Experimental analysis of simple and low cost three band (C-band, Ku-band and K-band) compact patch antenna

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Abstract— **This paper presents a simple, low cost compact microstrip antenna, which works in triple frequency band. This compact microstrip antenna realized by changing the geometric shape, obtained by inserting a vertical slot. The simulation has been performed by simulation software GEMS version 7.71.01 and using Taconic TLY-5 dielectric substrate with relative permittivity 2.2 and height 1.588mm. The simulated return losses are obtained -21dB, -23.67dB and -9.859dB at 7.7GHz, 16.2GHz and 22GHz respectively. Therefore, this antenna can be applicable for C-band, Ku-band and K-band applications respectively.**

Keywords- ***Triple band patch antenna, slotted rectangular patch, compact patch, C-band patch, Ku-band patch.***

I. INTRODUCTION

Microstrip antennas are also referred to as patch antennas. The radiating elements and the feed lines are usually photo etched on the dielectric substrate. The radiating patch may be square, rectangular, thin strip, circular, elliptical, triangular etc. [1].

A microstrip antenna could be made compact through number of methods. Some of the methods involve the use of a shorting pin, while others involve geometrical modification [2].

With the rapid growth of the wireless communication system the future technologies need a very small and multiband antenna. Nowadays, people demand multiband wireless phone supporting more than one network, having different frequencies and simultaneous transmission of audio, video and data. These services are possible with the help of microstrip patch antenna having multiband characteristics. Modern wireless communication system also requires low profile, light weight, high gain, ease of installation, high efficiency, simple in structure to assure reliability and mobility characteristics. Microstrip antennas satisfy such requirements. The key features of a microstrip antenna are low profile, relative ease of construction, low weight, comfortable to planar and non-planar surfaces, low cost, simple and inexpensive to manufacture by using printed circuit board. These advantages of microstrip antennas make them popular in many wireless communication applications such as satellite communication, radar, medical applications, aircraft, spacecraft, and missile applications [3, 4, 5]. Many researchers have designed a single element patch in different way to gate multiband application such as double PIFA [6], U-slot [7], double U slot, E slot, H slot and other structures.

We know that C-band Ku-band and K-band are worked at 2-4GHz, 12-18GHz and 18-27GHz respectively [8].

In this paper the antenna is designed to support 7.7GHz and 16.2GHz and 22GHz frequencies. So, this antenna is able to meet the demand of C-band, Ku-band and K-band applications. This frequency can be changed by varying the antenna size. And simulation has been done by simulation software GEMS simulator version 7.71.01. Here the substrate with height 1.588mm, Taconic TLY-5 dielectric substrate with permittivity 2.2 is used.

II. RECTANGULAR PATCH DESIGN

Microstrip antenna consists of a thin film with different shape such as rectangular or circular or triangular etc. This strip of thin film placed on ground plane where the thickness of the metallic strip is restricted by $t \ll \lambda_0$ and height is restricted by $0.000\lambda_0 \leq h \leq \lambda_0$ [8, 9]. In this paper we designed each array using rectangular patch. For a rectangular patch, the length L of the element is usually $\lambda_0/3 < L < \lambda_0/2$. There are numerous substrates that can be used for the design of microstrip antennas and their dielectric constants are usually in the range of $2.2 \leq \varepsilon_r \leq 12$ [9, 10]. The performance of the microstrip antenna depends on its dimension. Depending on the dimension the operating frequency, radiation efficiency, directivity, return loss and other related parameter are also influenced [11].

For an efficient radiation a practical width of the rectangular patch element becomes [9, 10, 11].

$$w = \frac{1}{2r_f\sqrt{\mu_0\varepsilon_0}} \times \sqrt{\frac{2}{\varepsilon_0 + 1}} \quad (1)$$

And the length of the antenna becomes [9, 10, 11]

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{eff}}\sqrt{\varepsilon_0\mu_0}} - 2\Delta L \quad (2)$$

Where,

$$\Delta L = 0.41h\frac{\varepsilon_{eff} + 0.3}{\varepsilon_{eff} - 0.259} \times \frac{(\frac{w}{h} + 0.245)}{(\frac{w}{h} + 0.3)} \quad (3)$$

And,

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2\sqrt{1 + 12\frac{h}{w}}} \quad (4)$$

Where, λ is the wave length, f_r (in Hz) is the resonant frequency, L and W are the length and width of the patch element in mm, respectively and ε_r is the relative dielectric constant. Fig.1 shows a rectangular patch antenna where, l_{qw} = Length of quarter wave transformer, W_{qw} = Width of quarter wave transformer, l_{50} = Length of 50Ω probe, w_{qw} = Width of 50Ω probe.

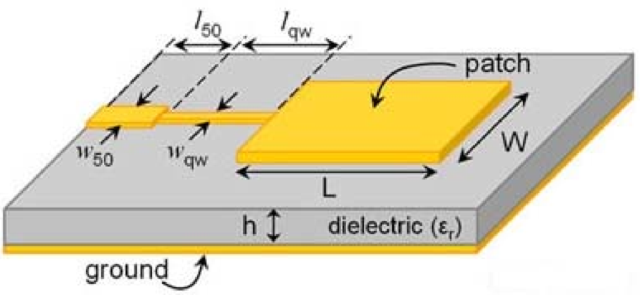

Fig. 1: Rectangular patch antenna

III. DESIGN OF PROPOSED ANTENNA

Fig. 2 shows the proposed compact microstrip patch antenna. Here the antenna is obtained by inserting a vertical slot of 9.6mm length and 1mm width in the middle position of the theoretically obtained antenna. The theoretical antenna dimension is 14.8×11.6mm^2. Length and width of this theoretical antenna is calculated using equation (1) and (2) respectively. Then 9.6×11.6 mm^2 slot is inserted into the rectangular patch to create a compact patch antenna. This simple compact patch antenna is operated in three bands.

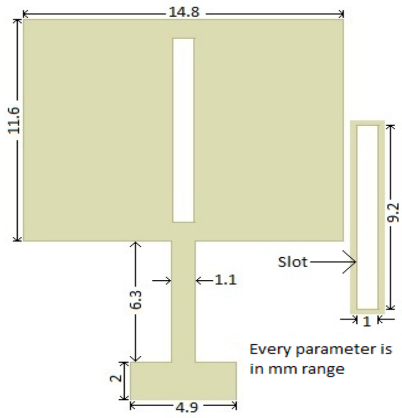

Fig. 2: Proposed compact microstrip patch antenna

IV. SIMULATION RESULT AND DISCUSSION

The simulation results of return loss, directivity and radiation pattern at 7.7GHz, 16.2GHz and 22GHz for compact patch antenna are shown below.

The simulated compact patch antenna is operating at 7.7GHz and 16.2 GHz and 22GHz. The corresponding return loss are -21dB, 23.67dB and -9.859dB respectively and are shown in Fig.3. The -10dB bandwidth is obtained 0.315GHz for C-band, 1.123GHz for Ku-band and nil for K-band respectively. The directivity at 7.7GHz, 16.2GHz and 22GHz are 7.80dB, 7.15dB and 5.9dB respectively and are shown in Fig.4. The gain at 7.7GHz, 16.2GHz and 22GHz are 7.76dBi, 6.1dBi and 4.9dBi respectively. The radiation pattern at 7.7GHz, 16.2GHz and 22GHz are shown in Fig. 5, Fig. 6 and Fig. 7 respectively. Now the all simulated graph are shown below.

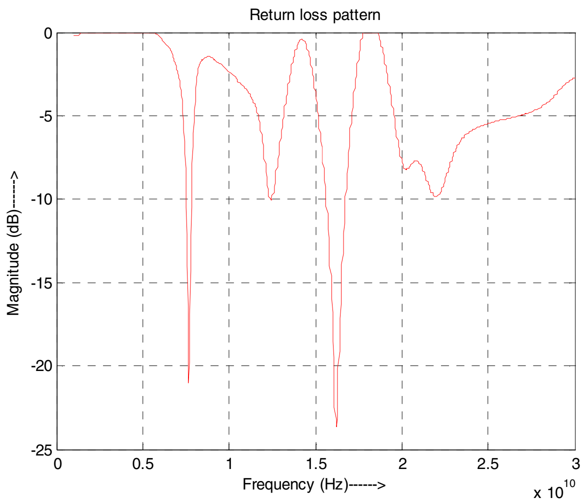

Fig. 3: Return loss pattern for compact patch antenna.

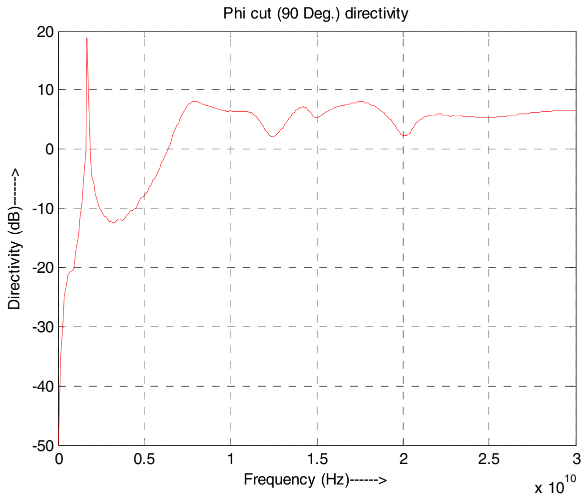

Fig. 4: Phi cut (90^0) directivity pattern for compact patch.

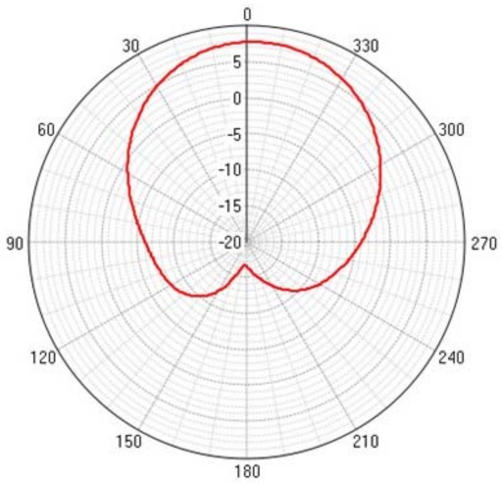

Fig. 5: Radiation Pattern (polar) at 7.7GHz

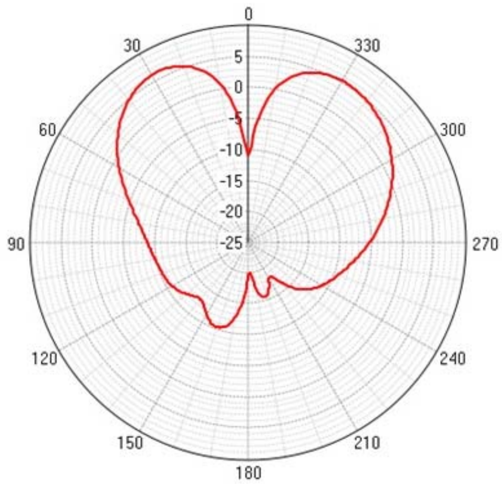

Fig. 6: Radiation pattern (polar) for 16.2GHz

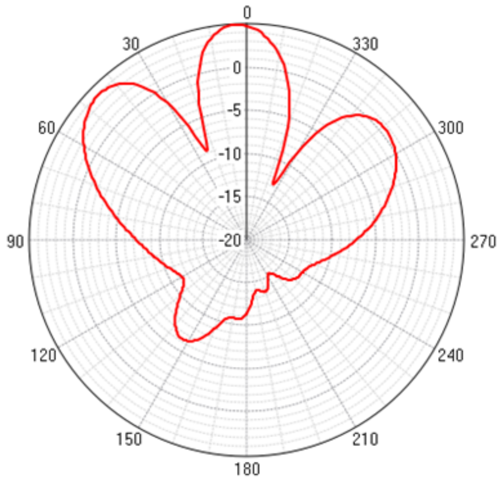

Fig. 7: Radiation pattern (polar) for 22GHz

After observing the performance analysis graph and pattern of compact patch antenna the obtained results are tabulated below for better analysis.

Table 1: Simulation results for compact patch at 7.7GHz and 16.2GHz and 22GHz

Performance parameter	Unit	Compact patch antenna		
		For 7.7GHz (C-band)	For 16.2GHz (Ku-band)	For 22GHz (K-band)
Simulated return loss	dB	-21	-23.67	-9.859
Directivity	dB	7.80	7.15	5.9
-3dB bandwidth	GHz	0.964	2.407	10.37
-10dB bandwidth	GHz	0.315	1.123	nil
Gain	dBi	7.76	6.1	4.9
Radiated power	mW	473.5	1106	1239

The corresponding tabulated result is shown in figure 8. Here the x axis, y axis and z axis represent operating frequency, return loss and simulated gain respectively.

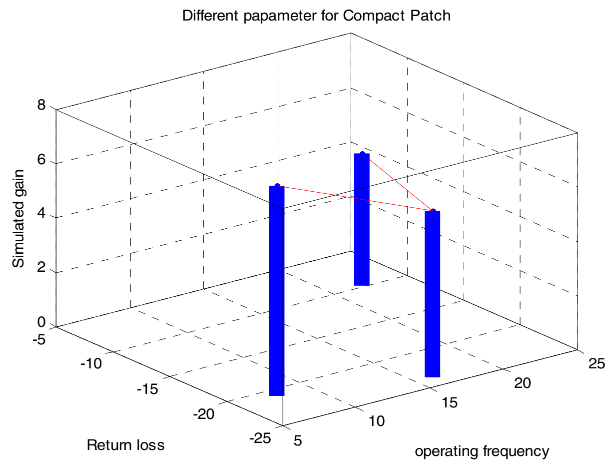

Fig.8: Different parameter value of compact patch antenna.

After investigation of the above graphs and tabulated results we can reach the following decision-

- ✓ Here we get three maximum return losses -21dB, -23.67dB and -9.859dB at 7.7GHz, 16.2GHz and 22GHz respectively. We know the range for X-band is 2GHz to 12GHz and for Ku-band is 12GHz to 18GHz. So the antenna proposed in this paper is operated in X-band and Ku-band.

- ✓ -10dB bandwidth at C-band is 0.315GHz and at Ku-band is 1.123GHz, but not found in K-band. Here the bandwidth is not narrower for C-band and Ku-band they can be applied in wideband applications. The main disadvantage of any patch antenna is narrow bandwidth; this is not happening for this proposed antenna designed in the case of C-band applications and Ku-band applications except K-band applications.

IV. CONCLUSION

This paper demonstrates a compact patch antenna inserting a slot that is operated in three bands such as C-band, Ku-Band and K-Band respectively. Using GEMS solver version 7.71.01 and Taconic TLY-5 dielectric substrate with relative permittivity 2.2 and height 1.588mm simulation has been achieved. The proposed compact antenna operate C-band, Ku-band and K-band with return loss -21dB, -23.67dB and -9.859db respectively.

This paper present a compact antenna which is covered the application of C-band, Ku-band and K-band. Here the C-band is mainly used in satellite TV channel, satellite navigation etc. The Ku-band is primary used for editing and broadcasting of satellite television, satellite Internet etc. The K-band is used primarily for radar, satellite communications, astronomical observations etc.

In future we will try to improve the return loss and try to get more than -10dB bandwidth for K-band. Using this simple compact patch we will design different types of array such as series feed array, corporate feed array or corporate-series feed array to get higher directivity and higher gain.

Here designed antenna is covered C-band, Ku-band and K-band operating frequency, but it is possible to design for other system such as WLAN, WiMAX, other X band etc. applications by changing the antenna size.

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