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# Design of Compact Multiband Antenna for S/C/X-band Applications

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**Abstract:** In this paper a Ω-shaped slotted Microstrip patch antenna having asymmetric U-shaped slot on reduced ground is presented. The antenna is designed using High Frequency Structural Simulator (HFSS) software. This antenna is designed for S-band, C-band and X-band applications. The proposed antenna is dual polarized multiband antenna. The proposed antenna is designed using FR4-epoxy substrate having permittivity 4.4. This material is selected as it has considerable mechanical strength and near zero water absorption. In this paper effect of variation of material, effect of height variation of substrate is also shown. Overall it is compact in size and has shown better results in terms of return loss, gain and VSWR.

**Index Terms:** Microstrip patch, HFSS, compact antenna, FR4-epoxy, multiband, s/c/x-band.

## I. INTRODUCTION

As a huge growth in wireless communication has taken place, the demand for multiband antennas has also risen up. This demand has risen up due to their support for different set of standards like one antenna can operate at various frequency bands. They support various wireless applications like WLAN, Wi-Fi, WiMAX, satellite communication etc. As their supporting standards and demand has risen, their compactness of size has always become a challenge for industry and researchers. In case of compactness, Microstrip antenna has always an edge over other antenna types. Because they can be easily fabricated on single printed circuit board integrated with other components. Other advantages like inexpensiveness, low profile, weighing comparatively little and low volume of Microstrip antenna also provide an edge over other antennas. These features attract researchers as an appealing area for research in the epoch of multiband. There is a demand of that type of antennas which has minimum multipath distortion and is insensitive to orientation of device. These types of antenna have high demand in RADAR communication, remote sensing and some other wireless systems. These antennas are circularly polarized. Polarization plays an important role. There are various types of polarization like linearly, circularly and vertical. Linearly polarized multiband antenna with all frequency bands are shown in [1,2].

But these have smaller impedance bandwidth. To obtain circular polarization various techniques like slits and truncated corners on patch, fractal geometry, inverting L-shaped slot on ground plan are used [3]-[6].It is found that fractal geometry antenna has very small impedance bandwidth and the size is also not compact than the proposed one. To get dual band circular polarization patch with asymmetric slits is used, but it has also limited application use because of smaller bandwidth [7].

Another method to achieve the same is use of an asymmetric U-shaped slot to be embedded on patch which is used by Tong KF et al [8]. But the problem with this is larger size and narrow bandwidth. In order to get dual polarization that is circular as well as linear polarization, there are various methods like using asymmetric trapezoidal shaped slot on patch [9] and using a ring slot with V-shaped slit and stub on patch [10].

The proposed antenna consists of a Ω-shaped slot embedded on patch, Microstrip feed, reduced ground having an asymmetric U-slot embedded on it. The designed antenna is made using FR4 substrate having dielectric constant 4.4 having properties like strong mechanical strength, near zero water absorption and have use as an electrical insulator.

## II. ANTENNA DESIGN

The geometry of antenna is as represented in figure 2.1. The size of antenna is 35mm x 30mm having 1.6mm thickness. The patch is embedded using a Ω-slot and rectangular stubs on it. The size of patch is 16mm x 18mm having four stubs, two horizontally as well as vertically. The size of stubs is 4mm x 2mm. The feed technique is strip line feed. The size showed that it is quiet compact.

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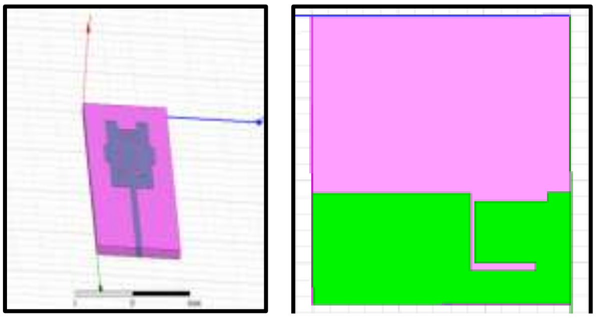

Figure 2.1 proposed antenna

Initial design image of antenna is shown in figure below 2.2.

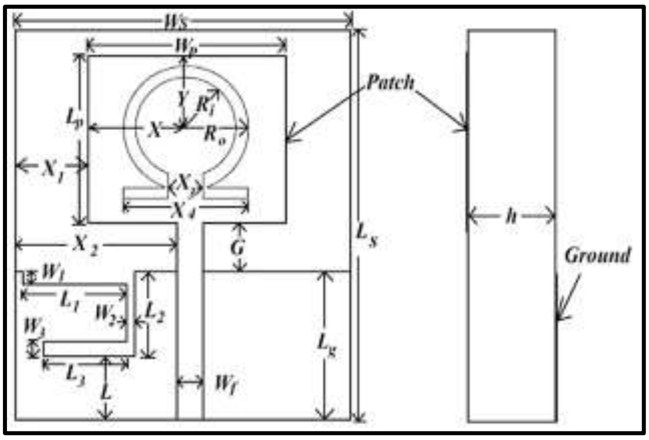

Figure 2.2 base antenna[11]

To convert base antenna into proposed modified antenna, four rectangular stubs having dimensions 4mm x 2mm are inserted. These stubs are inserted to get enhanced gain and bandwidth. The dimensions of modified proposed patch are shown in table 2.1

Table 2.1 parameters of patch

| Patch parameter | dimension |
|---|---|
| Width of patch | 14 |
| Length of patch | 14 |
| Length of stub | 4 |
| Width of stub | 2 |

Table 2.2 dimensions of antenna parameters

| parameters | Dimensions (mm) | parameters | Dimensions (mm) |
|---|---|---|---|
| $w_s$ | 30 | $L_1$ | 8.5 |
| $w_p$ | 14 | $L_2$ | 8.5 |
| $L_s$ | 35 | $L_3$ | 7.7 |
| $L_p$ | 14 | $X_1$ | 8.5 |
| $L_g$ | 13.5 | $X_2$ | 14 |
| $w_f$ | 2 | $X_3$ | 4 |
| $w_1$ | 1 | $X_4$ | 11 |
| $w_2$ | 0.5 | X | 7 |
| $w_3$ | 1 | Y | 6 |
| h | 1.6 | $R_i$ | 4.5 |
| G | 1.5 | $R_o$ | 5 |

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The base antenna resonates for 2.21-2.39 GHz, 2.81-2.93 GHz, 3.34-4.19 GHz, 5.52-7.03, 7.03-8.56 GHz. The resonant frequency for base antenna is 5.8 GHz. The results shown in terms of return loss show that bandwidth is much smaller and gain is also less. Maximum gain is 6.56dB.

## III. RESULTS AND DISCUSSION

The designed antenna is simulated using high frequency structural simulator (HFSS). The results are represented in terms of return loss, VSWR, gain, directivity etc. They are shown below in following figures.

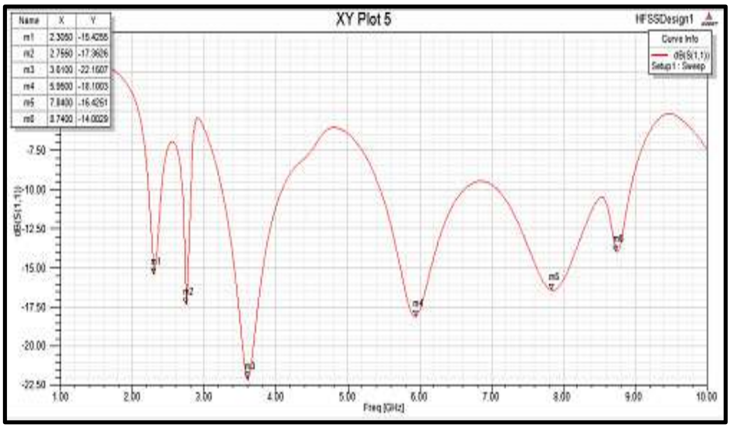

Figure 3.1 Return loss

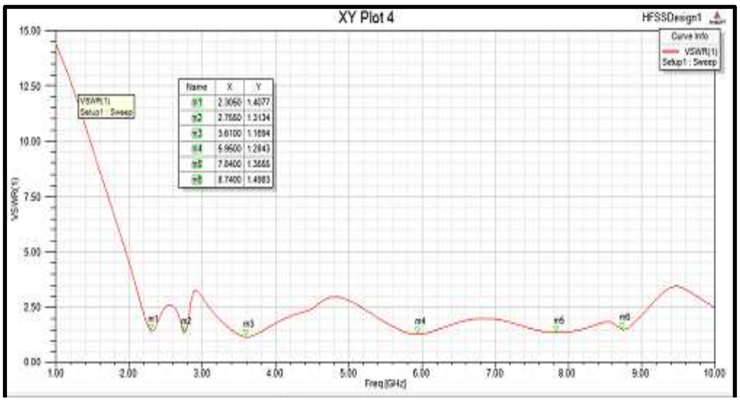

Figure 3.2 VSWR

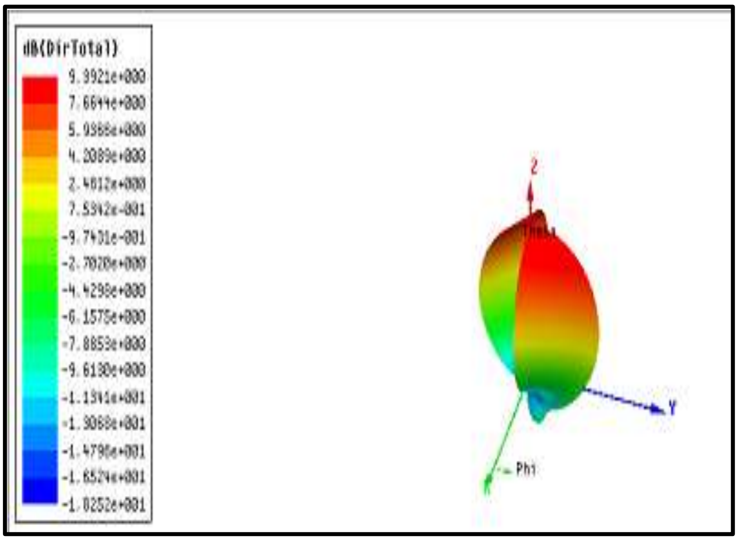

Figure 3.3Directivity at 5.95 dB

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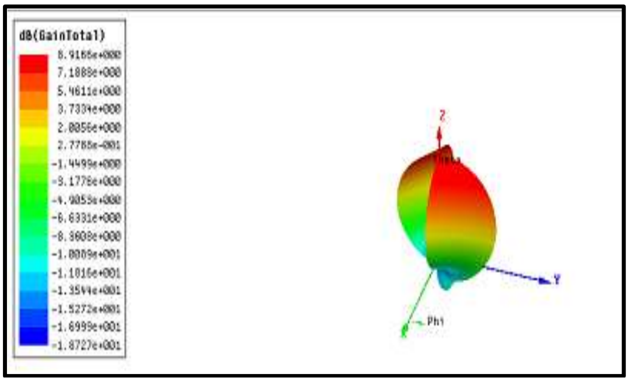

Figure 3.4Gain at 5.95dB

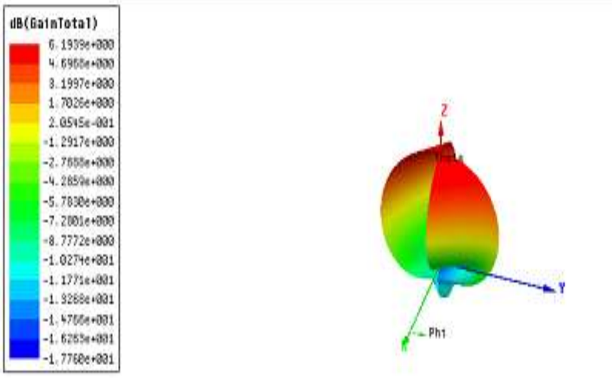

Figure3.5 Gain at 3.61 GHz

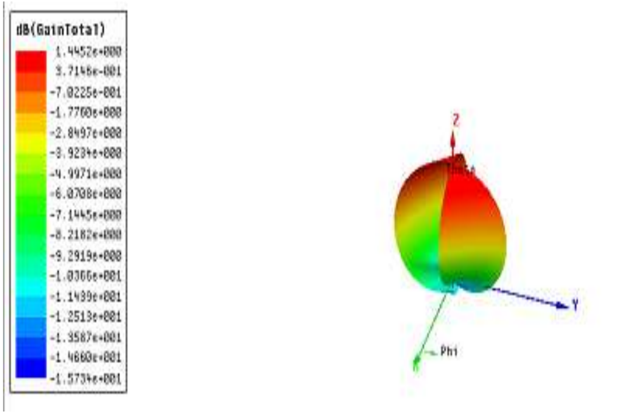

Figure3.6 Gain at 2.75 GHz

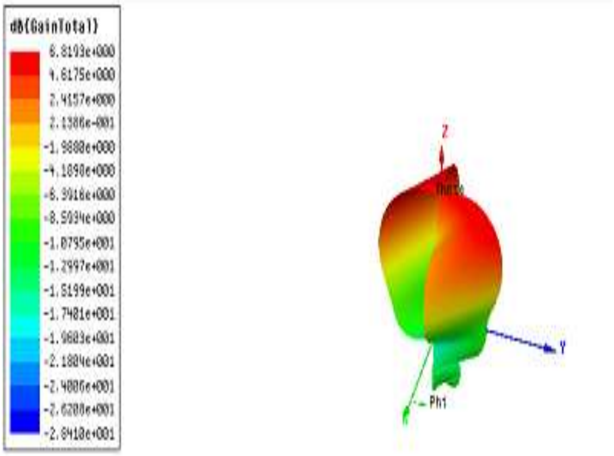

Figure3.7 Gain at 7.84 GHz

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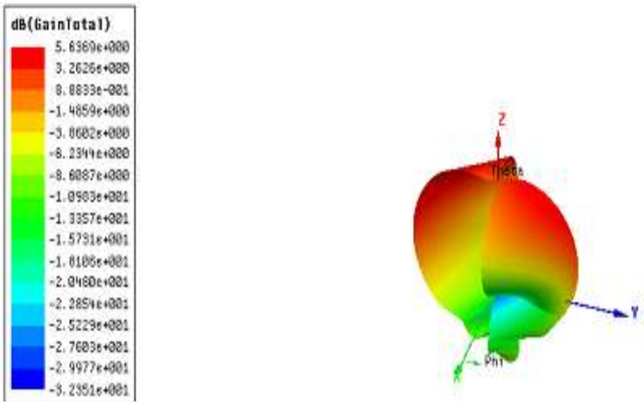

Figure 3.8 gain at 8.74 GHz

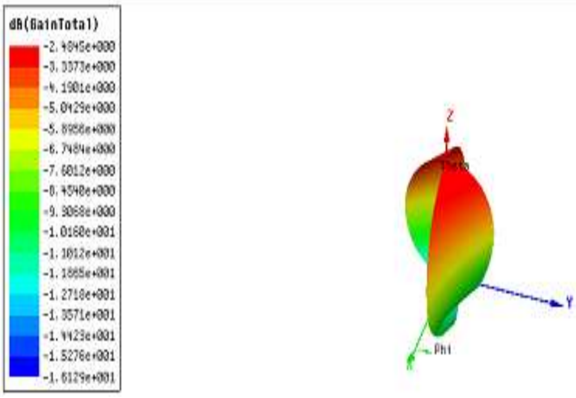

Figure3.9 gain at 2.305GHz

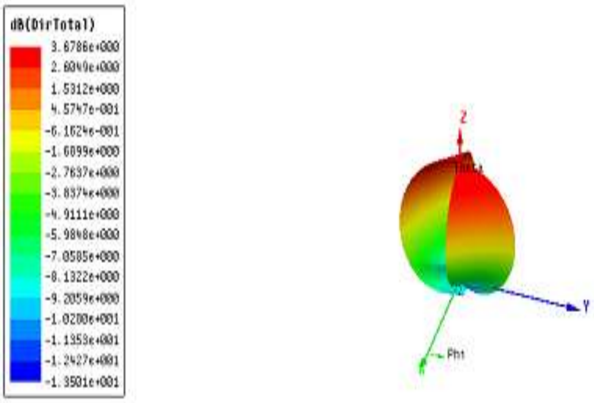

Figure3.10 Directivity at 2.75GHz

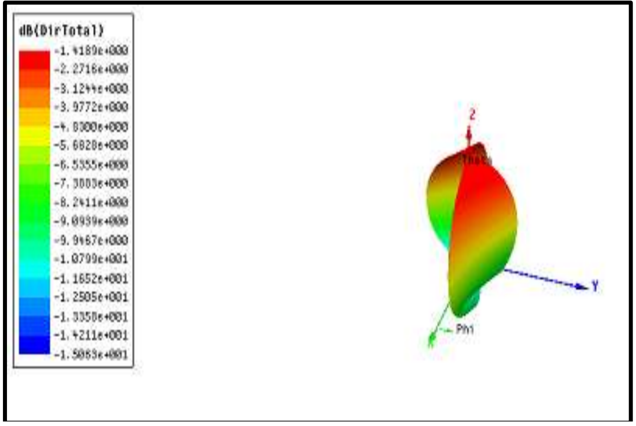

Figure3.11 Directivity at 2.305 GHz

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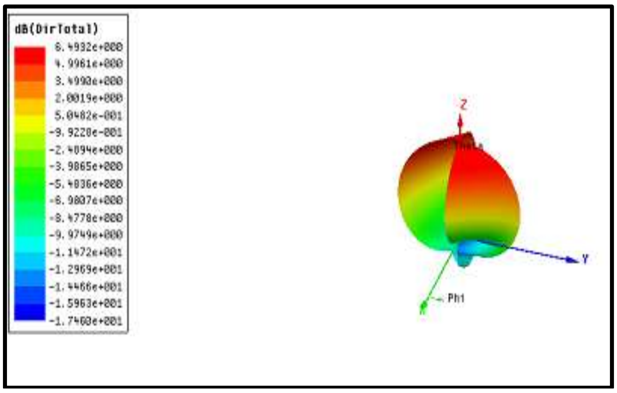

Figure3.12 directivity at 3.61GHz

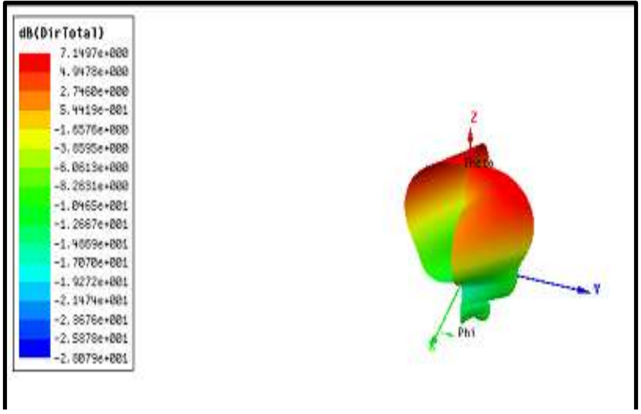

Figure3.13 Directivity at 7.84GHz

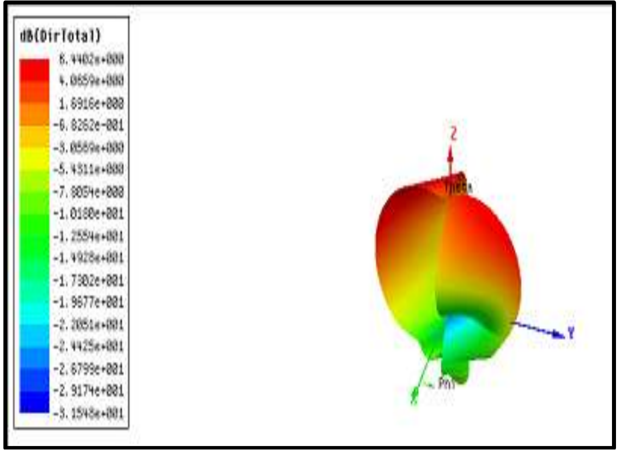

Figure3.14 Directivity at 8.74 GHz

From above mentioned figures, it is shown that the proposed antenna has better results in terms of return loss, VSWR, gain, directivity. In case of return loss, the antenna resonates for 2.23-2.40 GHz, 2.71-2.76, 3.25-4.00, 5.45-6.61, 7.08-8.92 GHz. The maximum gain for this is 8.91 dB which is quiet high compared to basic Microstrip antenna.

Table 3.1 resonant frequency and results in terms of antenna parameters

| Frequency (GHz) | Return loss (dB) | VSWR | Gain (dB) | Directivity (dB) |
|---|---|---|---|---|
| 2.305 | -15.42 | 1.40 | -2.484 | -1.418 |
| 2.75 | -17.36 | 1.31 | 1.445 | 3.678 |
| 3.61 | -22.15 | 1.16 | 6.193 | 6.493 |
| 5.95 | -18.10 | 1.28 | 8.916 | 9.392 |
| 7.84 | -16.42 | 1.35 | 6.819 | 7.149 |
| 8.74 | -14.00 | 1.49 | 5.656 | 6.440 |

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The value of VSWR for all resonating frequency band is less than 2 which is the basic requirement for Microstrip antenna. The directivity at resonating frequency 5.95 GHz is 9.39dB. The bandwidth range for resonating bands is 170 MHz, 750MHz, 1.16 GHz, 1.84 GHz, which is quiet high. The results in terms of return loss, VSWR, gain, directivity, and bandwidth are compiled in tabular form.

The proposed antenna resonates for 2.23-2.40, 2.71-2.79, 3.25-4.00, 5.45-6.61, 7.08-8.92 GHz (covering two frequencies 7.84GHz and 8.74GHz) frequency band. The represented frequency band shows that the proposed antenna is applicable in military radar communication by US military, Weather surveillance radar, WiMAX, C-band Satellite communication, air and sea surveillance target acquisition, point to point communication, ATC and military training applications, and radiolocation satellite.

## IV. COMPARISION OF ANTENNA WITH SUBSTRATE HAVING DIFFERENT MATERIALS

The basic issue while designing an antenna comes for selection of appropriate material for substrate. There are various materials having good characteristics are available in market for designing a good Microstrip patch antenna. In this paper, the effect of different substrate materials having different permittivity is shown. It is found that when dielectric constant changes, the bandwidth, return loss, gain also changes. It is found that when there is decrease in dielectric constant of material, there is increase in gain, bandwidth and directivity and decrease in return loss. It shows that to enhance gain and bandwidth and better return loss the dielectric constant of antenna should be low. The materials and their effect on antenna parameters are shown in tabular form.

### 4.1ROGERS DUROID/RT 5880 (tm) HAVING DIELECTRIC CONSTANT 2.2

Rogers Duroid, product of Rogers Corporation, having dielectric constant 2.2 has lowest electrical loss, low moisture absorption and excellent chemical resistance makes it useful for Microstrip and strip line circuits.

The effect of this substrate material on Microstrip antenna is shown in tabular form.

Table 4.1 Rogers Duroid 5880 with dielectric constant =2.2

| frequency | Return loss | VSWR | gain | bandwidth | directivity |
|---|---|---|---|---|---|
| 2.755 | -23.43 | 1.14 | 2.68 | 220 MHz | 2.196 |
| 4.285 | -37.05 | 1.02 | 8.11 | 1 GHz | 7.984 |
| 7.345 | -30.46 | 1.06 | 9.68 | 1.35 GHz | 9.879 |

### 4.2 GIL/GML 1000 (tm) HAVING DIELECTRIC CONSTANT 3.12

GML/GIL is a substrate material having best mechanical as well as electrical properties. When it comes to dielectric constant, it remains stable in every environment whether humid or dries one. This material is specifically best in case of cost performance and suitable for high frequency antenna. Its effect on antenna parameters is mentioned below.

Table 4.2 GIL/GML 1000 with dielectric constant =3.12

| Frequency | Return loss | VSWR | Gain | Bandwidth | Directivity |
|---|---|---|---|---|---|
| 3.07 | -10.60 | 1.83 | 3.89 | 80 MHz | 4.877 |
| 3.88 | -24.80 | 1.12 | 7.25 | 830 MHz | 7.190 |
| 6.58 | -19.90 | 1.22 | 9.62 | 1.35GHz | 9.605 |
| 9.23 | -19.38 | 1.24 | 7.68 | 1.93GHz | 7.185 |

### 4.3 EPOXY_KEVLAR_XY HAVING DIELECTRIC CONSTANT 3.6

This material has low dielectric constant as well as moisture content. Its loss tangent is also low. Its impact on antenna parameters is compiled in table form.

Table 4.3 epoxy_Kevlar_xy with dielectric constant =3.6

| Frequency | Return loss | VSWR | Gain | Bandwidth | directivity |
|---|---|---|---|---|---|
| 3.79 | -22.04 | 1.17 | 7.079 | 800 MHz | 6.910 |
| 6.31 | -19.15 | 1.24 | 9.566 | 1.15 GHz | 9.488 |
| 8.65 | -20.21 | 1.21 | 7.17 | 1.70 GHz | 6.797 |

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## V. EFFECT OF THICKNESS OF SUBSTRATE ON ANTENNA

Thickness of substrate material is another important factor while designing an antenna. It is an important task to select an appropriate thickness of substrate. Before selecting an appropriate thickness, it is mandatory for designer to know the effect of thickness of substrate on antenna parameters. In this paper, four various thicknesses of substrate and its effect on antenna parameters are shown. The selected material is FR4_epoxy. The selected thickness for FR4-epoxy is h=1.6, 1.3, 1, and 0.8mm. The impact of thickness variation is compiled in following tables.

### 5.1 WHEN h=1.6mm

Table 5.1 antenna parameters for h=1.6mm

| Frequency (GHz) | Return loss | VSWR | Gain (dB) | Directivity (dB) |
|---|---|---|---|---|
| 2.75 | -17.36 | 1.31 | 1.445 | 3.678 |
| 3.61 | -22.15 | 1.16 | 6.193 | 6.493 |
| 5.95 | -18.10 | 1.28 | 8.916 | 9.392 |
| 7.84 | -16.42 | 1.35 | 6.819 | 7.149 |
| 8.74 | -14.00 | 1.49 | 5.656 | 6.440 |

### 5.2 WHEN h=1.3mm

Table 5.2 Antenna parameters for h=1.3

| Frequency | Return loss | VSWR | Gain | Directivity |
|---|---|---|---|---|
| 2.89 | -25.81 | 1.10 | 2.81 | 4.60 |
| 3.52 | -16.75 | 1.33 | 6.11 | 6.42 |
| 6.08 | -18.48 | 1.27 | 9.02 | 9.47 |
| 7.84 | -11.35 | 1.74 | 7.52 | 7.77 |

### 5.3 WHEN h=1mm

Table 5.3 Antenna parameters for h=1mm

| Frequency | Return loss | VSWR | Gain | Directivity |
|---|---|---|---|---|
| 2.845 | -23.10 | 1.15 | 2.878 | 4.035 |
| 3.29 | -17.22 | 1.31 | 5.259 | 5.550 |
| 6.40 | -22.15 | 1.16 | 9.092 | 9.454 |

### 5.4 WHEN h=0.8mm

Table 5.4 Antenna parameters for h=0.8mm

| Frequency | Return loss | VSWR | Gain | Directivity |
|---|---|---|---|---|
| 2.80 | -12.27 | 1.64 | 3.29 | 3.295 |
| 3.20 | -25.63 | 1.11 | 5.28 | 5.07 |
| 6.67 | -35.34 | 1.06 | 9.12 | 9.42 |

From above mentioned results, it is found that when thickness of antenna decreases, bandwidth as well as return loss improves but antenna resonates away from the operating frequency.

## VI. CONCLUSION

In this paper, a compact in size, dual polarized, Microstrip fed multiband Microstrip patch antenna having reduced ground and slotted patch is presented for S, C, and X-band applications. It is found that this antenna is also useful for US military applications like target acquisition, weather radar and satellite communications. The proposed antenna designed using FR4-epoxy substrate is also being compared with various substrate materials like Rogers Duroid 5880,

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GIL/GML 1000, and epoxy_Kevlar_xy and with antenna having varied substrate thickness. After comparison it is found that proposed antenna is multiband while others are tri-band antennas and it has wider bandwidth and it is good for better return loss and gain.

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