Performance Enhancement of Microstrip Patch Antenna by Simultaneously Incrementing the Symmetrical V-slots in Three Different Configurations

Anchal Pandey[1]
Student
Department of Electronics & Communication Engineering
Guru Nanak Dev University, RC Gurdaspur
Punjab, India

Dr. Shashi B. Rana[2]
Assistant Professor
Department of Electronics & Communication Engineering
Guru Nanak Dev University, RC Gurdaspur
Punjab, India

Rajat Arora
Research Scholar
Department of Electronics & Communication Engineering
Guru Nanak Dev University, RC Gurdaspur
Punjab, India

Abstract: **This paper highlights a new strategy to improve the bandwidth and gain of a microstrip patch antenna. For its implementation, we are using three symmetrical V-shaped slots which are oriented 60 degree with respect to each other to give us illusion of forming the cone type structure as a whole. In this approach, we are incrementing all the three V-slots simultaneously, which were symmetrically oriented in above said pattern in each antenna configuration. The modeling and simulation of all these structures is performed by using HFSS software. Simulating analysis further reveals that by increasing subsequent slots in each antenna configuration results in change in aperture and radiation properties significantly. It is evident from the simulative analysis that in third configuration of proposed antenna, we are getting highest gain of 6.71 dB and achieving bandwidth enhancement up to 64 percent in comparison to first antenna configuration. The proposed configurations can be used for the applications corresponding to S (2-4GHz), C (4-8 GHz), X (8-12 GHz) and Ku (12-18 GHz) bands of microwave frequency.**

Keywords: Patch Antenna; Symmetrical V-Slots; Bandwidth; Gain; Multiband Applications

I. INTRODUCTION

The antennas, as a vital part of every communication system, should have features like light weight, small volume, omni directional radiation properties, low fabrication cost and ease of installation. All these requisite features can be satisfied by using the Microstrip patch antenna. The concept of microstrip antenna was first proposed by G.A. Deschamps in 1953. In year 1970 it was modified further by Robert E. Munson with some fellow researchers. They used low-loss soft substrate materials to make it useful for practical applications [1]. The microstrip antenna has characteristic features such as low gain, narrow band and wide beam antenna. There are various factors that effects the gain and resonant frequency of the antenna, like the thickness (h) and dielectric constant (ϵ_r) of substrate, shape of patch, the dimensions of ground plane and method of feeding etc. [2-4].

The necessity of high gain, wide band response and miniaturization inspired us to focus on patch antenna by altering its shape and structure. One method is by creating slot or cavity on the antenna aperture. This patch cavity or slot can raise the resonant frequency in an appreciable way in different antenna configuration. Creating slots on the patch shows variation in different parameters of the antenna. A slot radiates electromagnetic waves in the same way as the dipole antenna does. The variation in shape and dimensions of slots influence different antenna characteristics like return loss, gain and radiation distribution pattern.

Many researchers have witnessed the improvement of return loss, gain and impedance bandwidth of the microstrip patch antenna using different slot configurations [5-9]. Wang et al. [10] presented a microstrip antenna array having tooth like slot structure used as array element for wide bandwidth, high gain and low cross polarization level. Lee et al. [11] proposed a U-slot patch antenna for dual and triple band operations which can be used for circularly polarized applications. In recent days, V-shaped slot is gaining considerable attention because of its small structure, broad band and multiband response. A number of experimental and theoretical research papers have been published regarding different shape of slot in patch antenna [12-19]. The advantages associated with V-shape slots for achieving the wideband, ultra wideband (UWB) and multiband operation inspired to focus us on proposed work.

In present work, we are designing and consequently performing simulation on three antenna configurations by simultaneously incrementing symmetrical V-slots which were oriented as shown in figure 1. The objective of this paper is to observe the effect of simultaneously incrementing the V-slots in each antenna configuration on the parameters which are return loss, VSWR, gain and radiation pattern. Simulated results show that the first antenna configuration resonates at

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

2.25, 4.80, 7.10, 8.0 and 9.70 GHz (five bands), so it can be used for the applications such as; for S (2-4GHz), C (4-8GHz) and X (8-12GHz) bands respectively. Considering second configuration, the resonant frequencies are 2.25, 4.60, 5.80, 6.80, 7.70 and 9.50 GHz (five bands) for S, C and X bands. Whereas for the third configuration, we found that it resonates at frequencies 3.52, 5.01, 6.58, 7.07, 8.11, 8.83, 9.91 and 14.50 GHz corresponding to C band, X band and Ku (12-18GHz).

As per the paper organization is concerned, the demonstration of antenna geometry is discussed in section *Description of Antenna Design*. The theory and analysis of antenna design is presented in the section *Analysis and Calculation*. The simulated parameters gain, return loss, radiation pattern and VSWR are explained in section *Results and Discussion*. The end of the discussion of work is followed by the *Conclusion*.

II. DESCRIPTION OF ANTENNA DESIGN

The structural demonstration of first antenna configuration by using three symmetrical oriented V-slots is shown in fig 1. Corresponding dimension of shape and size are highlighted in table 1. The symmetrical V shaped slots (width W_S = 1 mm and length L_S = 6mm) are etched from the antenna aperture. These cavities radiates in the similar way as the dipole antenna. As the dimensions of antenna are the functions of wavelength, so the radiation properties can also be determined by the dimensions of the cavity. We are increasing these V-shaped cavities in a particular pattern in each configuration.

The antennas are designed on Rogers RT/Duroid 5880 (tm) substrate with thickness (h) of 3.2 mm having relative permittivity (ϵ_r) of 2.2. RT/Duroid 5880 also called as high frequency laminates, are PTFE (PolyTetraFluoroEthylene) composites reinforced with glass microfibers. The advantagesof using this material are its low dielectric constant, high operating temperature, low friction coefficient, excellent chemical and abrasion resistance. It shows low dielectric loss which makes it best suited for high frequency or broadband applications, where dispersion and losses needs to be minimized.

The coaxial probe feed is used to excite the antenna. In this method, the exterior conductor of the coaxial connector is connected to the ground plane and the interior conductor (probe) is extended upto the radiating patch. The advantage of using probe feed is that the feed point can be easily placed at any desired position on the aperture of patch for input impedance matching.

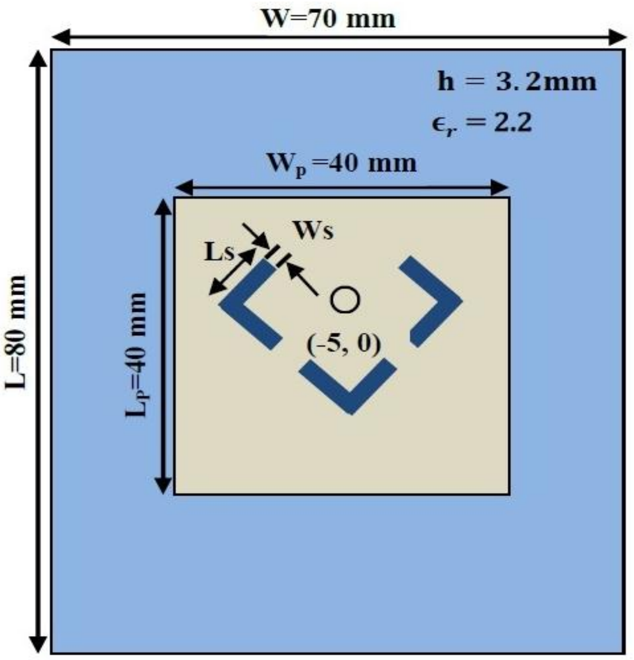


Fig. 1. Dimensional representation of basic geometry of proposed antenna (Top view)

TABLE I. DESIGN SPECIFICATIONS

Sr. no.	Parameters	Value (in mm)
1.	Length of substrate (L)	80
2.	Width of substrate (W)	70
3.	Length of patch (L_P)	40
4.	Width of patch (W_P)	40
5.	Length of slot (L_S)	6
6.	Width of slot (W_S)	1
7.	Feed position	(-5,0)

III. ANALYSIS AND CALCULATIONS

There are various modeling methods for the analysis of patch antenna. The mostly used models are the *transmission-line model*, *cavity model* and *full-wave model (moment method)*. Among all these methods, the transmission line model is the easiest and less complex. Radiation properties of antenna can be controlled by its dimensions because the parameters length and breadth are dependent on the operating wavelength of antenna. The radiation effect in the patch antenna is due to fringing field effect which is the further function of the thickness of the substrate and the dimensions of patch. The permittivity of substrate controls the fringing fields. Lower permittivites have wider fringes and therefore better radiation. The efficiency can also be increased by using lower value of the permittivity.

In this paper we have designed the antenna for resonant frequency (f_c) of 2.25 GHz which can be used for S-band applications. The stepwise calculations for this are shown below.

Step 1: Wavelength corresponding to the resonant frequency is given by equation (1).

$$\lambda_c = \frac{c}{f_c} = 133\text{mm} \tag{1}$$

Where, c is the speed of light in free space (3×10^8 m/sec) and fc is the frequency of operation.

Step 2: Calculations for patch: The width of a patch is comparable to the wavelength and thickness of the substrate and is kept very much smaller than wavelength. We are using Rogers RT/Duroid for substrate which has relative permittivityas $\epsilon_r = 2.2$ and height of substrate as $h = 3.2$mm.Width of patch calculated by equation (2) is 52.72mm.

$$W = \frac{c}{2f_c\sqrt{\frac{\epsilon_{r+1}}{2}}} = \frac{3\times10^8}{2\times2.25\sqrt{\frac{2.2+1}{2}}} = 52.72\text{mm} \tag{2}$$

Step 3: Effective relative permittivity in the medium is given by equation (3). By substituting the values of h, ϵ_r and W, we calculated ϵ_{eff} =2.056.This is kept slightly less than the dielectric constant of the substrate so that the fields not entirely get confined to the substrate but also fringe and spread in the air.

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \tag{3}$$

Step 4: Calculation of length difference due to fringing fields. Actually, the patch is bit bigger electrically than its physical dimensions because of fringing fields. This difference length is given by equation (4).

$$\Delta L = 0.412h\frac{\left(\epsilon_{eff} + 0.3\right)\left(\frac{w}{h} + 0.264\right)}{\left(\epsilon_{eff} - 0.258\right)\left(\frac{w}{h} + 0.8\right)} \tag{4}$$

Step 5: Calculation of actual wavelength and effective length in medium. The actual wavelength in medium and the effective length is given by equation (5) and (6) respectively.

$$\lambda = \frac{\lambda_c}{\sqrt{\epsilon_{eff}}} = 93.04\text{mm} \tag{5}$$

$$L_{eff} = \frac{c}{2f_c\sqrt{\epsilon_{eff}}} = 46.52\text{mm} \tag{6}$$

Step 6: Actual patch length is calculated as 43.18mm using equation (7).

$$L = L_{eff} - 2\Delta L = 43.18\text{mm} \tag{7}$$

Step 7: Calculation for ground plane dimensions are given by equations (8) and (9).

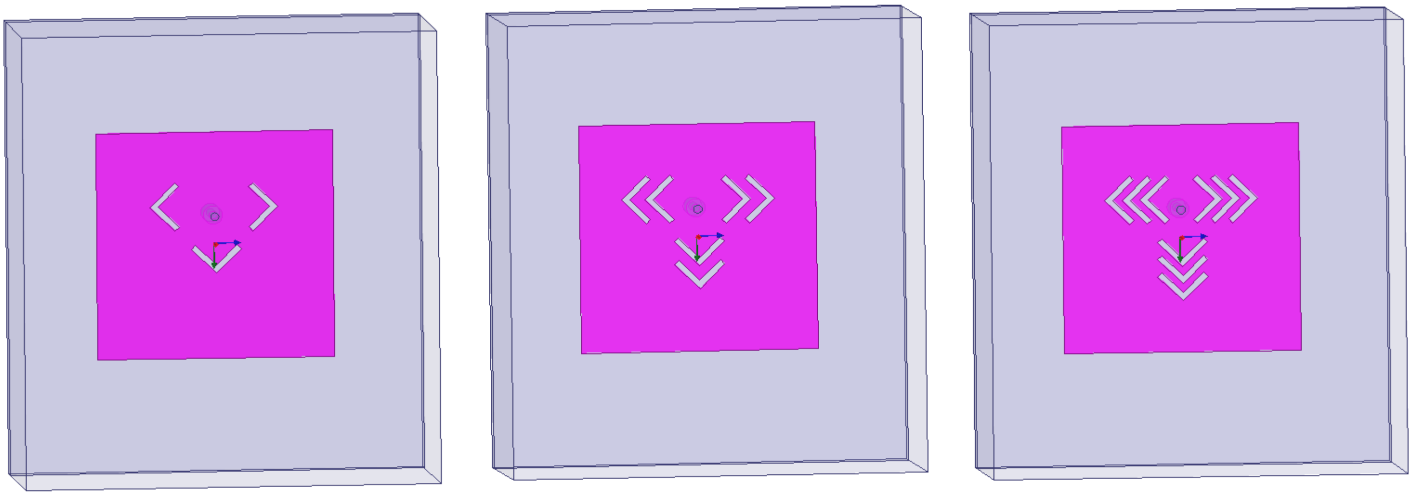
$$L_G = 6h + L = 62.38\text{mm} \tag{8}$$

$$W_G = 6h + W = 71.92\text{mm} \tag{9}$$

From analysis, we have calculated the patch length of 43.18mm. But we are using the 40 mm patch length which is the approximated value of calculated actual patch length.

IV. RESULTS AND DISCUSSION

This section will discuss and compare the results of each configuration with one another.The proposed configurations are shown in fig. 2 (a), (b) and(c) respectively. The microstrip patch has default profile of low gain narrow band antenna, therefore to improve its default response; an approachof simultaneously increasing the symmetrical V-slots which are oriented 60º with respect to each other, is used. Using this strategy, the simple microstrip patch antenna can be used for multiband operations without changing its external dimensions. It has been observed that by introducing the symmetrical V-slots, the radiating behavior of the antenna get changed and we are observing change in other performance parameters as well. These slots produce a significant effect on the time varying electric and magnetic fields generated from the patch's surface which further influence the surface charge distributions. The approach of increasing the number of V-slots on the aperture of patch makes antenna adequate to deal with theS (2-4 GHz), C (4-8 GHz), X (8-12.4 GHz) and Ku (12-18GHz) bands. The applications associated with these bands are wireless LAN, bluetooth, GPS, weather radar, microwave devices, long distance radio telecommunication, satellite communication, space communication, radar and terrestrial broadband etc. The performance parameters like return loss, standing wave ratio and radiation pattern are measured from simulated results.



(a) First Configuration (3 slots) **(b) Second Configuration (6 slots)** **(c) Third Configuration (9 slots)**

Fig. 2. Proposed configurations of symmetrical V-slots loaded patch antenna (a) three slots with 60 degree orientation with respect to each other (b) modified structure with six slots (c) modified structure with nine slots

A. *Observations for Return loss and Bandwidth*

The return loss is the very important factor to satisfy the condition of impedance matching. Impedance matching is the phenomenon of designing the output impedance of the source or the input impedance of corresponding load to maximize the power transfer and to minimize the reflection from the load end. The S_{11} element of the scattering matrix defines the return loss. The characteristic impedance taken is 50 ohms for the impedance matching. Figure 3 (a), (b) and (c), representsthe return loss (dB) versus frequency (GHz) graph of different configuration having multiple V-shaped slots. For less reflection losses, the value of the return loss is taken as -10 dB.

Figure 3 (a) is the return loss plot for the first configuration (three V-slots). The total bandwidth for first configuration comes out to be 16.55 percent. Figure 3 (b) shows the return loss plot for the second configuration (six V-slots). Total bandwidth in this case is calculated as 22.18 percent. We are modifying the structures by increasing number of V-slots in a particular fashion in each configuration, the third configuration with nine slots (figure 3 (c)) is found with excellent results. The total impedance bandwidth of third case is calculated as 64.46 percent. The results show that the configurations can be used for multiband applications. The values of return loss at different resonant frequencies are described in table 2 (a), (b) and (c). The significant variation of return loss as a function of frequency can be observed (table 2 (c)) for the third antenna in comparison with first and second antenna configurations.

TABLE II. RETURN LOSS OBSERVATIONS FOR FIRST ANTENNA

First Antenna Configuration		
Sr. no.	*Resonant Frequency (in GHz)*	*Return loss (in dB)*
1.	4.80	-13.37
2.	7.10	-15.81
3.	8.00	-19.70
4.	9.70	-15.59

TABLE III. RETURN LOSS OBSERVATIONS FOR SECOND ANTENNA

Second Antenna Configuration		
Sr. no.	*Resonant Frequency (in GHz)*	*Return loss (in dB)*
1.	4.60	-11.00
2.	5.80	-17.28
3.	6.80	-12.86
4.	7.70	-20.72
5.	9.50	-13.64

TABLE IV. RETURN LOSS OBSERVATIONS FOR THIRD ANTENNA

Third Antenna Configuration		
Sr. no.	*Resonant Frequency (in GHz)*	*Return loss (in dB)*
1.	3.52	-11.27
2.	5.09	-15.44
3.	6.58	-25.60
4.	7.07	-17.65
5.	8.11	-15.79
6.	8.83	-31.59
7.	9.91	-37.36

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

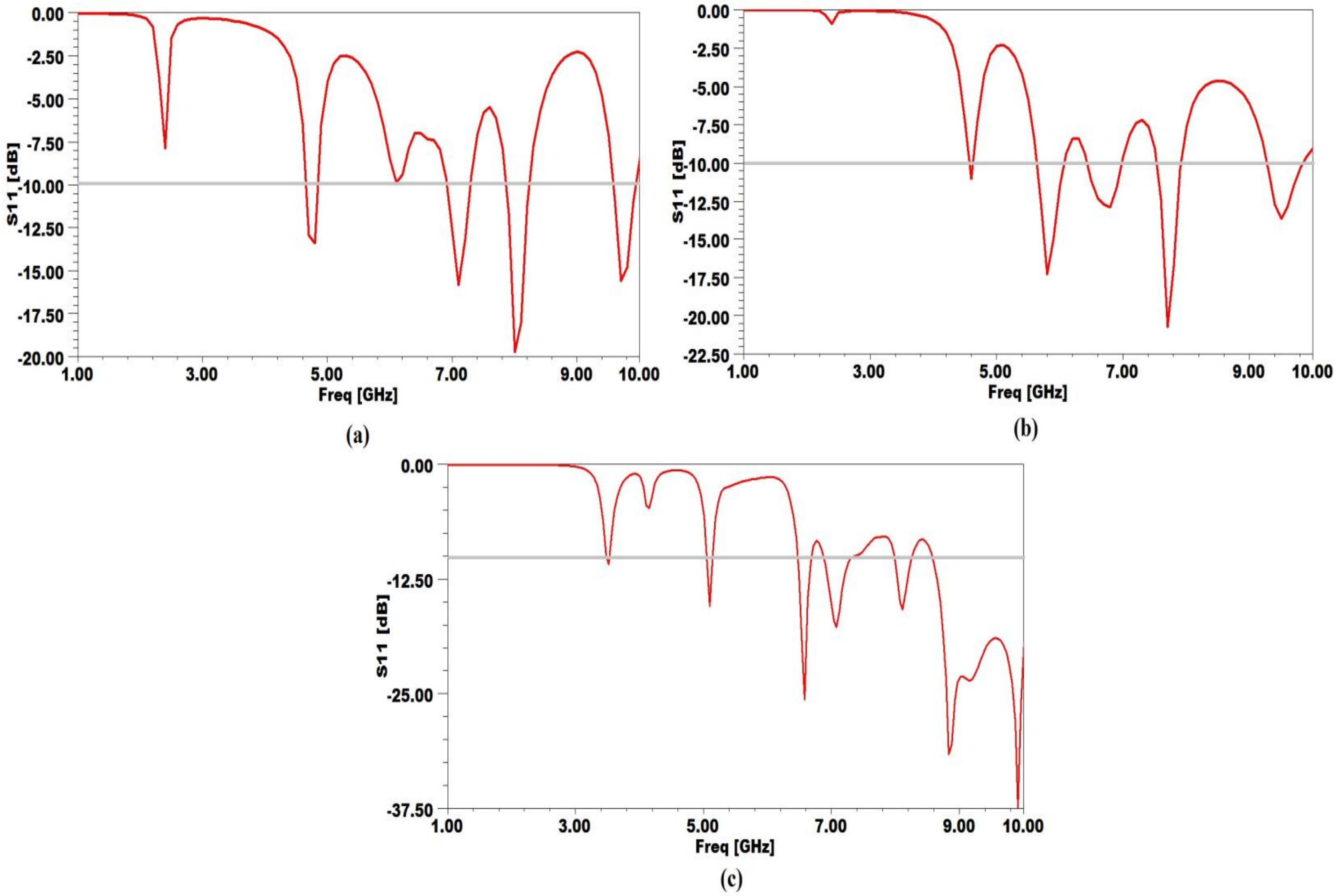


Fig. 3. Return loss vs. frequency plots (a) First configuration (b) Second configuration (c) Third Configuration

B. Observations for VSWR and Radiation characteristics

The VSWR is another important parameter which varies linearly with the impedance mismatch. This mismatching leads to the increment in reflections of the electromagnetic waves back to the source, which can also cause the excess heating of source. VSWR is the measure of reflections in terms of dB and also defines the reflection coefficient Γ, as these two parameters are mutually dependent. The valueof VSWR should be $1 \leq VSWR \leq 2$ for perfect impedance matching.Figure 4 (a), (b) and (c) describes the frequency (GHz) versus VSWR (dB) plots of the first, second and third configuration respectively. The standing wave ratios calculated are 1.80dB at 8 GHz and 1.60dB at 7.70 GHz for first and second configuration respectively. Whereas for third configuration, the value obtained is 1.17dB at 8.83GHz.

The next parameter observed is the radiation pattern. Radiation pattern of the antenna is associated with its radiation capabilities and is measured on the surface of a constant radius sphere. The spherical coordinate system is used to study the radiation pattern. Keeping the radial component constant, the two angular coordinates (θ, φ) are used for positional identification. From the figure 5 (a) it has been observed that the antenna is showing unidirectional radiation gain of 5.54dB at 0° and 1.93dB at 90°. As we are increasing the number of slots in second and third configuration (figure 5 (b) and 5 (c)), the radiation gain increases. For second antenna configuration, it is given as 6.57dB at 0° and 2.80dB at 90° and for third it is calculated as 6.70dB at 0° and 2.81dB at 90°. This shows that the antenna is giving the enhanced unidirectional radiation pattern as we are increasing the number of slots.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

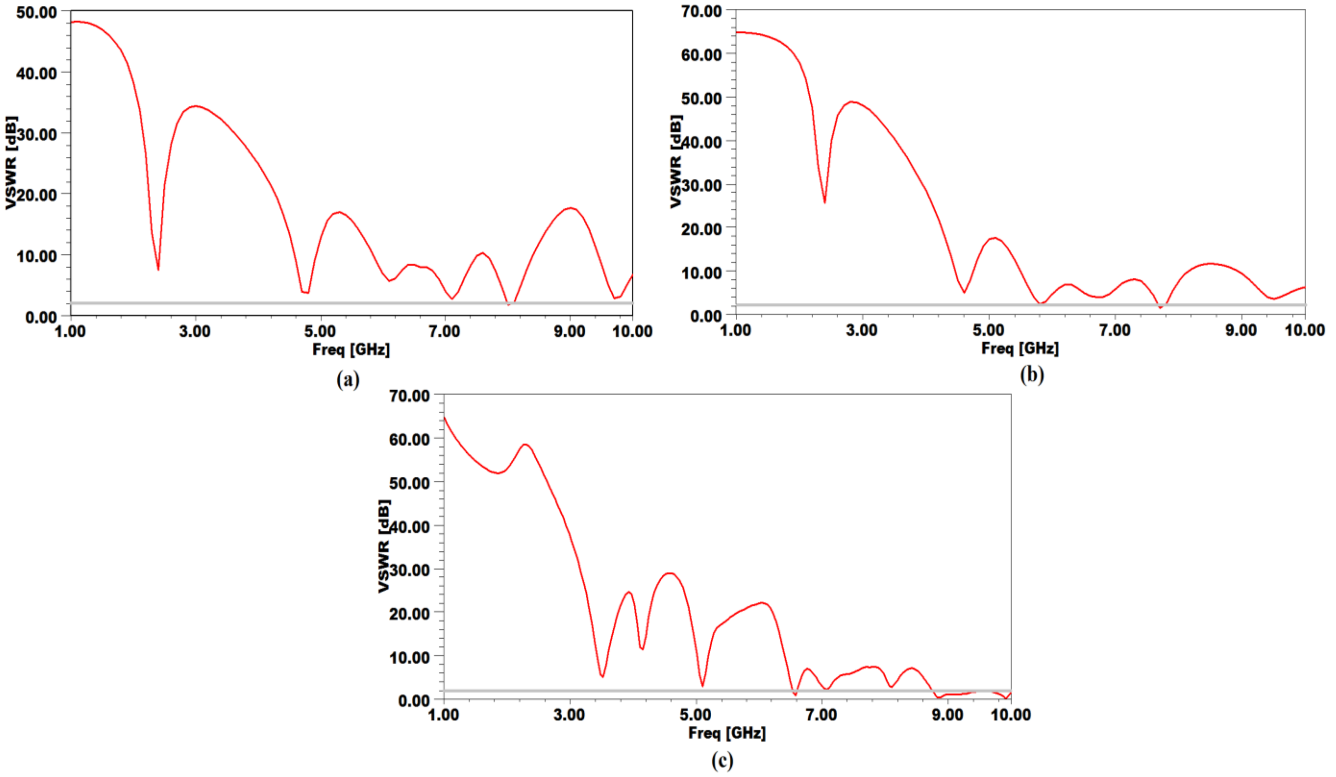


Fig. 4. VSWR vs. frequency plot (a) First configuration (b) Second configuration (c) Third Configuration

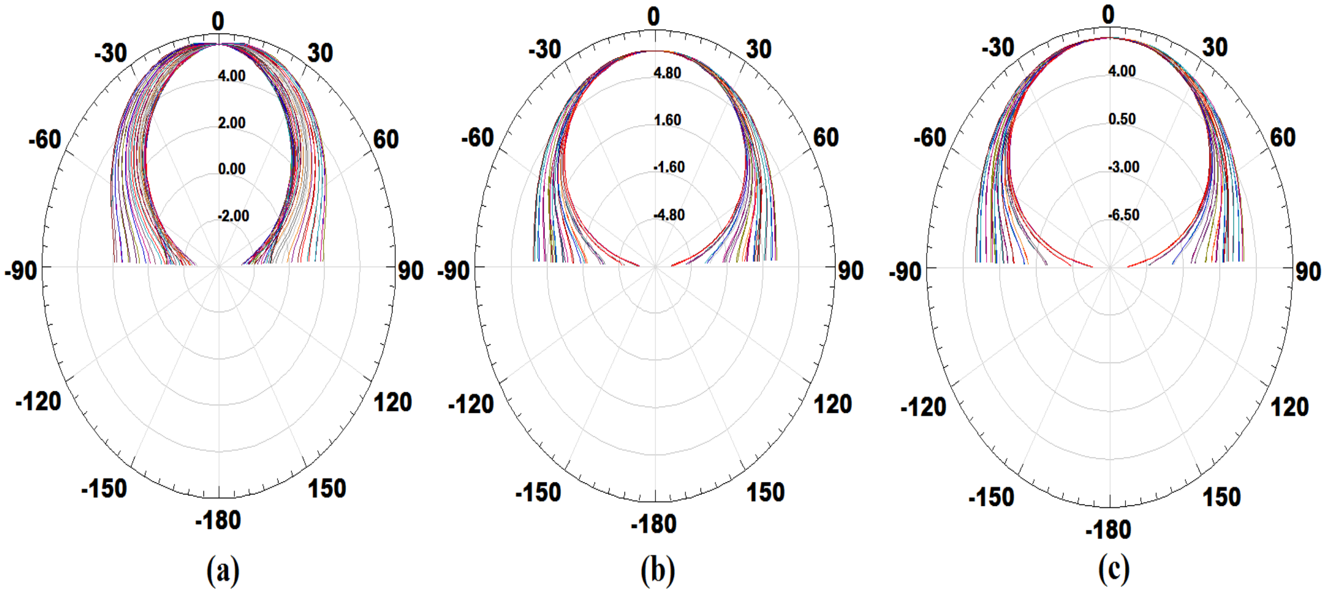


Fig. 5. Radiation patterns (a) First configuration (b) Second configuration (c) Third Configuration

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

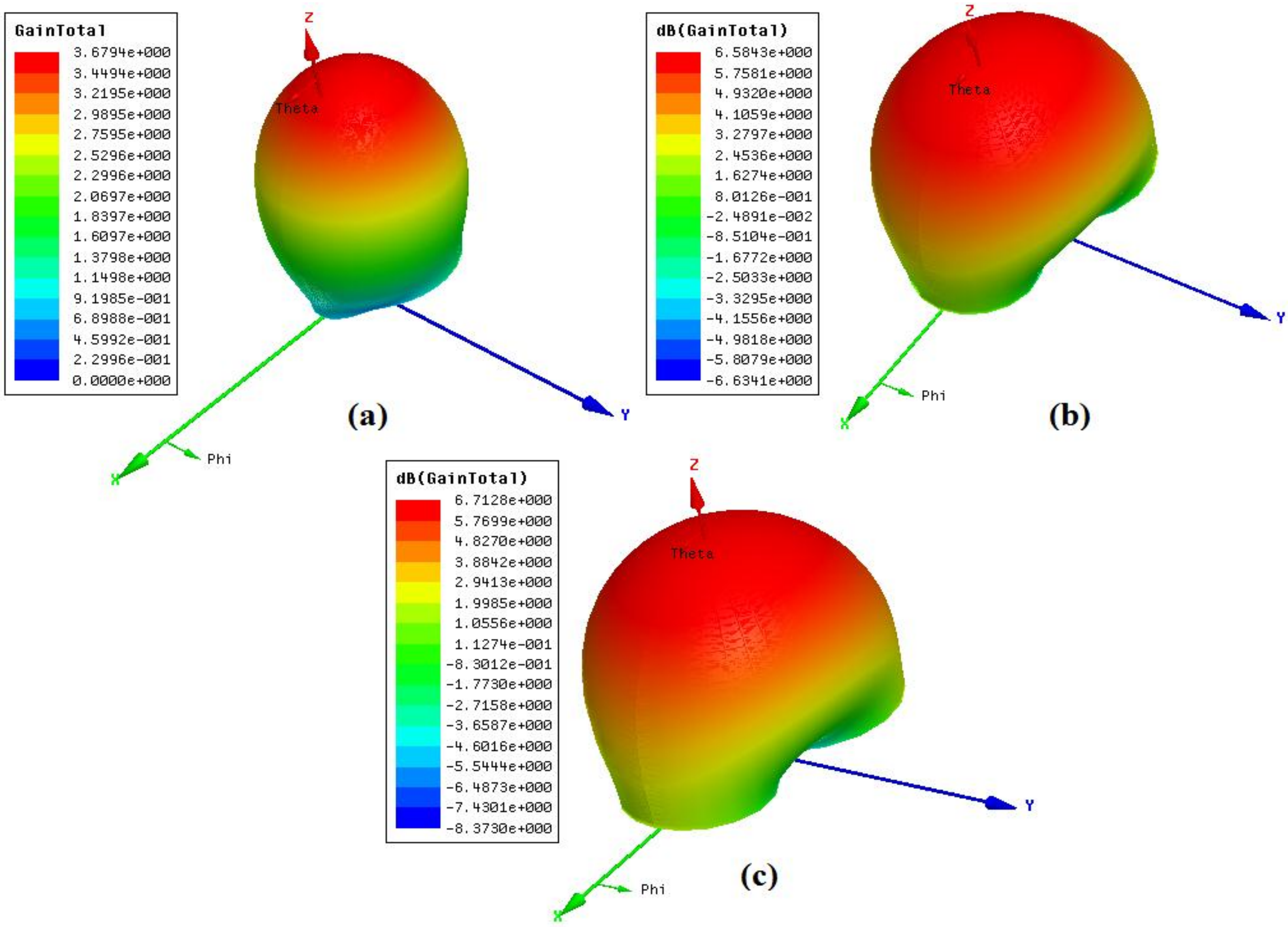


Fig. 6. Far field antenna Gain (a) First configuration (b) Second configuration (c) Third Configuration

C. *Observations for Gain*

The most important figure of merit that describes the performance of an antenna is the Gain. There are two correlating terms: *directivity* and *gain*. The difference between these two is that the directivity is the measure of directional properties of antenna where as the gain is the measure of radiation intensity in any given directions. Figure 6 shows the far field gain of different configurations. Fig 6 (a) shows the maximum directional gain of 3.67dB at resonant frequency for first configuration. The maximum gain observed for second configuration (fig 6 (b)) and third configuration (fig 6 (c)) are 6.58dB and 6.71dB respectively. The tabular representation of values of gain of all the antenna configurations is presented in the table 3. The gain and directivity of an antenna is dependent on the physical area or the maximum effective area of aperture. The modification in the antenna aperture results drastic change not only in gain and directivity but also in beam-widths and side lobe levels. Thus, according to this paper concept, by increasing the slot effect on the antenna aperture to an extent, we can further increase the directional gain response.

TABLE V. GAIN AND BANDWIDTH OBSERVATIONS

Sr. no.	Antenna Configuration	Gain(in dB)	Bandwidth (%)
1.	First antenna	3.67	16.55
2.	Second antenna	6.58	22.18
3.	Third antenna	6.71	64.46

V. CONCLUSION

An approach of incrementing the slots effect on the radiating patch to enhance the performance of antenna is proposed in this paper. It is evident from the simulative analysis that, we can make a simple rectangular patch antenna capable of exhibiting multiband response by introducing the V-slots on the patch antenna. The bandwidth, gain and return loss of patch antenna is enhanced by 64 percent, 6.71dB and -37.36dB respectively. The characteristics impedance of 50Ω is maintained for impedance matching. The antenna configurations are found useful for satellite and wireless communication application. The proposed approach can be used further to enhance the bandwidth, return loss and radiation properties. We are getting very encouraging results for all three configurations, so we have planned to fabricate these three antenna configurations in future course, which can further be used for S, C, X and Ku microwave frequency bands applications.

REFERENCES

[1] Constantine A. Balanis, "Antenna Theory: Analysis and Design" Wiley, 3rd edition, 2005.

[2] David M. Pozar, Daniel H. Schaubert, "Microstrip Antennas: The Analysis and Design of Microstrip Antennas and Arrays" *IEEE Antennas and Propagation Society*, 1995.

[3] Rui Guan, Xiaomiao Zhang, Li Jin, Zhen Zhang and Weixi Zhou, "A Compact Multi-Folded Patch Antenna for UWB Application at the UHF Band" *Proceedings of International Symposium on Signals, Systems and Electronics*, 2010.

[4] V. V. Thakare, "Bandwidth analysis by introducing slots in microstrip antenna design using ann" Progress In Electromagnetics Research M, Vol. 9, pp. 107-122, 2009.

[5] U. Chakraborty, A. Kundu, S. K. Chowdhury and A. K. Bhattacharjee, "Compact Dual-Band Microstrip Antenna for IEEE 802.11a WLAN Application" *IEEE Antennas and Wireless Propagation Letters*, Vol. 13, 2014.

[6] Achmad Munir, Guntur Petrus and Hardi Nusantara, "Multiple Slots Technique for Bandwidth Enhancement of Microstrip Rectangular Patch Antenna", IEEE, 2013.

[7] Radha Sharma," Trapezoidal patch with H and V shaped slot loaded microstrip antenna" IEEE, 2013.

[8] Pratap N. Shinde and Jayashree P. Shinde, "Design of compact pentagonal slot antenna with bandwidth enhancement for multiband wireless applications" International Journal of Electronics and Communications, 2015.

[9] Shailander Singh Khangarot, Gajendra Sujediya, Tejpal Jhajharia, Abhishek Kumar, "Design and Fabrication of E-slot microstrip patch antenna for WLAN Applications" International Journal of Advanced Research in Computer and Communication Engineering Vol. 4, No. 6, June 2015.

[10] H. Wang, X. B. Huang, D. G. Fang, and G. B. Han, "A Microstrip Antenna Array Formed by Microstrip Line Fed Tooth-Like-Slot Patches" *IEEE Transactions on Antennas and Propagation*, Vol. 55, No. 4, April 2007.

[11] Kai Fong Lee, Shing Lung Steven Yang, Ahmed A. Kishk and Kwai Man Luk, "The Versatile U-Slot Patch Antenna" *IEEE Antennas and Propagation Magazine*, Vol. 52, No. 1, 2010.

[12] Gh.Z. Rafi and L. Shafai, "Wideband V-slotted diamond-shaped microstrip patch antenna", Electronics Letters Vol. 40 No. 19, 2004.

[13] A.A. Deshmukh and G. Kumar, "Broadband compact V-slot loaded RMSAs" Electronics Letters, Vol. 42, No. 17, 2006.

[14] Shi-Wei Qu and Quan Xue," A Y-Shaped Stub Proximity Coupled V-Slot Microstrip Patch Antenna" IEEE Antennas and Wireless Propagation Letters, Vol. 6, 2007.

[15] Tariq Al-maznaee and Hany E. Abd-El-Raouf, "Design of reconfigurable patch antenna with a switchable V-Slot" Asia-Pacific conference on applied electromagnetics proceedings, 2007.

[16] J A Ansari, SatyaKesh Dubeyl, Prabhakar Singhl, R. U. Khan, BabauR.Vishvakarma, "Stacked V-slot Loaded Patch Antenna" Proceeding of International Conference on Microwave, 2008.

[17] HalaElsadek and Dalia M. Nashaat, "Multiband and UWB V-Shaped Antenna Configuration for Wireless Communications Applications", IEEE Antennas and Wireless Propagation Letters, Vol. 7, 2008.

[18] Sanjeeva R. Rama and Vakula. D, "Triangular Patch Antenna with Asymmetric V-Slots for Tri-band Wireless Applications", IEEE International Microwave and RF Conference, 2014.

[19] Mahrukh Khan, Dhivya Ketharnath, Varun K. Dandu and Deb Chatterjee, "UWB L-probe proximity fed V-slot patch antenna for early detection of breast cancer" IEEE, 2015.