ISSN 2347 - 3983
Volume 8. No. 8, August 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter29882020.pdf
https://doi.org/10.30534/ijeter/2020/29882020

# Development of Offset Microstrip Line Fed Patch Antenna for 4.9 GHz Public Safety WLAN

**A. Sudhakar[1], M. Sunil Prakash[2], M. Satyanarayana[3]**
[1]GMR Institute of Technology, Rajam, India, sudhakar.a@gmrit.edu.in
[2]MVGR College of Engineering, Vizianagaram, India, profsunil@mvgrce.edu.in
[3]MVGR College of Engineering, Vizianagaram, India, profmsn26@gmail.com

## ABSTRACT

This paper deals with development of offset microstrip line fed patch antenna to operate at resonant frequency of 4.9 GHz for public safety WLAN video surveillance services. The patch of suggested antenna looks like C shaped stub attached to offset microstrip feed line and the ground is etched with two rectangular slots. These two rectangular slots of dimensions 12.25 mm × 1.75 mm and 17 mm × 1.75 mm are observed to enhance the gain. All the simulations are carried out by HFSS. Initially the design evolution of the developed antenna started with traditional rectangular shaped patch antenna. To make the patch effective with respect to current distribution, rectangular patch is converted as a ring with offset microstrip line feed. Improvement in the reflection coefficient at desired frequency is obtained by separating the two strips of rectangular loop and optimizing their measurements as 25 mm × 1.5 mm and 17 mm × 3.5 mm. The developed antenna resonates at 4.93 GHz covering 132 MHz bandwidth with reflection coefficient of -24.89 dB. The simulated maximum gain is 3.8 dB which is improved from -17.19 dB. The change in resonant frequency can be obtained by offsetting the feed. Prototype antenna material is FR-4 of permittivity value 4.4 and overall dimensions of 60 mm × 60 mm. Experimental and software tested results exhibits good concurrence. The proposed design shows improved gain and better reflection coefficient compared to conventional geometry.

**Key words:** Microstrip antenna, offset microstrip fed, public safety LAN, rectangular slots

## 1. INTRODUCTION

Microstrip antennas are preferred over other antennas because of its highlights suitable principally for applications usable in RF and microwave zone. In its simple form, patch is a conductive coating of insignificant thickness on the top compared to the substrate thickness being middle with the ground plane of similar conductive coating as of patch at the bottom [1]. Though the formulas are available in the literature to find out initial dimensions of length and width of a patch at a required resonant frequency, other factors also influence the design. Some of the other factors are position, length and width of the feed structure, dimensions and position of the slots either on ground structure or on patch. The achievement of the antenna can be upgraded by carefully optimizing the measurements and shape of feed, ground or patch structures.

Among the different feeding procedures, the microstrip line is simple and has capacity to adequately manage the impedance with the change in feed location [2]. When the feed is located on the symmetry axis of the ring, its impedance increases toward the outer edge and the appropriate place to feed the ring is along its edge, to lower the input impedance at resonance and cross-polarization in both planes [3]. Small sized square-ring shaped microstrip antenna is discussed in [4]. The parameters influencing the resonant frequency of split ring are demonstrated in [5]. Defected ground was obtained by removing some conducting surface from the ground plane of planar circuits. It is shown in the paper [6] that elliptical slots embedded in the ground to improve the depth of return loss. It is reported in [7-8] that slots on patch will increase the gain.

The different purposes of microstrip antenna include wireless LANs (WLANs), Wi-fi hotspots, bluetooth, cellular phones, public safety etc. Public safety is a part of emergency management which includes emergency response, video streaming, wireless security systems etc. Voice services use the frequencies below 1 GHz, where as licensed video surveillance services use 4.9 GHz. Accordingly, design considerations for conventional systems are discussed in [9] at 800 MHz frequency. A broad band antenna with stepped T-shape ground with tapered patch is presented in [10] operating in the range of 426-861 MHz for wireless communications with gain around 2 dBi. An asymmetrical coplanar strip fed antenna for dual band operation is reported in [11] with maximum gain of 3.7 dBi of 2.4–2.5 GHz and 4.0–6.1 GHz frequencies. A customized triangular patch array at 4.9 GHz of bandwidth 120 MHz is reported in [12]. A dual band center fed circular disc antenna is available in [13] to have dual resonance at 481 MHz and the 806 MHz to use on public safety vehicles. Simulation study on tri band frequency tunable antenna with MEMS switches is demonstrated in [14] for three different frequencies with maximum gain 6dB for public safety spectrum but no proto type is available. Practical demonstration and investigations were carried in [15] throughout large urban structures and measurements were analyzed in the range 430 MHz - 4.9 GHz. Investigation in [17] gives bits of knowledge to improve current PCB precise, effective and cost-proficient. A compact dipole array slotted antenna with DGS for multiband applications is demonstrated in [18]

In this paper, development of offset microstrip line fed patch antenna with overall substrate size of 60 mm x 60 mm x 1.6 mm operating at 4.9 GHz resonant frequency for public safety WLAN video surveillance services. Two rectangular slots are positioned on the ground plane to increase the gain. Rectangular loop is split at one corner to have better reflection coefficient.

Parametric examination is carried out and the presentation of developed antenna is surveyed with traditional antenna. The parameters like reflection coefficient, gain and radiation characteristics are tested with software and checked experimentally.

## 2. ANTENNA DESIGN PROCEDURE AND ANALYSIS

To start with the design of microstrip antenna, commonly available FR4 substrate of dielectric constant 4.4 with 1.6 mm thickness of size 60 mm × 60 mm is taken since FR4 is known for good flame resistance and strength [16].

As the rectangular shape is most widely used for the traditional geometry, rectangular patch with 31.5 mm × 27 mm is printed on FR4 substrate on front side as indicated in Figure 1a. Rear side of the substrate consists of full copper coated ground without any slots as exhibited in Figure 1b. The microstrip line width is 3.5 mm, and length is 15 mm. Though many shapes are available, rectangular shape of the patch is most commonly used one. Hence, the developed work initiated with a rectangular patch and a ground with no slots.

Four antennas named Antenna I, Antenna II, Antenna III and Antenna IV are depicted in the Figure 2 as a part of design evolution. Overall dimensions of all these antennas kept same. Antenna I is a conventional antenna and Antenna IV is a proposed one. Current distributions of all these antennas are illustrated in Figure 1c. From the current distribution of the traditional geometry (Antenna I) as indicated in Figure 1c, it is more on the feed line and bottom part of the patch. The patch has no considerable effect on the properties as the current concentration is less.

To have improvement of gain over the conventional antenna (Antenna I), offset microstrip line feeding is used as shown in Antenna II and it is seen that that current density is more on feed line and no significant effect on the patch. To make the patch effective with respect to current concentration, it is made into a rectangular ring as shown in Antenna III. Two rectangular slots (vertical slot "c" and horizontal slot "d") are etched on the ground structure to increase the gain as evident from Figure 3b. Antenna IV is the proposed geometry with a separation at the corner. The change in simulated resonant frequencies, reflection coefficients, bandwidth and gain of proposed structure with variations of size of slots ("c" and "d" on ground structure) and the variation of size of arms (lengths of "a" and "b") are recorded in Tables 1-4. Optimization is carried out by varying one parameter keeping all other parameters fixed.

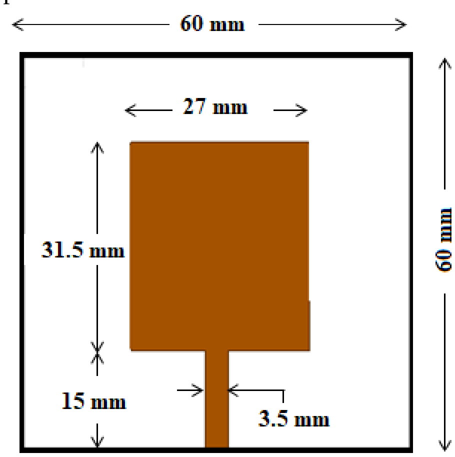


**Figure 1a:** Front view of traditional antenna

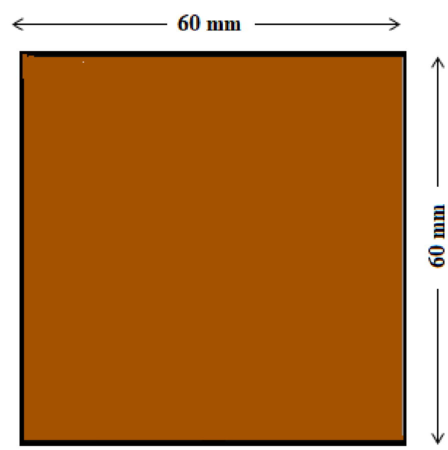


**Figure 1b:** Rear view of traditional antenna

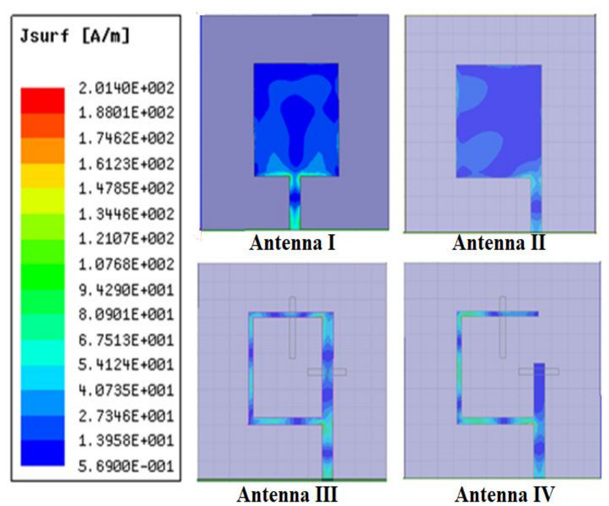


**Figure 1c:** Simulated current densities on patch

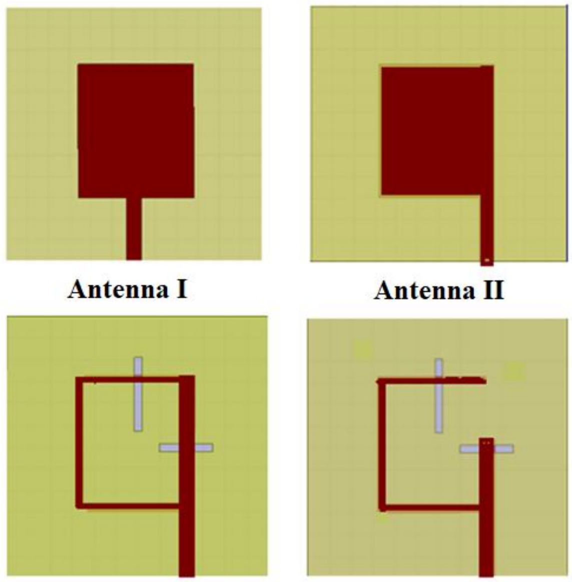


**Figure 2:** Design evolution of the proposed antenna

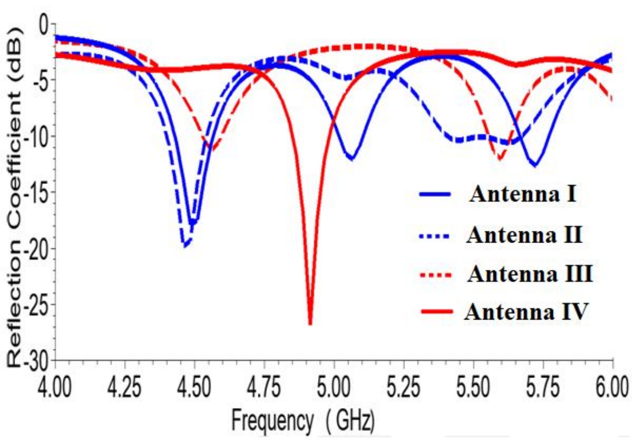


**Figure 3a:** Reflection coefficient vs frequency of antennas shown in Figure 2

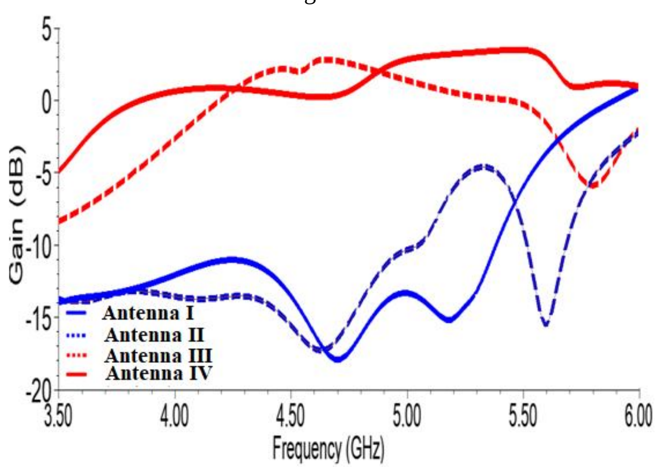


**Figure 3b:** Gain of antennas as shown in Figure 2

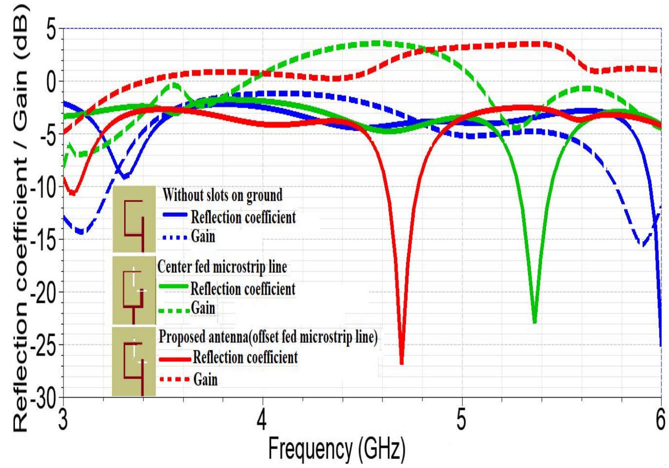


**Figure 3c:** Gain of antennas for change in location of microstrip line feed and introduction of slots

Table 1 illustrates the outcomes of the antenna parameters with the variation of dimension "a". Table 2 depicts effect of variations of dimension "b", showing a significant change in gain and resonant frequency. Basing on the recorded values, dimension "b" is fixed at 32 mm. A small change in dimension "b" produces the negative gains. Table 3 reports the consequences on radiation parameters of antenna with range of variation of vertical slot "c" and a small change in reflection coefficient with almost uniform gain is noticed. It is evident from the Tables 4 that horizontal slot "d" is affecting the gain and resonant frequency significantly. Comparison of all the antennas with respect to reflection coefficient and gain are demonstrated in Figure 3a and 3b. The effect of slots on the ground and change in the location of feed in terms of reflection coefficient and gain is depicted in Figure 3c.

**Table 1:** Variation of the width "a"

| Width (mm) | Resonant frequency (GHz) | Reflection coefficient (dB) | Band width (%) | Gain (dB) |
|---|---|---|---|---|
| 23 | 4.91 | -23.74 | 2.73 | 2.57 |
| 24 | 4.91 | -28.1 | 2.73 | 2.61 |
| 25 | 4.91 | -26.85 | 2.71 | 2.67 |
| 26 | 4.91 | -21.5 | 2.75 | 2.38 |
| 27 | 4.91 | -18.46 | 2.73 | 2.42 |

**Table 2:** Variation of length "b"

| Width (mm) | Resonant frequency (GHz) | Reflection coefficient (dB) | Band width (%) | Gain (dB) |
|---|---|---|---|---|
| 26 | 5.57 | -15.94 | 1.90 | -2.46 |
| 28 | 4.63<br>5.57 | -16.79<br>-14.54 | 2.16<br>2.89 | 0.86<br>-2.54 |
| 32 | 4.91 | -26.85 | 2.71 | 2.67 |
| 34 | 5.59 | -10.6 | 29.4 | 0.28 |
| 36 | 5.52 | -15.88 | 1.59 | -4.7 |

**Table 3:** Variation of the length of vertical slot "c"

| Length (mm) | Resonant frequency (GHz) | Reflection coefficient (dB)) | Band width (%) | Gain (dB) |
|---|---|---|---|---|
| 15 | 4.96 | -22.58 | 2.56 | 2.34 |
| 16 | 4.94 | -25.41 | 2.61 | 2.25 |
| 17 | 4.91 | -26.85 | 2.71 | 2.67 |
| 18 | 4.89 | -29.46 | 2.9 | 2.31 |
| 19 | 4.86 | -25.73 | 3.19 | 2.57 |

**Table 4:** variation of the length of horizontal slot "d"

| Length (mm) | Resonant frequency (GHz) | Reflection coefficient (dB)) | Band width (%) | Gain (dB) |
|---|---|---|---|---|
| 10.25 | 3.55 | -12.08 | 2 | -3.64 |
| 11.25 | 3.55 | -11.49 | 1.8 | -4.02 |
| 12.25 | 4.91 | -26.85 | 2.71 | 2.67 |
| 13.25 | 4.86 | -13.26 | 1.6 | 2.60 |
| 14.25 | 5.60 | -11.34 | 1.1 | -0.24 |

According to the Tables 1 - 4, the dimensions a = 25 mm, b = 32 mm, c = 17 mm and d = 12.25 mm are finalized.
The patch is of corner separated rectangular ring patch and the top view of the developed antenna is sketched in Figure 4a. Figure 4b depicts the defected ground etched with two rectangular slots (vertical slot "c" and horizontal slot "d") in order to enhance the depth of reflection coefficient and gain. Dimensions of vertical and horizontal slots are 17 mm x 1.75 mm and 12.25 x 1.75 mm respectively.

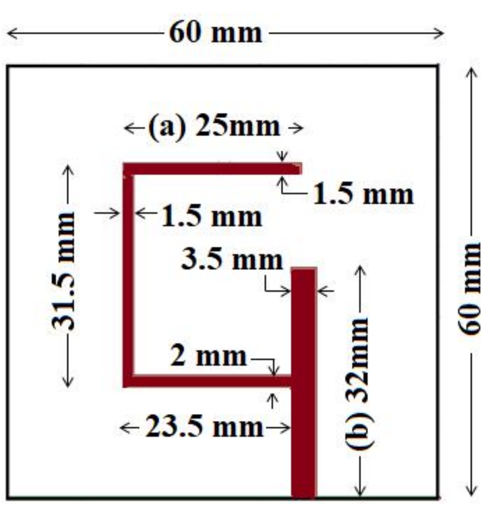


**Figure 4a:** Front view of developed antenna

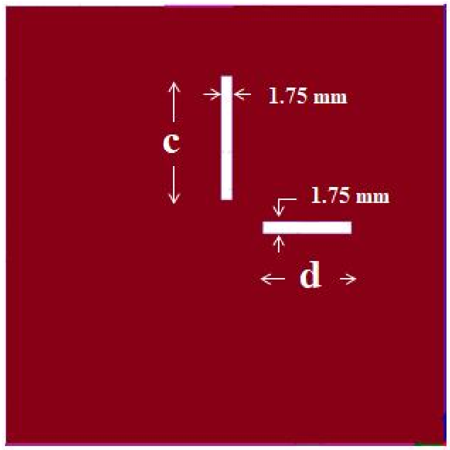


**Figure 4b:** Rear view of developed antenna with c=17 mm and d= 12.25 mm

## 3. RESULTS AND DISCUSSIONS

The traditional microstrip line-fed antenna has -5.01 dB reflection coefficient and -13.77 dB gain. The proposed antenna with two rectangular slots in the ground as compared to traditional antenna attains a considerable simulated reflection coefficient of -26.85 dB from 4.85 - 4.98 GHz with central frequency at 4.91 GHz and 2.67 dB gain. The accomplished reflection coefficient and gain makes this antenna to be used for public safety WLAN. With proposed modifications, the achievement of antenna is appreciably improved. As indicated in Figure 5a, developed antenna is resonating at 4.91 GHz and traditional antenna is having multiple resonant frequencies. With the introduction of slots in the ground and separation of arms at the corner of rectangular ring patch enhances the depth of reflection coefficient from -5.01 dB to -26.85 dB and gain increased from -13.7 dB to 2.67 dB at 4.91 GHz.

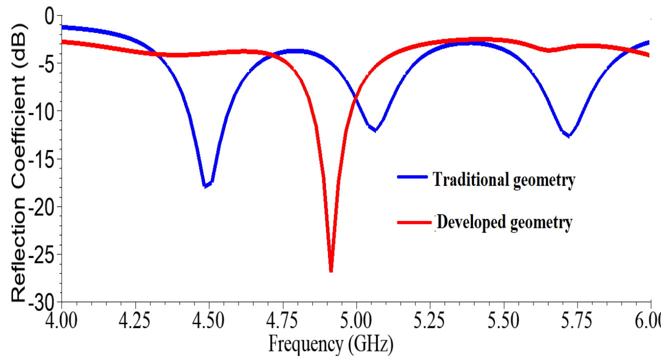


**Figure 5a:** Simulated reflection coefficient (dB) of traditional and developed antennas

The simulated gain and VSWR values for developed and traditional geometry are depicted in Figure 5b and c. They are exhibiting 2.67 dB gain and VSWR of 1.91 at resonant frequency of 4.91 GHz.

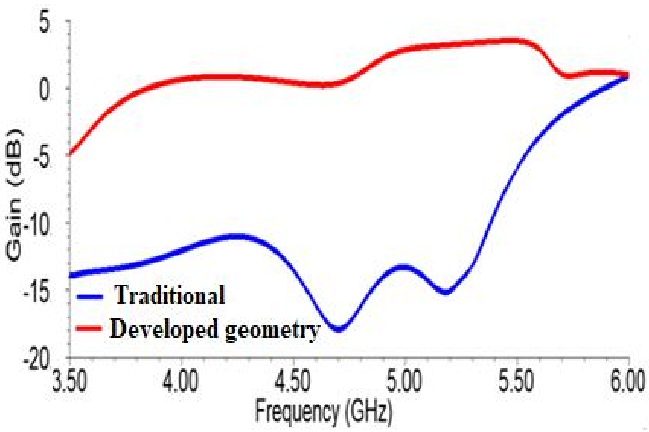


**Figure 5b:** Gain (dB) of traditional and developed geometry as a function of frequency

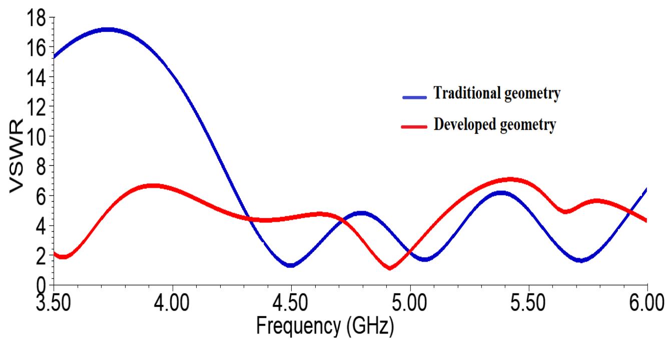


**Figure 5c**: VSWR curve of traditional and developed geometry

The radiation patterns of the traditional antenna at 4.48 GHz frequency (first resonant frequency) and proposed antenna at 4.91 GHz frequency are depicted in Figures 6a and 6b. The radiation pattern of developed antenna is of broadside directive in nature. The simulated and the measured results for reflection coefficient and VSWR are seen in good conformity at 4.91 GHz as shown in Figures 7a and 7b. However a slight shift in resonant frequency is observed during measurement. The prototype of developed antenna is depicted in Figure 8.

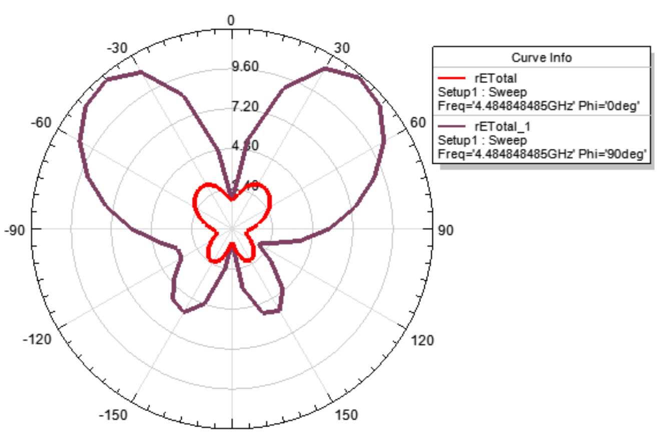


**Figure 6a:** E and H plane patterns for traditional geometry

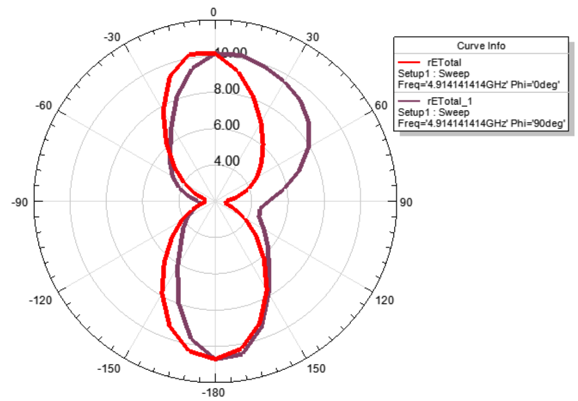


**Figure 6b:** E and H plane elevation for developed geometry

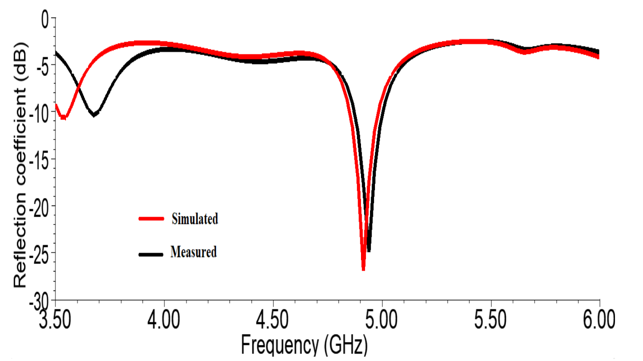


**Figure 7a:** Measured and simulated results of developed antenna

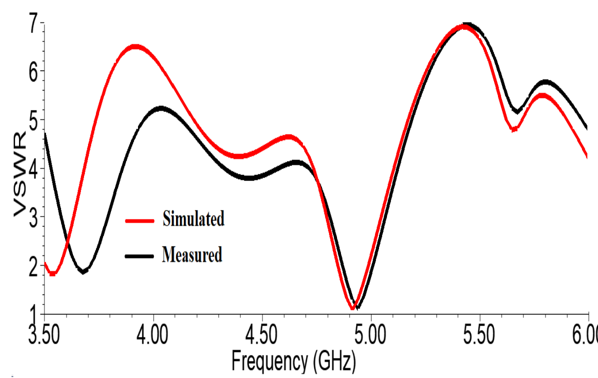


**Figure 7b:** VSWR results of developed antenna

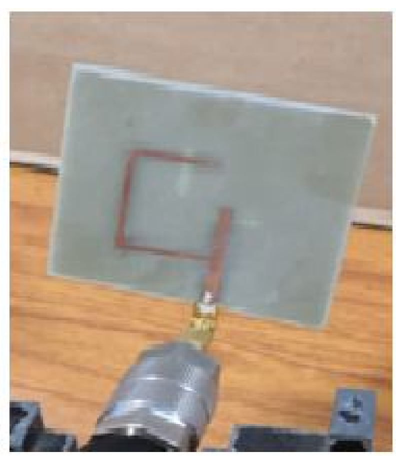

**Figure 8:** Proto type of developed geometry.

Simulated maximum gain of the proposed antenna is 3.86 dB as illustrated in Figure 9. The performance of the antenna for all phi values is almost similar as illustrated in Figure 10.

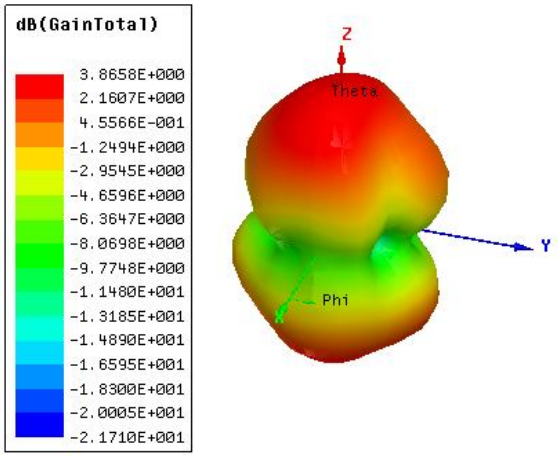


**Figure 9:** Simulated gain of developed antenna.

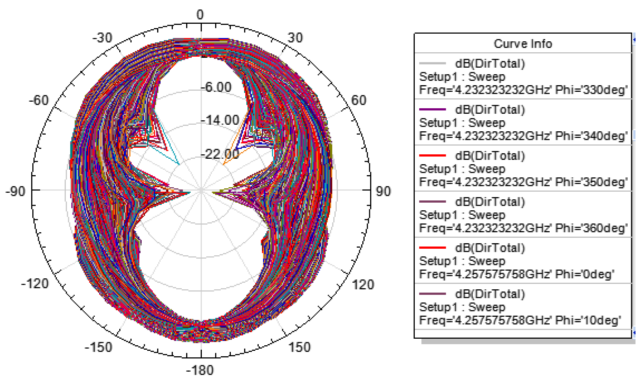


**Figure 10:** Directivity plot for developed geometry at different values of "phi"

## 4. CONCLUSION

Microstrip line-fed rectangular patch antenna is designed, simulated and fabricated to attain good return los at 4.9 GHz resonant frequency to suit for public safety video surveillance systems. The proposed antenna presents -26.85 dB reflection coefficient with 2.71% impedance bandwidth at 4.91 GHz frequency. The gain of conventional antenna was very low of -13.77 dB. Two rectangular slots are introduced in ground to increase the gain of proposed antenna to 2.67 dB at 4.91 GHz frequency. The proper selection of separation at the corner arms "a" and "b" increases the depth of return loss. The maximum simulated gain is 3.86 dB. The resonant frequency with good return loss and gain is noticed by varying the location and measurements of the rectangular slots and lengths of the arms "a" and "b". The antenna design is easy and can be integrated with microwave circuits. The directivity plot is also observed to be similar over all the "phi" values.

## REFERENCES


1. G. A. Deshamps. **Microstrip Microwave Antennas,** *Third USAF Symposium on Antennas,* 1953.
2. W. F. Richards, Y. T. Lo, and D. D. Harrison. **An improved theory for microstrip antennas and applications,** *IEEE Transactions on Antennas and Propagation*, vol. AP-29, no. 1, pp. 38-46. Jan. 1981. https://doi.org/10.1109/TAP.1981.1142524
3. P. Moosavi and L. Shafai. **Characteristics and design of microstrip square ring antennas**, *Proceedings of 5th Iranian Conference Electrical Engineering (ICEE97),* Tehran, Iran, May 7-9, 1997.
4. M. A. S. Alkanhal and A. F. Sheta. **A novel dual-Band reconfigurable square-ring microstrip antenna,** *Progress In Electromagnetics Research, PIER*, vol. 70, pp. 337-349, 2007.
5. L. Li, S. Ye, J. Xu, Y. Hao and L. Guoy. **Split-ring resonator-based compact microstrip antenna,** *Modern Physics Letters B*, vol. 33, no. 4, pp. 1-9, Jan. 2019.
6. J. S. Khinda, M. R. Tripathy and D. Gambhir. **Improvement in depth of return loss of microstrip antenna for S-band applications,** *Journal of Circuits, Systems, and Computers*, vol. 27, no. 4, pp. 1-16, Aug. 2017. https://doi.org/10.1142/S0218126618500585
7. P. Pathak and P. K. Singhal. **Compact broadband monopole antenna for C band applications,** *Advanced Electromagnetics*, vol. 7, no. 5, pp. 117-123, Dec. 2018.
8. G. V. Raviteja. **An insight into impact of partial ground and dual trapezoidal slots on bandwidth and gain considerations for a microstrip antenna array for WiMax application,** Advanced Electromagnetics, vol. 7, no. 5, pp. 111-117, Dec. 2018.
9. B. Ebstein and G. M. Stone. **800 MHz for public safety-design considerations for conventional systems**, *32nd IEEE Vehicular Technology Conference,* San Diego, CA, USA, 1982, pp. 339-353.
10. H. Mopidevi, D. Rodrigo, O. Kaynar, L. Jofre and B. A. Cetiner. **Compact and broadband antenna for LTE and public safety applications**, *IEEE Antennas And Wireless Propagation Letters*, vol. 10, pp. 1224-1227, Oct. 2011.
11. P. V. Naidu and A. Kumar. **ACS-fed e-shaped dual band uniplanar printed antenna for modern wireless communication applications**, *Radio Electronics Communication Systems*, vol. 61, pp. 87-93, Apr. 2018. https://doi.org/10.3103/S0735272718030019
12. G. Singh and A.P. Singh. **On the development of a modified triangular patch antenna array for 4.9 GHz public safety WLAN**, *Advanced Electromagnetics*, vol. 8, no. 4, pp. 24-31, Sep. 2019.
13. N. G. Akbar, O. Kanlioglu, V. Komanduri, J. T. Williams and D. R. Jackson. **Design of a dual-band uhf antenna for a multiband low-profile antenna system on public safety vehicles,** *IEEE Antennas and Propagation Society International Symposium*, Honolulu, HI, 2007, pp. 1000-1003.
14. X. Yuan, Y. Damgaci, H. Mopidevi and B. A. Cetiner. **RF-N/MEMS integrated reconfigurable antenna for public safety applications,** *IEEE Antennas and Propagation Society International Symposium, Charleston*, SC, 2009, pp. 1-4.

15. W. F. Young, K. A. Remley, C. L. Holloway, G. Koepke, D. Camell, J. Ladbury and C. Dunlap. **Radiowave Propagation in urban environments with application to public-safety communications,** *IEEE Antennas and Propagation Magazine*, vol. 56, no. 4, pp. 88-107, Dec. 2014.
16. T. P. T. Aguilar and Beadle M. **The microwave and RF characteristics of FR4 substrates,** *IEE Colloquium on Low Cost Antenna Technology (Ref. No. 1998/206),* pp. 2-6.
https://doi.org/10.1049/ic:19980078
17. A. Africa. **PCB/Microstrip antenna design and simulation,** *International Journal of Emerging Trends in Engineering Research,* vol. 7, no. 8, pp. 157-162, Aug. 2019.
https://doi.org/10.30534/ijeter/2019/09782019
18. K. V. Krishna, H. Khan and K. K. Naik. **A compact rectangular shaped dipole array slot microstrip antenna with DGS for multiband applications,** *International Journal of Emerging Trends in Engineering Research,* vol. 8, no. 2, pp. 408-413, Feb. 2020.
https://doi.org/10.30534/ijeter/2020/28822020