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U-Slot Dual Band Aperture Coupled Microstrip Antenna for WLAN And WiMAX Applications

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Abstract : *Microstrip antennas are very cheap and their cost of fabrication is also very less. Most of the wireless communication systems are based on these antennas. Though it has many advantages, there is one drawback which is narrow bandwidth. Aperture coupling technique helps to improve this bandwidth upto some extent. Therefore, this technique has been used in the design which is demonstrated in this paper. Here the substrates used in aperture feeding have thickness of 1.57mm. This antenna has bandwidth of 74.5 MHz at 3.62 GHz frequency and 111 MHz at 5.772 GHz frequency. Both these operating frequencies have application in WLAN and WiMAX bands. The simulation is done using CST 2010 software.*

I. INTRODUCTION

Nowadays, in mobile communication systems, the requirement of small sized antenna for miniaturisation purpose of mobile units has been increased. Hence, reduced size and enhanced bandwidth are the major considerations in microstrip antennas for practical applications. Therefore, study regarding small size and enhanced bandwidth of microstrip antenna has been greatly increased. In the past few years, great progress in the design of small sized microstrip antenna with dual and circular polarisation, dual frequency, broadband and gain enhanced performance has been reported [1]. The proposal of microstrip antenna was launched in 1950's but it gained importance in 1970's and was used in various applications at that time. After 1970 large number of authors explained the radiations coming from the ground plane with the dielectric substrate for different designs of antenna. Howell [2] and Munson [3] developed the first antenna which was practical antenna. Munson showed that the microstrip antenna was a practical antenna to be used in various antenna system problems by using it in missiles and rockets as a flush mounted low profile antenna. For this antenna mathematical model was developed and its applications were enhanced in many other fields. Microstrip antenna consists of a conducting patch on upper side of dielectric substrate and a ground plane on the lower side of dielectric substrate. The material of patch is copper or gold and the patch can have any shape such as rectangular and circular etc. On the dielectric substrate the feedline and the patch are photo etched. The length of the patch is usually between 0.3333 λ_0 < L< 0.5 λ_0, where λ_0 is the wavelength in free- space. The thin patch is selected where t is the thickness of the patch. The h is the height of the dielectric substrate and is usually between 0.003 $\lambda_0 \leq h \leq 0.05\ \lambda_0$. The dielectric constant (ϵ_r) of the substrate has range typically between $2.2 \leq \epsilon_r \leq 12$.

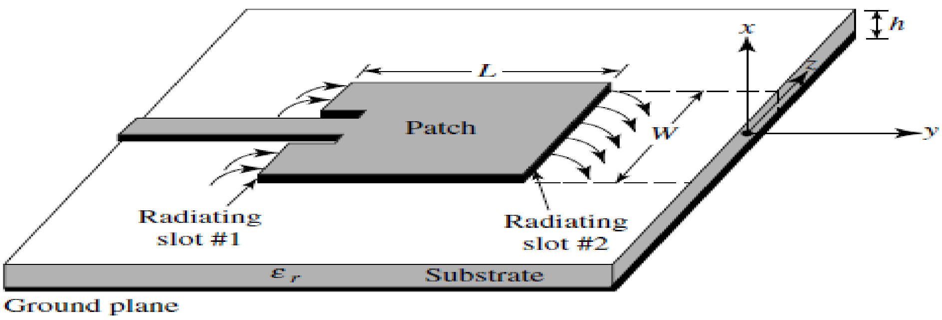

Fig 1 Structure of Micro-Strip Patch Antenna [1]

Mathematical Model Of Microstrip Patch Antenna

Mathematical model help us to find the various dimensions of the antenna according to resonant frequency of separation and the mathematical model of microstrip patch antenna is as discussed below:

Transmission Line Model

Transmission line model is used to describe the mathematics behind working of MSA. This has an advantage of being simple but lacks versatility in some cases.

Effect of Fringing

According to transmission line model, along the length and width, the dimensions of patch are finite and therefore at the edges of the patch the fields undergo fringing. The quantity of fringing is basically the function of the height of the substrate and the patch dimensions. For E-plane fringing are basically the function of the substrate's dielectric constant ϵ_r and the length of the patch to the height of the substrate ratio. Since L/h>1, fringing is reduced for microstrip antennas; as it influences antenna's resonant frequency and it should be considered.

Waves are moving in both substrate and air. Due to this the dielectric constant is not considered but effective dielectric constant of material is considered for fringing effects and wave propagation. The effective dielectric constant is calculated by the formula which is as given below in equation (1.1). [1]

$$\frac{W}{h} > 1$$

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \quad (1.1)$$

2.3 Effective Length, Resonant Frequency, and Effective Width

Due to fringing effects, the patch of the antenna looks electrically greater than the physical dimensions of the patch. A practical and very popular relation for extension of length is

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (1.2)$$

$$L_{eff} = L + 2\Delta L$$

The resonant frequency of microstrip patch antenna is as given below

$$(frc)_{010} = \frac{1}{2L_{eff}\sqrt{\epsilon_{reff}}\sqrt{\mu_0 \epsilon_0}} \quad (1.3)$$

The values of length and width of the patch is given by

$$W = \frac{1}{2f_r\sqrt{\mu_0 \epsilon_0}}\sqrt{\frac{2}{\epsilon_r + 1}} = \frac{\upsilon_0}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}} \quad (1.4)$$

$$L = \frac{1}{2f_r\sqrt{\epsilon_{reff}}\sqrt{\mu_0 \epsilon_0}} - 2\Delta L \quad (1.5)$$

This model is related to only those ground planes which are infinite. For practical considerations, it is necessary that there should be a finite ground plane. It is found that for both infinite and finite ground planes same results can be obtained if the dimensions of the ground is greater than the patch dimensions by nearly six times the thickness of the substrate all around periphery[4]same. Therefore, the length and width of ground is given

$$L_g = 6h + L \quad (1.6)$$

$$W_g = 6h + W \quad (1.7)$$

Where
h= thickness of the substrate
L = Length of the patch
W= Width of the patch
L_{eff} = Effective length
C= speed of light which is $3X10^8$ m/sec
ϵ_r = relative permittivity
ϵ_{reff} = effective permittivity
L_g= Length of ground
W_g= Width of ground

II. VARIOUS FEEDING TECHNIQUES OF MICROSTRIP ANTENNAS

There are various techniques of feeding microstrip antennas. These techniques are classified into two categories one is contacting and the other is non-contacting. In the first technique, the RF power is fed to the patch directly using a joining element like microstrip line. In the second technique, electromagnetic coupling is done between the radiating patch and microstrip line to transfer the power [4]. There are four feeding techniques which are used. Out of them two are contacting, one is called microstrip feed line and other is called coaxial probe and other two are non-contacting called proximity coupling and aperture coupling. In the thesis below

Aperture Coupled technique is followed for antenna design because it has less spurious feed radiations and large bandwidth.

Table 1.1 Reason of choosing aperture coupled feeding technique

Characteristics	Microstrip Feed line	Coaxial Feed	Aperture Coupled Feed	Proximity Coupled Feed
Spurious feed radiation	More	More	Less	More
Reliability	Better	Poor due to Soldering	Good	Good
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth	2-5 %	2-5 %	13 %	21 %

Due to good reliability, ease in impedance matching and more spurious radiation, aperture coupled technique is used. This technique has better bandwidth in comparison to Microstrip line and Coaxial coupled feeding techniques [5]. Higher Bandwidth is achieved in Aperture Coupled Feeding technique.

III. IMPROVEMENT IN BANDWIDTH USING AN APERTURE COUPLED DESIGN

- Coupling level of antenna and bandwidth are greatly affected by substrate thickness. A thick substrate has less coupling for a given aperture size, but wider bandwidth.
- The back radiation level and the coupling level are determined by slot length. Therefore, for good impedance matching the slot should not be larger.
- When the length of patch is increased the resonant frequency tends to move towards the lower band and when the length of patch is decreased the resonant frequency tends to move towards upper band. Maximum coupling will be obtained when the patch will be in the centre.
- The major drawback of microstrip antennas is narrow bandwidth. It can be improved by using the technique of stack patches. Stack patches also remove back radiation level. In stacked patches parasitic element is placed above the lower patch. Lower patch has generally constant size. The dimensions of the upper patch, slot and foam spacer can be optimised to obtain wide bandwidth characteristics. But the best bandwidth is obtained when the dimensions of top patch is equal to that of bottom patch [7]. Therefore, it must be taken into consideration that patches must have same dimensions in order to maximise coupling and the resonance of each patch must be far apart in frequency [8].

IV. DUAL BAND OR MULTIBAND BEHAVIOUR OF APERTURE COUPLED MICROSTRIP ANTENNA USING DGS

- A novel structure called Defected Ground Structure is widely used in several applications such as reducing the size of patch antennas without degrading the performance of antenna as better as efficiency, better bandwidth etc. DGS has alsoapplication of suppression of harmonics without introducing attenuation in the fundamental frequency[6]
- By varying the dimensions of U-shaped slot antenna, E-shaped slot and length of matching stub 1.e. Ls, the antenna can be designed to obtain high gain and dual band or quad band characteristics[9]
- For multiband applications, a series of curved microstrip antenna with DGS, which are smaller, with wider radiation beam are suitable for WLAN applications in different environments. The Defected Ground Structure in the ground plane of the microstrip patch antenna are used to achieve small size, multiband and high gain[10].

V. DESIGN OF DUAL BAND APERTURE COUPLED MICROSTRIP ANTENNA WITH U-SLOT

In this design U-slot is cut in the patch and ground and dual band is obtained. Various parameters of the antenna are as shown below:

Antenna Design

The design of the antenna is as shown below. U-slot is cut in the ground plane as well as on the patch. The antenna is resonating at two frequencies 3.62 GHz and 5.77 GHz. The stub is also used in this antenna. Stub is used for the matching purpose. The higher return loss shows that the impedance matching is good. The values of length and width of patch are calculated using Transmission line model as discussed above.

(a)Perspective view (b)Front view (c)Back view

Fig.2. Different views of Antenna

Table 1.2 Antenna Dimensions

Dielectric constant of the material	4.4
Width of ground	40mm
Length of ground	32mm
Width of patch	22mm
Length of patch	18mm
Thickness of the substrate	1.57mm

Return Loss and Bandwidth

Fig. 3 has return loss (S_{11}) -40 dB and -14 dB for the designed antenna operating at 3.62 GHz and 5.772 GHz. The coupling will be more if the return loss will be more negative and this shows that the matching is good. The gain and directivity of the antenna will be more in a particular direction and this is what needed for WLAN and WiMAX. This antenna has bandwidth of 74.5 MHz at 3.62 GHz and 111 MHz at 5.772 GHz.

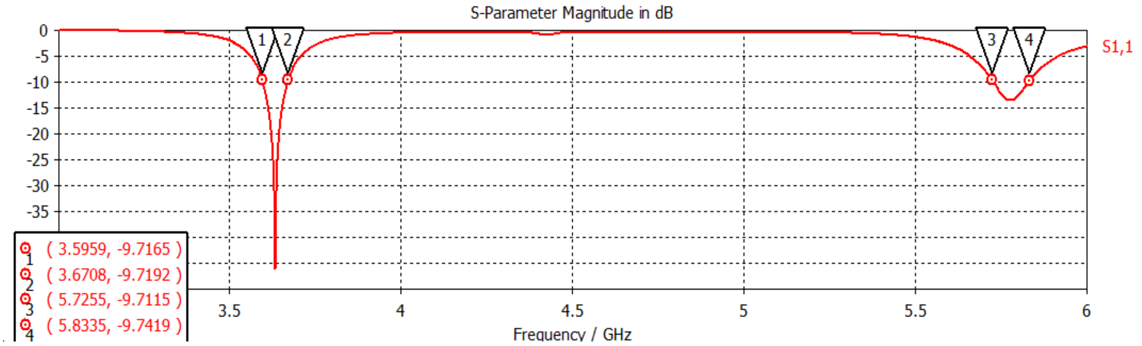

Fig. 3 Return Loss S11 (in dB)

Smith Chart

The Smith Chart shown below has two circles. These two circles are obtained because it is a dual band antenna. In Smith chart the upper part is inductive and lower part is capacitive and centre circles are constant resistance circles. The impedance is complex in case of Smith Chart. The lower circle (1, 2) belongs to lower frequency band and upper circle (3, 4) belongs to 5.8 GHz band.

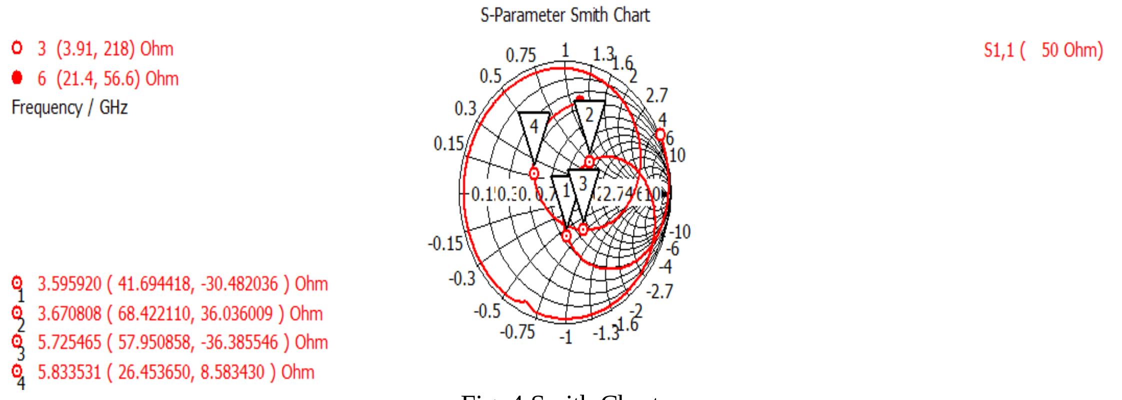

Fig. 4 Smith Chart

Directivity

The 2D and 3D plot of directivity is as shown in Fig. 5 which is representing the amount of radiation intensity and in this case it is equal to 6.035 dBi for 3.62 GHz. The value of directivity should be greater than 5 dBi and it is satisfying in this case. This antenna is directional and operating in one particular direction in comparison to the antenna which radiates equally in all the directions like isotropic antenna. This value of directivity has application in WiMAX and WLAN bands.

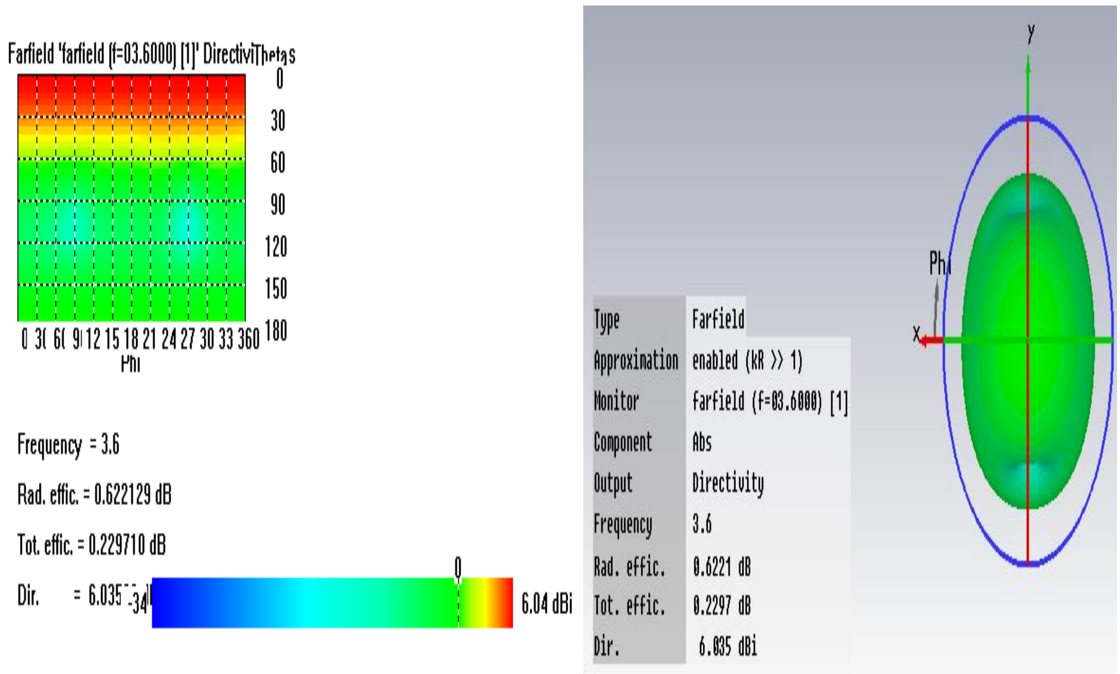

Fig 5 Directivity (2D and 3D view) at 3.6 GHz

Gain

The radiation pattern of gain at 3.62 GHz is shown in Fig. 6. The radiation pattern shown below is omnidirectional and the main lobe is directed at 359 degree angle. The angular beam width obtained is 89.9 degree and the main lobe magnitude is 6.7 dB.

In Fig. 7 the 3D view of gain at 5.772 GHz is discussed. In this design the gain comes out to be 6.388 dBi. The gain obtained in this design is more than the isotropic antenna which radiates in all directions equally. This antenna is more directional therefore it has applications in WLAN and WiMAX applications.

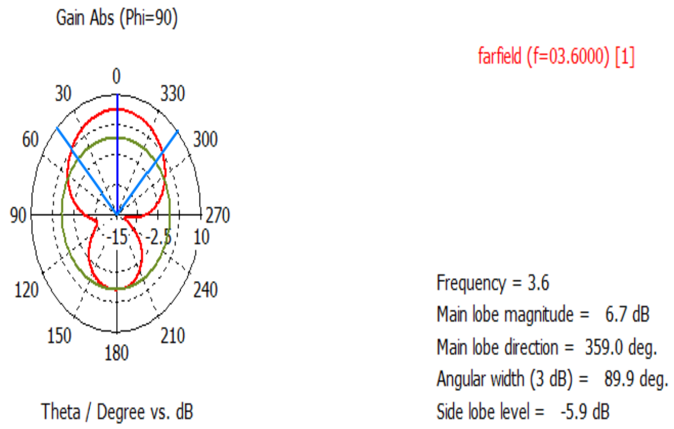

Fig. 6 Radiation pattern of Gain at 3.6 GHz

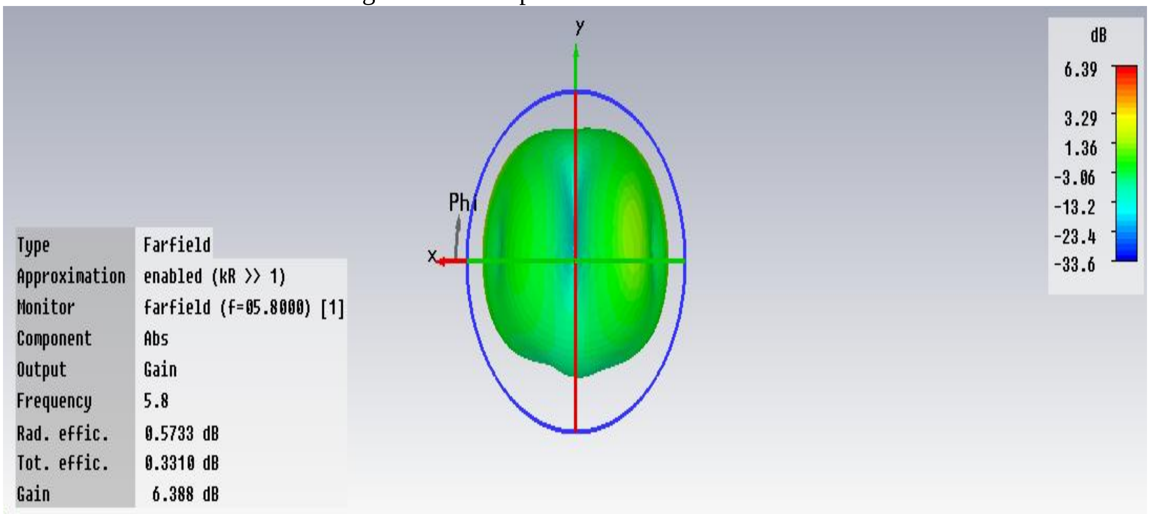

Fig. 7 Gain (3D view) at 5.8 GHz

Surface Current

The surface current at both the resonating frequencies are shown. The current is maximum at the centre of the patch and at the edges of the rectangular slot as shown in Fig. 8 and 9 by the red arrows. Basically the current intensity is shown by the current distribution. The current should be maximum at the centre of the patch and minimum at edges which are as obtained in this case. The lower resonant frequency is due to the slot which has been cut in the ground and upper resonant frequency is due to patch.

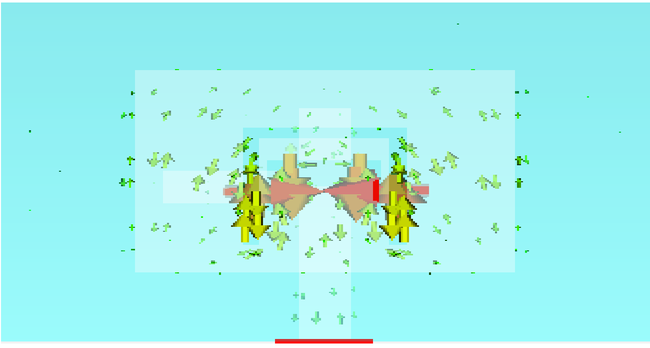

Fig. 8 Current Distribution at 3.6 GHz

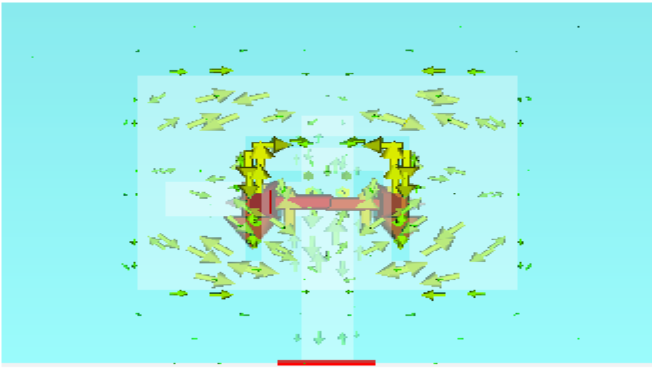

Fig. 9 Current Distribution at 5.8 GHz

VI. Conclusion

In this above design U-slot is cut in the ground as well as on the patch. The dimensions of the slot, ground, patch etc. are calculated using transmission line model as discussed in chapter (using equations (1.1), (1.4), (1.7), (1.8)). The antenna is resonating at 3.62 GHz and 5.772 GHz. The bandwidth, VSWR and other parameters shows good results. Due to U-slot which is cut in the patch, the dual band is obtained. The Smith chart has also two circles showing that it is a dual band antenna. This antenna has applications in WiMAX and WLAN bands respectively.

References

[1] Constantine A. Balanis , "Antenna theory Analysis and Design", 2nd edition, John Wiley and Sons, 2009.
[2] Howell, J. Q., "Microstrip Antennas", IEEE AP-S int. Symp. Digest pp 177-180, 1972.
[3] Munson, R.E., "Conformal Microstrip antennas and Microstrip phased arrays", IEEE transaction on antennas and propagation, vol-AP22, pp74- 78, 1974.
[4] S K Behera, "Novel Tuned Rectangular Patch Antenna As a Load for Phase Power Combining" PhD Thesis, Jadavpur University, Kolkata.
[5] Ramesh Garg, Prakash Bharti, Inder Bahl, "Microstrip Antenna Design Handbook", Artech House, Boston London.
[6] Awasthi Y.K. ;Singh Himanshu, and Verma A.K. (2008): "Microstrip Patch Antenna with the Defected Ground Structure and Defected Microstrip Structure" proceedings of International Confrence on Microwave.
[7] Clarke B; Chuhaci M. and Ittipiboon A. (1990): "Slot-Coupled Stacked Microstrip Antennas"IEEE.
[8] Targonski S.D. and Waterhouse R.B. (1996): "An aperture coupled stacked patch antenna with 50 % bandwidth" IEEE. suppression with photonic bandgap and defected ground structure for a microstrip patch," IEEE microwave and wireless component letters, pp.1-2.
[9] Omid Hoseini Izadi and Mandana Mehrparvar (2010): "A Compact Microstrip Slot Antenna With Novel E-shaped Coupling Aperture", 5^{th} International Symposium on Telecommunication.
[10] JGeng J.P. *et al*. (2009): "The Developments of Curved Microstrip Antenna with Defected Ground Structure" Progress in Electromagnetics Research, PIER, Vol. 98, Pg No 53-73.