Design of Microstrip patch antenna with slotted ground and patch to support multiband applications

N.Nazeeya Anjum,

Department of Electronics and Communication Engineering
Sri Sairam Engineering College,Chennai,Tamilnadu,India.

Abstract - In this paper investigation have been carried out to design a printed monopole antenna which is basically a printed microstrip rectangular patch. The antenna has been designed and simulation work carried out which shows that the antenna is working effectively in triple band of frequency.The proposed antenna has capability to work in the range of 2.4GHz to 7 Ghz.The proposed antenna has a size of 41x44x1.6 mm^3.The antenna resonated at 2.4 GHz with a return loss of -20.481 dB and VSWR as 1.2198,at 5.338GHz with a return loss of -19.576dB and had a VSWR 1.2358 , at 6.91GHz it resonated with a returnloss of -40.376dB and had a VSWR of 1.1572.The substrate used here is commercially avialable subrate FR -4 (Flame resistant) which has a dielectric constant of 4.4 and loss tangent of 0.023.The Miniature size of the antenna makes it suitable for wireless applications.

Keywords: Patch Antenna, Slotted Patch , Slotted ground, Multi frequency , inset feed.

I INTRODUCTION

Patch antennas are widely used in modern wireless communication systems because of its inherent properties like light weight, high gain, low profile, low cost and ease of fabrication. An antenna which has a substrate with low dielectric constant provides better efficiency [4]. Since the impedance matching capability of the Microstrip feed line method is efficient in comparison to others it is used for feeding the patch antenna. The patch antennas mostly find their applications in satellite, radar, GPS and GSM communication systems [4]. Antennas capable of resonating at multiple frequencies not only provides low-cost and high data rate features but also serves as an effective integration of huge wireless communication standards [7]. Slots create some kind of discontinuity [5] in the electric current path leading to positive impact on input impedance thereby creating additional resonance frequencies. Surveys have reported that by cutting slots and slits in the radiating patch and ground plane, the operating frequency gets shifted and thereby increasing the resonating frequencies [5]. When a slot antenna is fed by a Microstrip line, it does not add weight and size to the system and is suitable for portable applications. Recently, printed planar slot antennas have become very attractive candidates for wireless systems due to their low profile, wide bandwidth, compact size, ease of fabrication [6]. Different structures of slots have been discussed in the open literature. Antennas can be designed to resonate at multiple frequencies by varying the feeding techniques, etching open-slots, circular slots, narrow rectangular slots, fractals etc.

II DESIGN METHODOLOGY OF PROPOSED ANTENNA

2.1 Steps to design a single Rectangular Micro strip Patch Antenna (RMSA):

The design of RMSA at a resonant frequency of 2.4GHz employs the following procedure .For an RMSA to be an efficient radiator, Wp should be taken equal to half the wavelength. The width of the patch is calculated as follows [1]

$$Wp = \frac{c}{2fr}\sqrt{\frac{2}{\varepsilon r+1}} \quad (1)$$

Where fr is the resonant frequency of the micro strip antenna (MSA), $c = 3 * 10^8$ m/sec and

εr = the relative dielectric constant of the substrate. In this design, Flame resistant (FR -4) substrate of relative permittivity of 4.4 and height h=1.6mm is used. The value of εeff is slightly less than εr because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air.

$$\varepsilon eff = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left\{1 - 12\frac{h}{Wp}\right\}^{-1/2} \textit{ for } Wp/h > 1 \quad (2)$$

Due to presence of the fringing fields at the two edges of the patch the dimensions of the patch vary, actually their length appears to be greater than its physical length thus the effective length of the RMSA is given by [1]

$$Leff = L + 2\Delta L = \frac{c}{2fr\sqrt{\varepsilon eff}} \quad (3)$$

A very practical approximate relation for the normalized extension of the length is given by [1]

$$\Delta L = (0.412 * h) * \frac{(\varepsilon eff+0.3)\left[\frac{Wp}{h}+0.264\right]}{(\varepsilon eff-0.258)\left[\frac{Wp}{h}+0.8\right]} \quad (4)$$

Where h is the thickness of the substrate and it is assumed to be much smaller than the dimensions of the antenna and Wp is the Width of the patch. The design is continued to match the antenna resistance to 50Ω of the input line. To obtain impedance matching with the Microstrip feed line, inset feeding technique is mostly used. The inset feed point is calculated as follows:

After calculation of the dimensions of the patch, the notch width or the gap of the feed is designed using the formula

$$g = \frac{c*fr*10^{-9}*4.65*10^{-9}}{\sqrt{2\varepsilon eff}} \quad (5)$$

The next step is to calculate the recessed distance of the feed " yo", length and width of the feed. The inset feed is used to match the characteristic impedance of transmission line i.e $Zo = 50\ \Omega$, According to [1]

$$Zo = Rin * \cos^2\left(\frac{\Pi}{Lp} * yo\right) \text{ and } Lf = \frac{\lambda g}{4} \text{ ; where } \lambda g = \frac{\lambda}{\sqrt{\varepsilon eff}} \quad (6)$$

The width (W_f) of the feed is found using the equation, According to [2]

$$Wf = \left(\frac{2h}{\Pi}\right) \text{ x } [B - 1 - \ln[2B-1] + \left(\frac{\varepsilon r-1}{2\varepsilon r}\right) * (\ln[B-1] + 0.39 - \frac{0.69}{\varepsilon r})] \quad (7)$$

for $\frac{Wf}{h} > 2$; where $B = 60\frac{\Pi^2}{Zo\sqrt{\varepsilon r}}$

Where, Z0 is usually chosen as 50 ohms, h and εr are fixed for a particular substrate.

The ground plane dimensions are calculated accordingly as,

Length of the ground plane $Lg = 6 * h + Lp$ and (8)

Width of the ground plane $Wg = 6 * h + Wp$ (9)

2.2 Structural Description of the proposed antenna

A rectangular patch is designed to resonate at a particular frequency initially. A rectangular slot is made in the thin patch and resonating effect of the antenna varies. A parametric study was carried out by varying the slot dimensions and positions. A slot was also cut in the ground and through parametrically varying the slot length, width and position, the time domain and frequency domain analysis were studied by simulating the antenna using CST Microwave Studio software. The return loss, VSWR and far field patterns of the antenna were obtained.

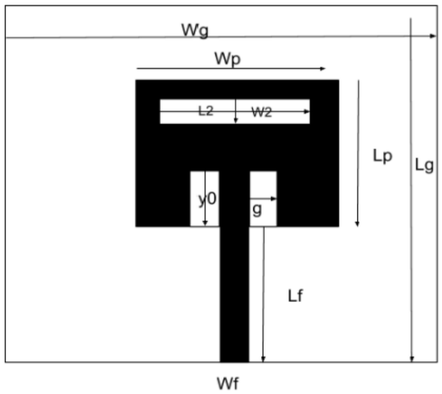

Figure 1: Geometry of Patch

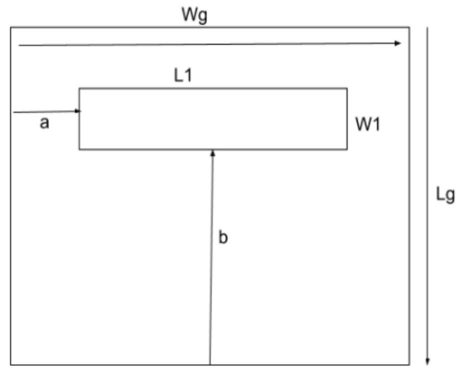

Figure 2: Geometry of the Ground

2.3 Design Specifications:

All the parameters of the antenna effect the performance of the antenna. For instance if the permittivity is increased the length decreases. Thus miniaturization of antenna can be achieved by increased permittivity, also the height of the substrate controls the bandwidth, when height of the substrate increases the bandwidth increases. Table 1 shows the specifications of the proposed antenna.

Table 1: Specifications of the proposed Antenna

Description of the Variable	**Value in mm**
Width of the ground (Wg)	44
Length of the ground (Lg)	41
Width of the patch (Wp)	26
Length of the patch (Lp)	21
Height of the ground & Patch (ht)	0.035
Substrate thickness (h)	1.6
Length of the feed (Lf)	10
Width of the feed (Wf)	2
Inset length (Y0)	5.2
Gap / Cut width (g)	1.5
patch slot length (L2)	20
Patch slot width (w2)	4.5
Ground slot length (L1)	22
Ground slot width (w1)	3.5
Position of the ground slot (a)	12
Position of the ground slot (b)	26
Position of the patch slot (m)	13

III PARAMETRIC STUDY OF THE MULTIBAND ANTENNA WITH SLOTTED GROUND AND PATCH

Performance of the Microstrip patch can be controlled by varying different parameters. An extensive study was carried out by varying feed length, width, gap, slot length, slot width and position etc relative to the slot. The optimal antenna resonated at three different frequencies. Parameters like return loss, VSWR and Radiation pattern were studied at these frequencies.

3.1 Structure of the Antenna

The proposed antenna was designed using CST MWS with the description as discussed in the specification table. The perspective view of the antenna is shown in the Figure 3 which shows the designed patch with slot and Figure 4 shows the slotted ground.

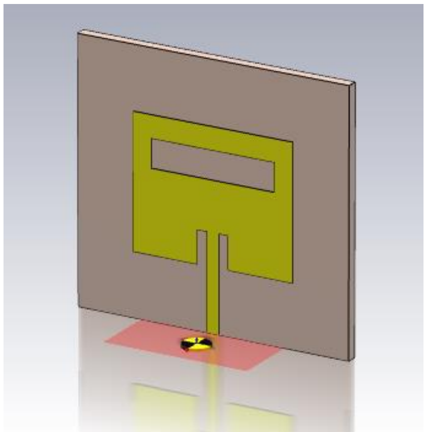

Figure 3: Perspective View of designed Antenna using CST MWS

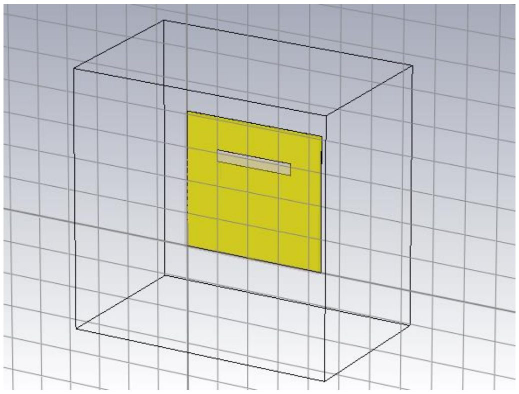

Figure 4: Perspective view of the Slotted ground of the Antenna

3.2 Return Loss S11:

The S11 plot shows that antenna resonated at three different frequencies. The Return Loss of the antenna was found to be -20.481 dB at 2.4583 GHz when it provided a return loss of -19.576 dB at 5.332 GHz and -40.376 dB at 6.9 GHz respectively. The return loss curve is shown in Figure 5.

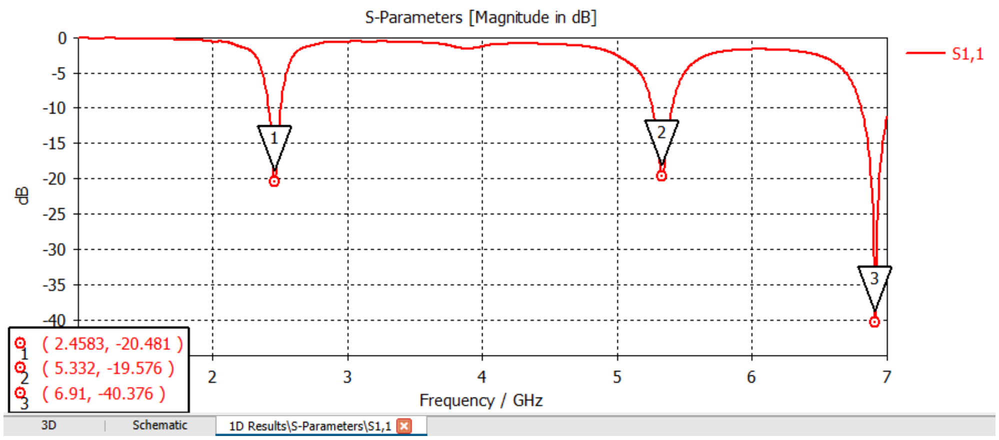

Figure 5: Antenna Return loss (S11) plot

3.3 Voltage Standing Wave Ratio (VSWR):

The proposed antenna had excellent standing waves rejection and its response at three different frequencies were analysed. The ideal value of VSWR for any good antenna should not exceed 2. If it is below 1.5 then the antennas radiation properties would be good. The proposed antenna marked a VSWR of 1.2198 at 2.452 GHz. The same antenna reflected a VSWR value of 1.2358 at 5.3328 GHz and 1.1572 at 6.93 GHz as shown in the Figure 6. This shows that the antenna works good at all these three frequencies hence can be utilized as a multiband antenna.

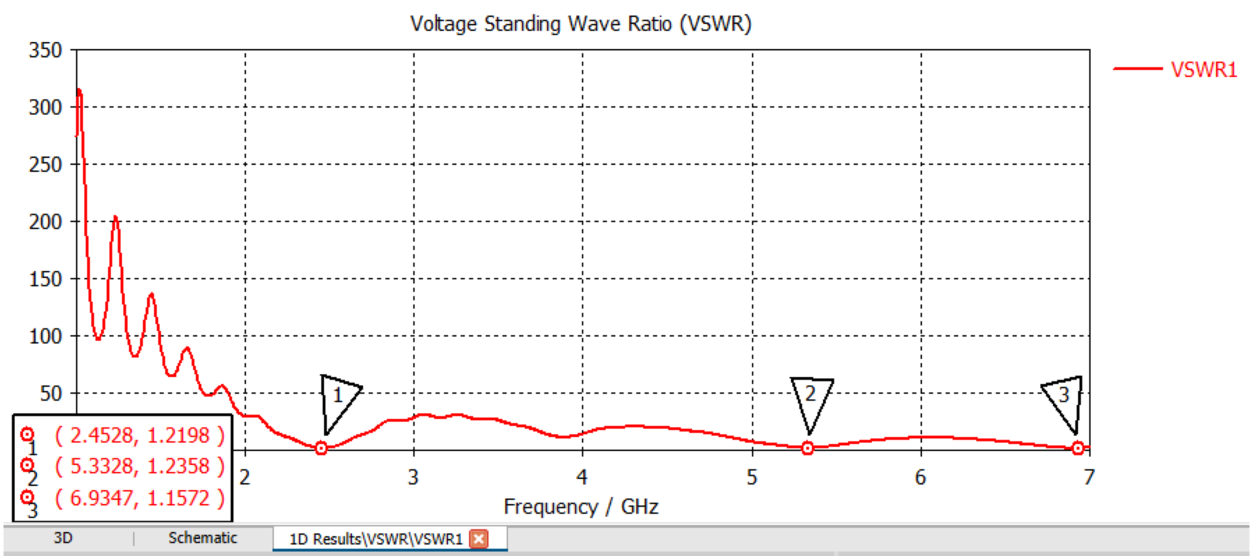

Figure 6: The VSWR plot of the proposed antenna

3.4 Radiation Pattern:

The antenna performance is seen to cover a wider range of frequency. It shows a directivity of 4.65dBi at 2.455 GHz, a directivity of 5.75 dBi is seen at 5.338 GHz while the directivity is 4.4 dBi at 6.93 GHz. The 3D Radiation pattern at various frequency are shown in Figures 7 - 9 and 1D radiation pattern namely the polar plot can be analysed from Figure10.

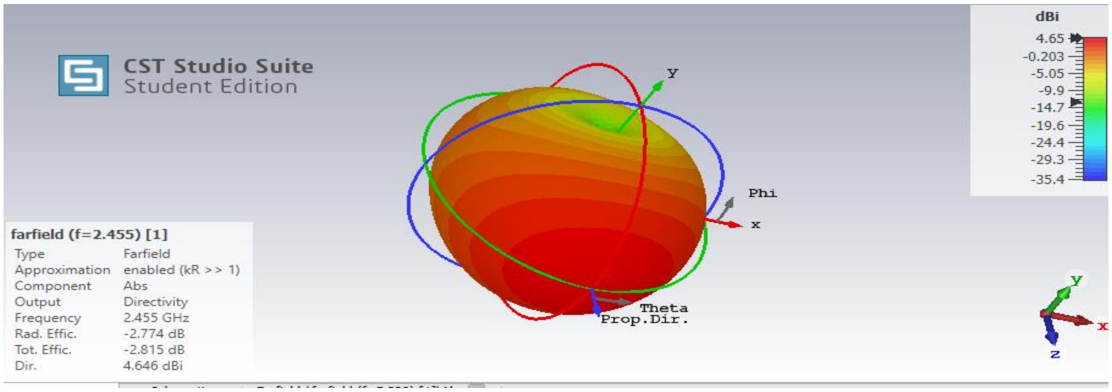

Figure 7: Radiation Pattern at 2.455 GHz, with Directivity 4.65 dBi

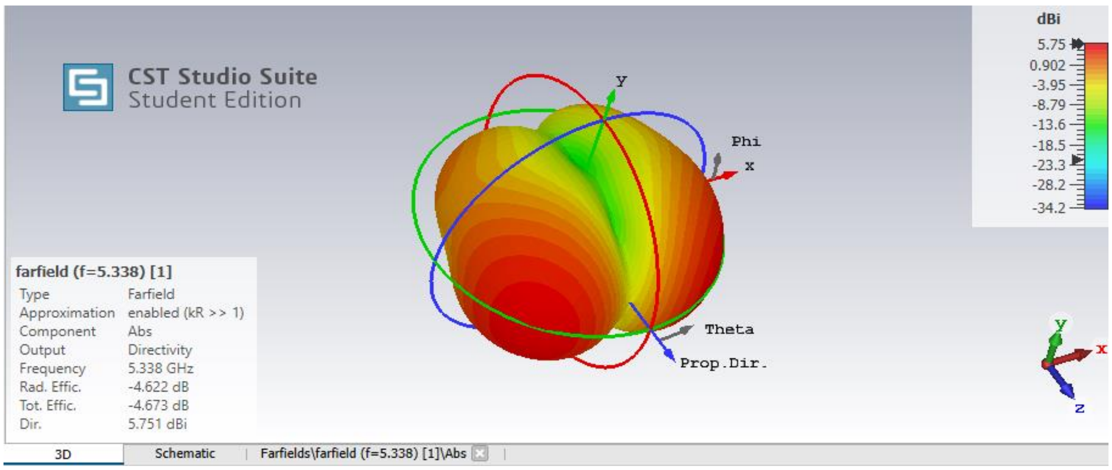

Figure 8: Radiation Pattern at 5.338 GHz, with Directivity 5.75 dBi

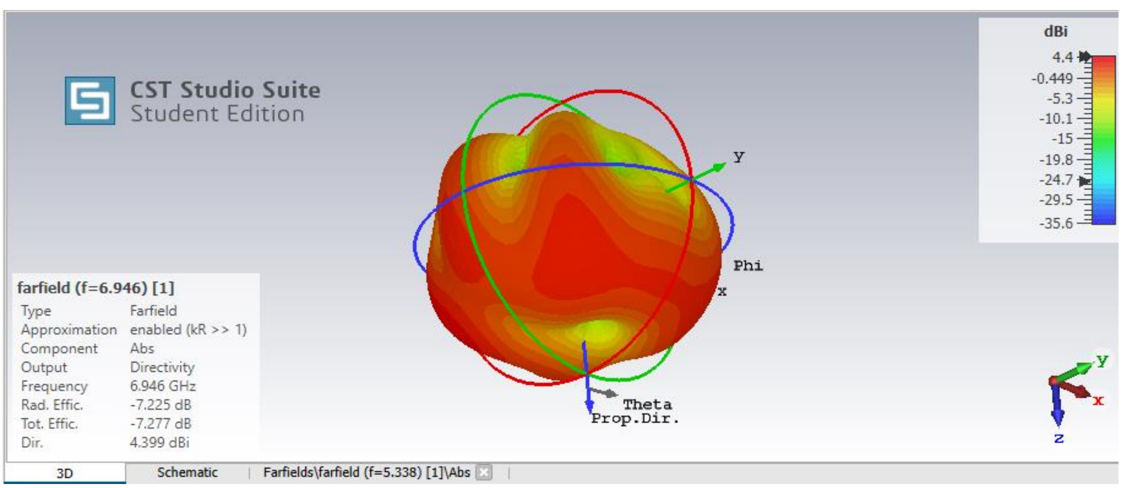

Figure 9: Radiation Pattern at 6.946 GHz, with Directivity 4.4 dBi

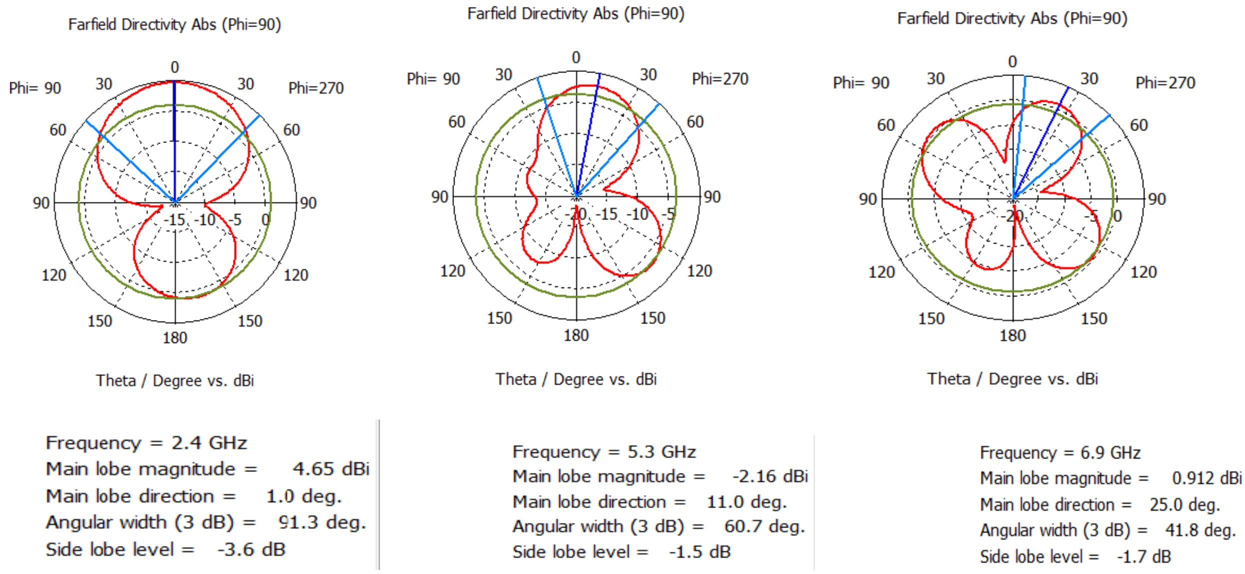

Figure 10: Polar plots of proposed antenna at frequencies 2.4 GHz,5.3 GHz and 6.9 GHz

IV CONCLUSION

The proposed Microstrip antenna with slotted patch and ground has resonated at three different frequencies, hence this antenna can be utilized to work in 2.45 GHz i.e IEEE802.11b/g/n where many applications like microwave ovens, Two way radios , mobiles Wireless LANs, TV broadcast etc works.It has also resonated at 5.3 GHz i.e IEEE 802.11b/ac where in radars and Commercial LANs find applications.The antenna performs well at 6.93GHz too which are in SHF range. Thus it could be concluded that the antenna could be used for multiband of frequencies serving multiple applications.It has been seen that the antenna has shown a Return Loss of -20.481 dB at 2.4583 GHz when it provided a return loss of -19.576 dB at 5.332 GHz and -40.376 dB at 6.9 GHz respectively. The VSWR at all these frequencies was found to be less than 1.5.The parametric study shows that the slots created in patch and ground introduces some discontinuty in the radiation path there by making the antenna to resonate at multiple frequencies. Optimal performance can be achieved by controlling various parameters in the antenna viz slot height , width and position respectively with reference to the patch dimensions. Also studies could be extended for different substrates with increased permitivity which will help in miniaturization of the antenna.

REFERENCES:

[1] Constantine A. Balanis, *"Antenna Theory: Analysis and Design," John Wiley & Sons, 2013, 3rd Edition.*

[2] David M. Pozar D, "Microwave Engineering", *John Wiley & Sons, 2012, 4th Edition.*

[3] CST Microwave Studio Suite 2006B, *CST Inc., 2007.*

[4] A.Swathy, N.Nazeeya Anjum, *"Design of Micro strip Patch Antenna for 2.45 GHz Wireless Applications", Journal of Recent Research in Engineering and Technology – JRRET, April 2015*

[5] Jayarengini N and Unni C, *"Hexagonal shaped Microstrip patch antenna for satellite and Military applications", International journal of Engineering and Advanced technology-IJEAT, June 2018.*

[6] WeiXing Liu, YinZeng Yin, WenLong Xu, and ShaoLi Zuo," *Compact Open-Slot Antenna with Bandwidth Enhancement",* IEEE Antennas and Wireless Propagation Letters, vol. 10, 850-853, 2011.

[7] K.-S. Lim, M. Nagalingam, and C.-P. Tan, "*Design And Construction Of Microstrip UWB Antenna With Time Domain Analysis", Progress In Electromagnetics Research M, Vol. 3, 153–164, 2008.*