmetrical slots created above and below the diamond patch induce new resonant frequencies in the structure making the antenna to resonate at four bands of operation. The symmetrical slots on the antenna reduce the effective area of the radiating patch and effectively increase the current path in the structure with the improved radiation characteristics supporting all the operating bands.

The design parameters with dimension of the symmetrical slotted diamond shaped MSA is shown in Figures 4(i) and (ii). The diamond patch is placed above a FR4 substrate 83 mm x 94 mm with dielectric permittivity of ε_r = 4.4. The ground dimension is 10 mm x 90 mm to achieve good impedance matching with the microstrip feed line.

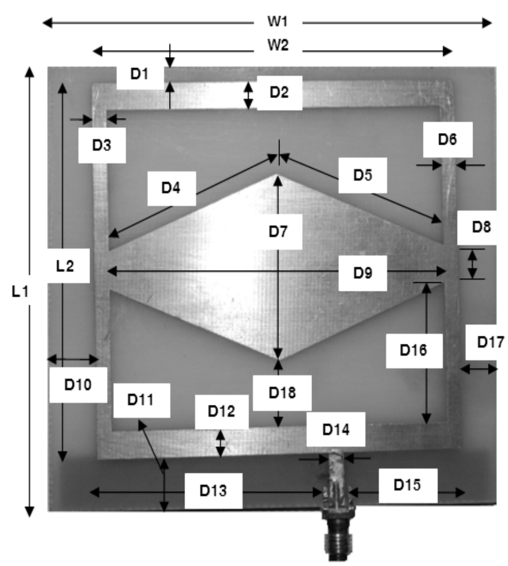

Figure 4(I). Dimension Of Diamond Shaped Symmetrical Slotted MSA –Front View

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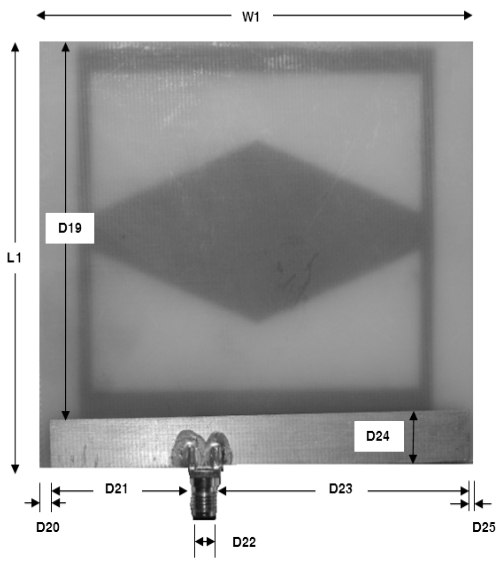

Figure 4(ii). Dimension of Diamond Shaped Symmetrical Slotted MSA –Back view

The detailed antenna parameters with dimensions shown in Figure 4(i) and (ii) are listed in Table 1. The antenna is fabricated and tested with specified dimensions.

Table 1. Antenna Design Dimensions

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
W_1	94	D_7	35	D_{16}	26
L_1	83	D_8	8	D_{17}	9
W_2	75	D_9	70	D_{18}	12
L_2	70	D_{10}	10	D_{19}	73
D_1	3	D_{11}	10	D_{20}	2
D_2	5	D_{12}	5	D_{21}	30
D_3	3	D_{13}	47	D_{22}	7
D_4	37	D_{14}	3	D_{23}	53
D_5	37	D_{15}	25	D_{24}	10
D_6	3	D_{15}	25	D_{25}	2

3. RESULTS AND DISCUSSIONS

3.1. Reflection coefficient (S_{11} dB)

After insertion of the symmetrical slot in the rectangular patch, the fundamental resonant frequency splits into multiple frequency bands starting from 2.15 GHz to 8 GHz in the fabricated antenna. The S_{11} value for the different band is moderate and has a maximum value of -31 dB at 6.83 GHz. The S_{11} at other bands are found to have values close to -10 dB due to the reduced ground plane. The tested S_{11} is found close to the simulated S_{11} characteristic of the antenna. The simulated S_{11} characteristics have four bands 1.11 GHz, 3.01 GHz, 4.5 GHz and 6.2 GHz with values of -17.9 dB, -30.3 dB, -13.9 dB and -21.6 dB respectively as shown in figure 5.

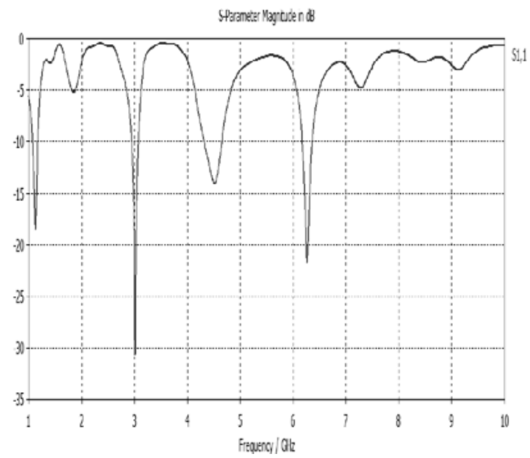

Figure 5. Simulated Frequency Versus S11[Db] For Slotted MSA

The antenna is tested using Agilent Network Analyzer and the antenna test results are found in good agreement with the simulated results as shown in Figure 6.

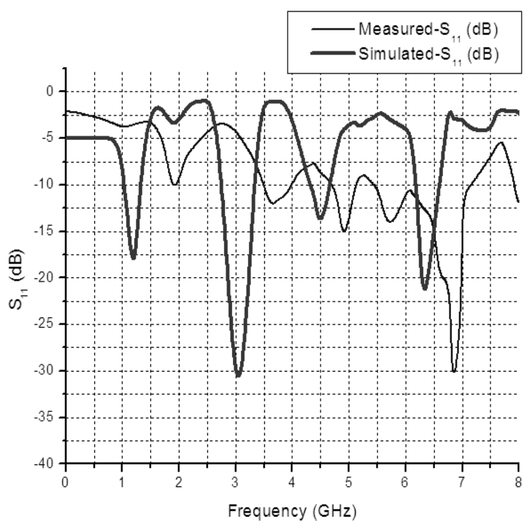

Figure 6. Frequency versus S_{11} (dB) for slotted MSA

The fabricated antenna operates as a multiband antenna with a good impedance bandwidth of 16.38 % between 6.03 GHz to 7.13 GHz suitable for the satellite application. The test conducted with network analyzer and the S_{11} dB is shown in figures 7(i) and 7(ii).

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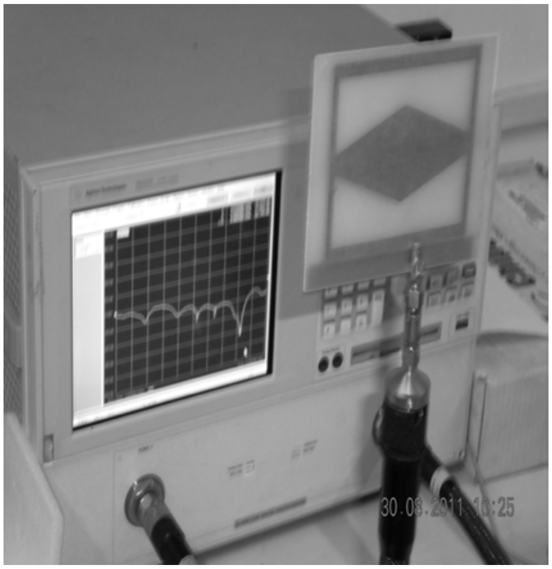

Figure 7(i). Antenna Testing With Network Analyzer

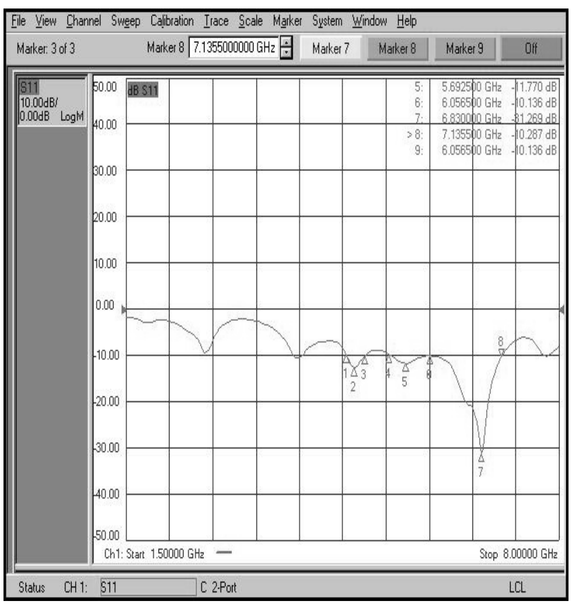

Figure 7(ii). S_{11} Characteristics of the Tested Antenna

3.2. Gain and VSWR

The antenna offers high gain over the entire operating band. The gain of the antenna varies from lower decibel in the non operating frequencies and increases above 2 dB in all the multiband frequencies.

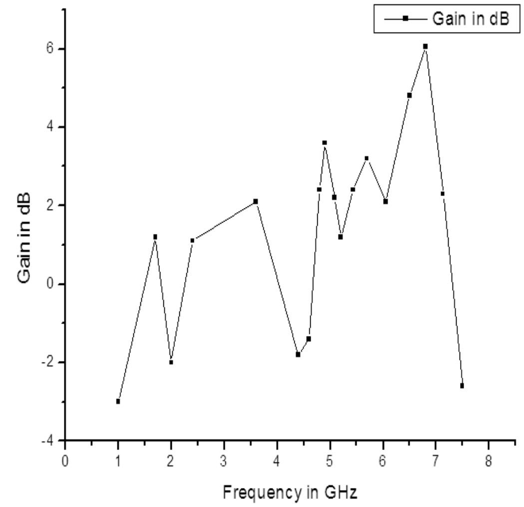

Figure 8. Frequency versus Gain

The antenna has reached a peak gain of 6.09 dB at 6.83 GHz. The frequency versus Gain plot for the antenna is shown in the Figure 8. The gain for the various operating frequencies in the band from 1 GHz to 8 GHz is plotted.

The microstrip feed is designed in such a way to have a strip width of W_s = 3 mm and length of the strip is L_s = 10 mm. The feed is designed to achieve good impedance matching over the entire operating bands. The microstrip feed is coupled with a 50 Ω SMA connector making the port perfectly matched.

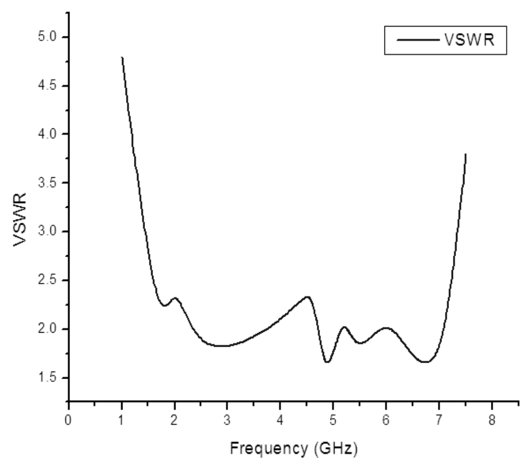

Figure 9(i). Frequency versus VSWR(Tested)

The VSWR against frequency graph of the antenna has VSWR values less than 2 in all the operating bands. The VSWR for the simulated and tested antennas are shown in the Figure 9 (i) and 9(ii).

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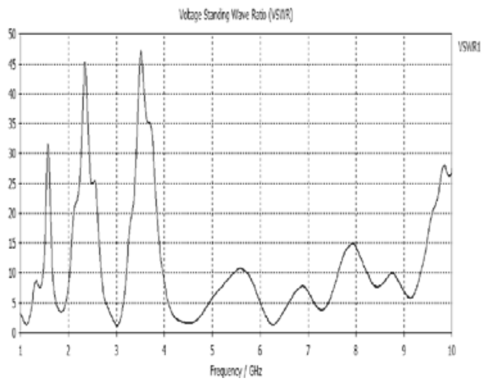

Figure 9(ii). Frequency versus VSWR (Simulated)

3.3. Radiation Pattern

The designed antenna is simulated for measuring the radiation pattern of the antenna in the E-Field and H-Field using CST Software. The simulated E-Plane radiation pattern for Theta = 90° and Phi = 90° for the operating frequency 6.3 GHz is shown in the figure 10(i) and 10(ii). The radiation pattern shows the antenna has a broad beam width with good directivity. The antenna achieves a peak gain of 3.2 dB at 6.3 GHz with minimum side lobes. The effect of reduced ground plane has the influence in generating side lobe level which can be minimized by increasing the dimension to a certain extent using EBG structures or defected ground plane structures. The E-field pattern with Phi = 90° has a minimum side lobe level of –1dB and angular 3 dB width of 54.2° showing good radiation characteristics.

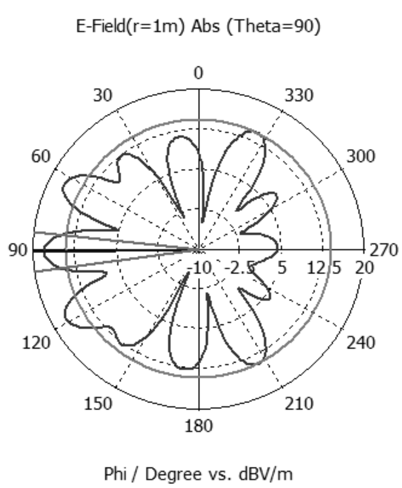

Figure 10(i). Simulated E-Field for Theta = 90°

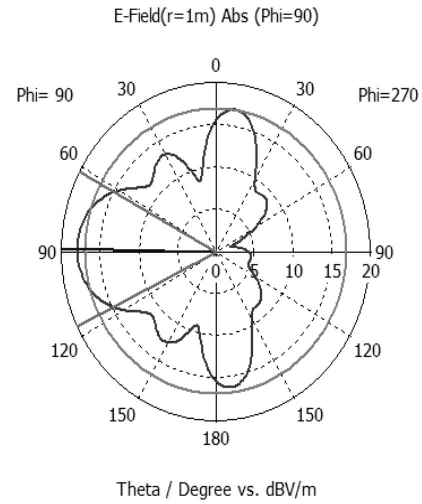

Figure 10(ii). Simulated E-Field for Phi = 90°

The simulated H-Plane radiation pattern for Theta = 90° and Phi = 90° for the operating frequency 6.3GHz is obtained as shown in the figure 11 (i) and 11 (ii).

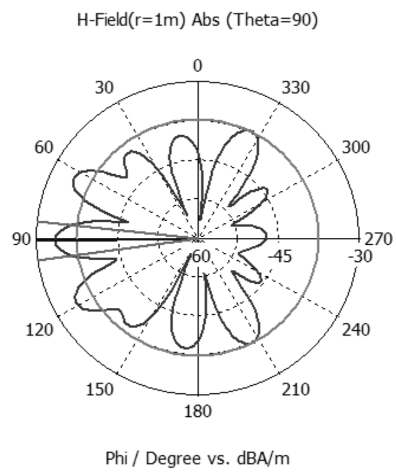

Figure 11(i). Simulated H-Field for Theta = 90°

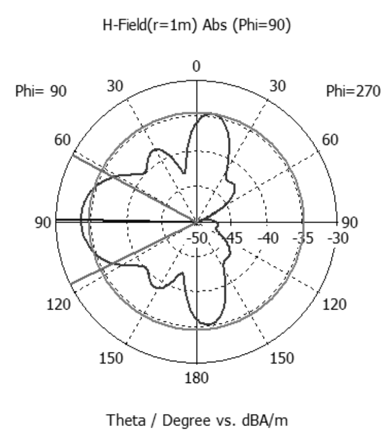

Figure 11(ii). Simulated E-Field for Phi = 90°

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The fabricated antenna is tested in the anechoic chamber and the radiation patterns for the E-Field and H-Field are plotted. The antenna exhibits good radiation pattern characteristics providing wide beam angle coverage with high gain of 6.09 dB at 6.83 GHz. The simulated radiation pattern with the tested pattern from the anechoic chamber shows the results are in good agreement. The tests are conducted in the anechoic chamber and the radiation plot from the chamber measurements are given in the figure 12(i) and figure 12(ii).

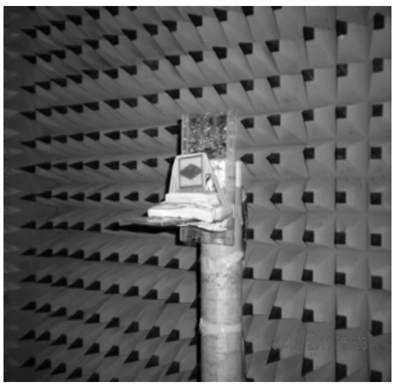

Figure 12(i). Anechoic Chamber Testing

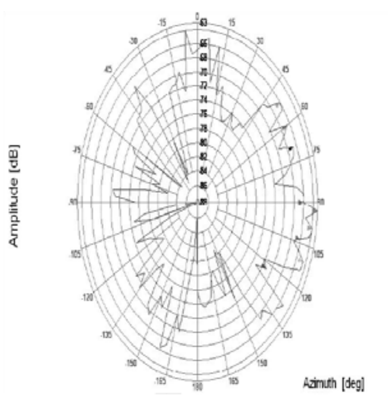

Figure 12(ii). Radiation Pattern Measured from Anechoic Chamber

4. CONCLUSION

The antenna has been designed with a novel diamond shaped patch antenna structure with reduced ground plane. The reduced ground plane makes the antenna flexible to be fixed on any surfaces without creating adverse effects on radiation characteristics. The antenna operates with a multiband frequency making it most suitable for the wireless applications of US first generation multiband-UWB systems which operate in part of the group A band of frequencies (3.1 GHz – 4.9 GHz) and also covers the spectrum allocated to group B (4.9 GHz – 6.0 GHz) and group C (6.0 GHz – 8.1 GHz) UWB devices. The antenna operating band ranges from 2.5 GHz to 7.8 GHz covering the applications Wi-Max (4.9 GHz Home Security Band), WLAN (802.11n,ac-2.4/5 GHz band), and Satellite frequency (4 GHz - 8 GHz C-band). The antenna has achieved good impedance matching at 6.83 GHz with S_{11} value of -31.26 dB and achieves a peak gain of 6.09 dB. The antenna has achieved a gain of above 2 dB in the entire band of operation. The antenna radiation pattern is well controlled by the reduced ground plane with reduced side lobe levels in all the bands. The S_{11} characteristics can be further improved using the EBG substrate or defected ground plane designs.

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