Slit Loaded Compact Shaped Patch Antenna for 5GHz Wireless Application

Sujata S. K. [1*] & P. S. Aithal [2]

[1] PDF Fellow, Institute of Engineering & Technology, Srinivas University, Mangalore, India.

& Assoc. Professor, Electronics & Communication, Sharnbasav University, Kalaburagi. India.

OrcidID: 0000-0001-5526-8141; E-mail: sujata.kamlapurkar@gmail.com

[2] Faculty, Institute of Management & Commerce, Srinivas University, Mangalore, India.

OrcidID: 0000-0002-4691-8736; E-mail: psaithal@gmail.com

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Sujata S. K. [1*] **& P. S. Aithal** [2]

[1] PDF Fellow, Institute of Engineering & Technology, Srinivas University, Mangalore, India.

& Assoc. Professor, Electronics & Communication, Sharnbasav University, Kalaburagi. India.

OrcidID: 0000-0001-5526-8141; E-mail: sujata.kamlapurkar@gmail.com

[2] Faculty, Institute of Management & Commerce, Srinivas University, Mangalore, India.

OrcidID: 0000-0002-4691-8736; E-mail: psaithal@gmail.com

ABSTRACT

Purpose: *The study and design of flexible patch antenna with different inset gap width fabricated on RT duriod 5880 substrate for fifth generation wireless application is presented in this article. The patch is composed of slits along the length and width separated by copper ground plane on backside and is directly fed by inset feed. The antennas resonated at multiband characteristics with better return loss (RL) suitable for fifth generation wireless and other indoor communication based applications. Radiation patters are nearly broadsided with a heart like shape for resonant band of frequency.*

Design/Methodology/Approach: T*he antenna is designed using a theoretical framework based on known equations as in literature. To construct and model the various antennas, the Computer Simulation Technology (CST) free student edition is employed.*

Findings/Result: *By the proposed simulated models, the slit based patch antenna design 1 has achieved dual band characteristics with bands namely: at* fr_1 *= 4.5 GHz (with return loss up to -30 dB) having bandwidth 1.5% and* fr_2 *= 10.5 GHz (with return loss up to -26 dB) having bandwidth of 2.2%. Whereas, the design 2 has again dual resonances at lower and higher frequency bands with the reduced return loss up to -23 dB at* fr_1 *= 4.5 GHz having bandwidth 1.5% and* fr_2 *= 12.5 GHz with return loss up to -17 dB having bandwidth of 14%. Hence, the antenna design 2 has achieved the maximum bandwidth of 14% suitable for wireless applications, RADAR, Fixed-satellite services.*

Originality/Value: *The design of slits cut on patch by varying inset feed width gap on flexible substrate for 5G frequency band is investigated.*

Paper Type: *Original Research Contribution.*

Keywords: Wireless system, Multiband, RT Duriod, Patch antenna, Slits

1. INTRODUCTION :

Thin, lightweight, high gain simple antennas are key factors in ensuring reliability, portability, mobility in today's wireless communication systems. So, Microstrip antennas meet all these criteria's to be suitable for wireless applications. Huque, M. T. I. et al., (2011), focussed on the microstrip antenna's features which include conformability to the mounting surface, relative ease of assembly, least weight, minimum cost for implementation and a thin projection of copper layer on the surface of the dielectric material. This antenna takes full advantages/ benefits from the concept of PCB technology. The use of microstrip antennas are found in satellite communication applications, radar and medical applications based wireless communication applications [1]. The main drawbacks of the microstrip antenna include constricted bandwidth nearly to 1%, low gain and high Q factor which make the antenna less efficient for 5G based applications. Robert J. Mailloux, et.al., (1981), discussed about the goal of microstrip antenna design is to maximise the desirable bandwidth while lowering the VSWR [2] by decreasing the mismatch between the input and load. This paper also reported the different feed methods so as to improve the characteristics of microstrip antenna. ChengChi Hu et al., (2000) reported an X-band 4x1 aperture coupled, series fed, electronically operable microstrip leak wave antenna (LWA) array design with dual beam radiation patterns and two-dimensional (2D) beam scanning capabilities. The proposed antenna array is suitable for wireless communications and radar systems [3]. K. Gi-Cho, et al. (2003) investigated the Ku-band, a linearly polarised microstrip array may achieve excellent efficiency by having correct impedance matching across the array and properly exploiting the corporate and series feeds by microstrip transmission lines. To achieve a somewhat broad bandwidth, the cavity-backed microstrip patch is utilised. In the azimuth orientation, the auto-tracking Ku-band antenna has created with a very low profile for car rooftop mounting, as well as a reduced production cost [4]. Abbaspour Tamijani, A., & Sarabandi, K. (2003) reviewed the design and manufacturing aspects of an affordable flat-beam steerable-array antenna with a simple design, stating that by way of grouping the elements of an array into a number of sub-arrays that partially overlap the array, and the use of a single-phase phase shifter for each sub-array will result in array size reduction and cost-of- production also [5]. By the use of moment method technique, the zero surface impedance and scattering characteristics of a patch antenna are investigated by Boufrioua A. and Benghalia A. (2006) [6]. The integral equation of the current is derived using the electric field boundary condition. Radar scattering cross-section (RCS) of the microstrip antenna as well as the effect of surface resistance and uniaxial substrate were studied. K. C. Lo and Y. Hwang. (1997), studied that compact version the patch antennas can be obtained (i.e., smaller in size) by using high permittivity materials [7] to be used in 5G applications. J. M. Rathod (2010), developed a 750 MHz centre frequency microstrip rectangular patch antenna on FR4 PCB dielectrics. The antenna employed a probe feed approach to feed power via a semi rigid coaxial cable with a 50-ohm impedance, with a completely copper plated PCB serving as the patch's ground plane [8]. The measure the radiation pattern, resonant frequency, bandwidth of an imperfectly conductive annular microstrip printed on a uniaxial anisotropic substrate, a full-wave approach was used [9] by Barkat O. and Benghalia A. (2009). The Galerkin's approach was also used to solve E-field integral equation. High efficiency and gain at millimeter wavelengths are the characteristics exhibited by microstrip superconductors. The results are compared to previously published data and are determined to be very similar [9]. Choon Sae L. and Kuo-Hua. T. (2005) explored hybrid antennas for broadband wireless devices with constrained antenna size. The prototype antenna has a bandwidth of 23.5 % and a steady radiation pattern with little cross-polarization. [10]. Islam, M. F. et al. (2010), presented a coaxially-fed single-layer small dual band (C- and X-band) microstrip patch antenna capable of having dual-polarized radiation for use in airborne synthetic aperture radar (SAR) systems. With a VSWR of less than 2, the constructed antenna reaches impedance bandwidths of 154 MHz (f0 = 6.83 GHz) and 209 MHz (f0 = 9.73 GHz) [11].

In the current work, the design of flexible patch antenna with different inset gap width fabricated on RT duriod 5880 substrates for fifth generation wireless application is carried out. The proposed design is able to function in at least more than two other frequency ranges satisfactorily, with wide bandwidth and better return loss. Details of the modelled antennas are described.

2. OBJECTIVE OF THE PAPER :

This work aimed to design antennas on RT Duriod 5880 material with slits cut on the patch to achieve the desired resonance suitable for fifth generation applications in lower frequency. In addition to the paper as listed in the literature review, so the designs are carried out within simulation constraints. The methodology applied in the designs will be studied to meet the following objectives:

(1) To study antenna characteristics like RL, 2D and 3D Radiation plots, SWR and current distribution.
(2) Slit-patch antenna compact design with inset excitation method.
(3) Modelling of antenna designs suitable for 5G wireless applications using computer simulation software (student edition).
(4) For antenna design in low frequency 5 GHz with varying inset width of the copper patch.
(5) To obtain multiple resonance with better SWR.

3. ANTENNA DESIGN PROCEDURE :

Antenna performance and its accuracy is always proportional to its size The resonant frequency, RL, SWR and factors are impacted by the chosen dimension of microstrip antenna. Firstly, convention design with inset-fed patch is considered and then slits are cut of this patch surface keeping its length and width unchanged. All prototypes are fed by a 50 Ω conventional connector in the CST software (student version) and are implemented on RT duriod 5880 substrate dielectric material.

To obtain efficient performance of patch, initially, patch (length *x* width) has to be mathematically calculated by equation 1&2 [12].

$$W = \frac{c}{2f_r}\sqrt{\left(\frac{\varepsilon_r+1}{2}\right)} \quad ---------- \quad (1)$$

The antenna patch length equation is written as,

$$L = \frac{c}{2f_r\sqrt{\varepsilon_r}} - 2\Delta l \quad -------- \quad (2)$$

At chosen frequency of operation, 5 GHz, the calculation yielded, the patch length and width (*A x B*) of the patch is (19.98 *x* 23.70 mm). The length and width of inset fed is optimized to get the better results as depicted in fig.1. The patch is designed on RT duriod 5880 substrate material of thickness h = 0.5mm and permittivity ε_r = 2.2. The slit dimensions are considered as a factor of free space wavelength (λ_o) as compared with conventional antenna intended design frequency i.e., 5 GHz.

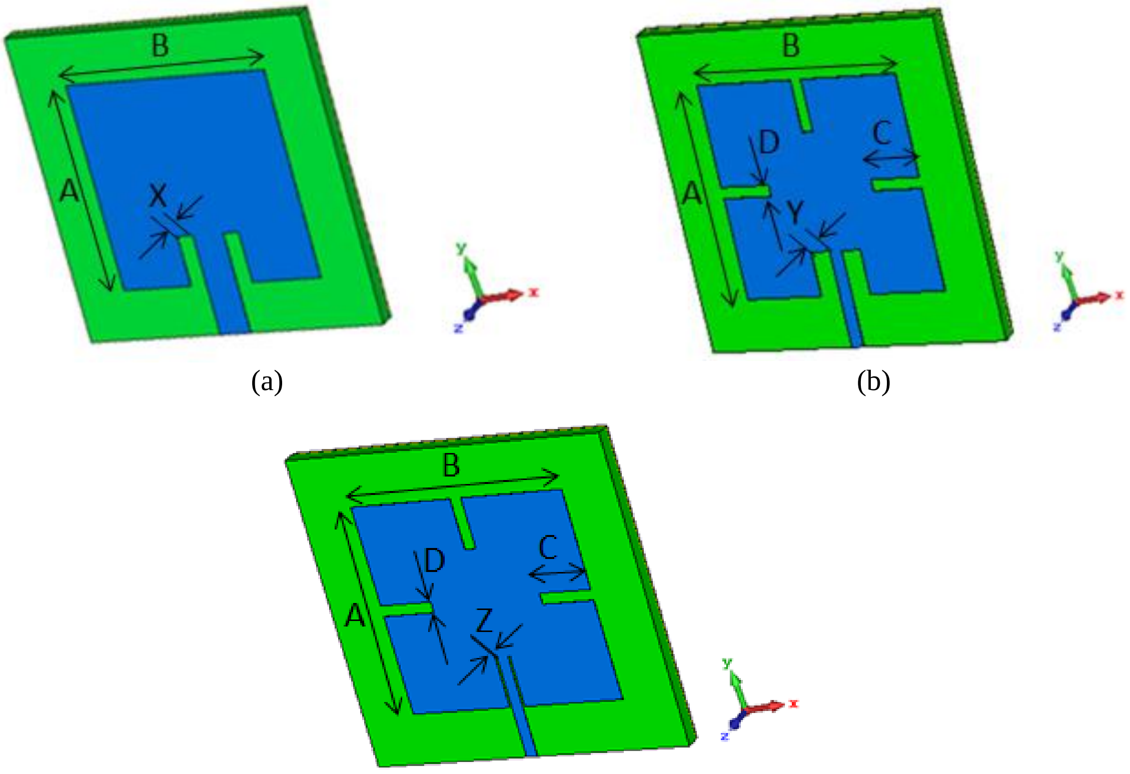


Fig.1: Geometry of Patch -top view. a) Conventional design, b) Design 1, & c) Design 2

The slit lengths and widths of design 1 and 2 are same (*C*) are 1 mm and (*D*) = 0.5 mm keeping the length, width of patch, inset feed line length and width unchanged as compared to the conventional design. In design 1, the inset gap in terms of width (*Y*) is increased to 0.4mm and in design 2, the inset gap in terms of width (*Z*) is decreased to 0.1mm as compared to the calculated inset gap in terms of width (*X* = 0.2mm).

4. RESULTS & DISCUSSION :

The plot of RL with resonant frequency (f_r) less than -10 dB of the designed antennas, which operate in 1 GHz to 20 GHz is shown in figure 2. Before and after cut of slits on patch, the fundamental resonant frequency splits into dual frequency bands in 1GHz-20GHz spectrum band. Figure 3 depicts the variations of return loss vs. frequency of a conventional design. In this case, first resonance is seen at fr1 = 5GHz, relatively to the specified 5GHz design frequency and so validates the design, as shown in the diagram. The bandwidths are calculated using the formula [3]. The bandwidth of conventional antenna is about 1 %.

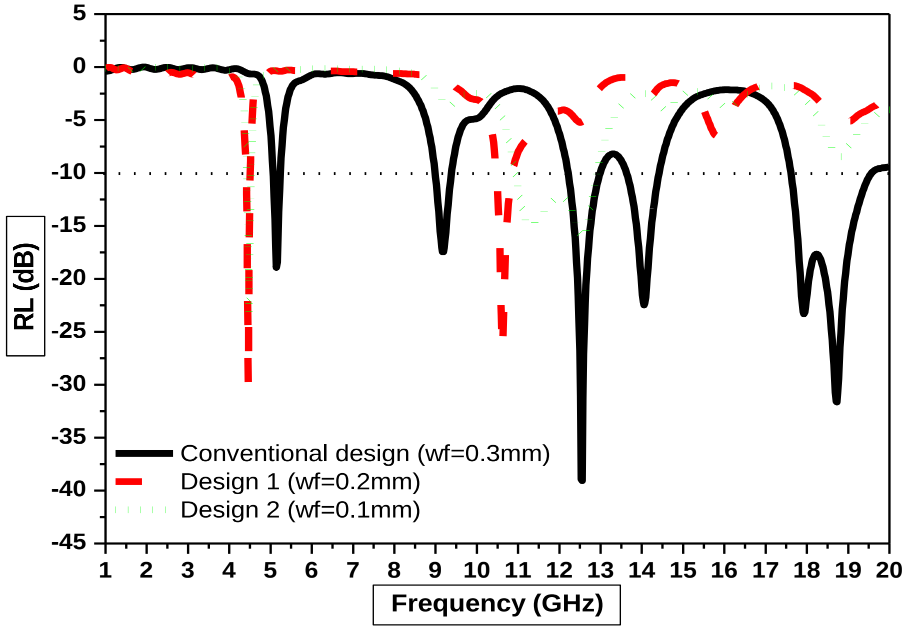


Fig. 2: RL Vs frequency of all three proposed antennas

The antenna resonates at five distinct resonances at fr_1 = 5 GHz (having RL= -18dB), fr_2=9GHz (having RL= -17dB), fr_3 = 12.5 GHz (having RL= -39dB), fr_4 = 14 GHz (having RL=-27dB), fr_5 = 18.8 GHz (having RL= -32dB) with corresponding impedance bandwidths of BW_1 = 0.9 %, BW_2 = 1.8 %, BW_3 = 3.5 %, BW_4 = 3.8 % for RL= -29.30 dB, BW_5 = 12 % respectively for the conventional design as in figure 2. Later, four slits are cut on the patch surface with retaining similar patch dimensions as that of conventional design with increased inset gap of the feed which is as shown in the figure 1.(b). With this configuration, the proposed antenna i.e., design 1, resonates for dual band response with the reduced return loss upto -30 dB at fr_1 = 4.5 GHz having bandwidth 1.5% and fr_2 = 10.5 GHz with return loss upto -26 dB having bandwidth of 2.2%.

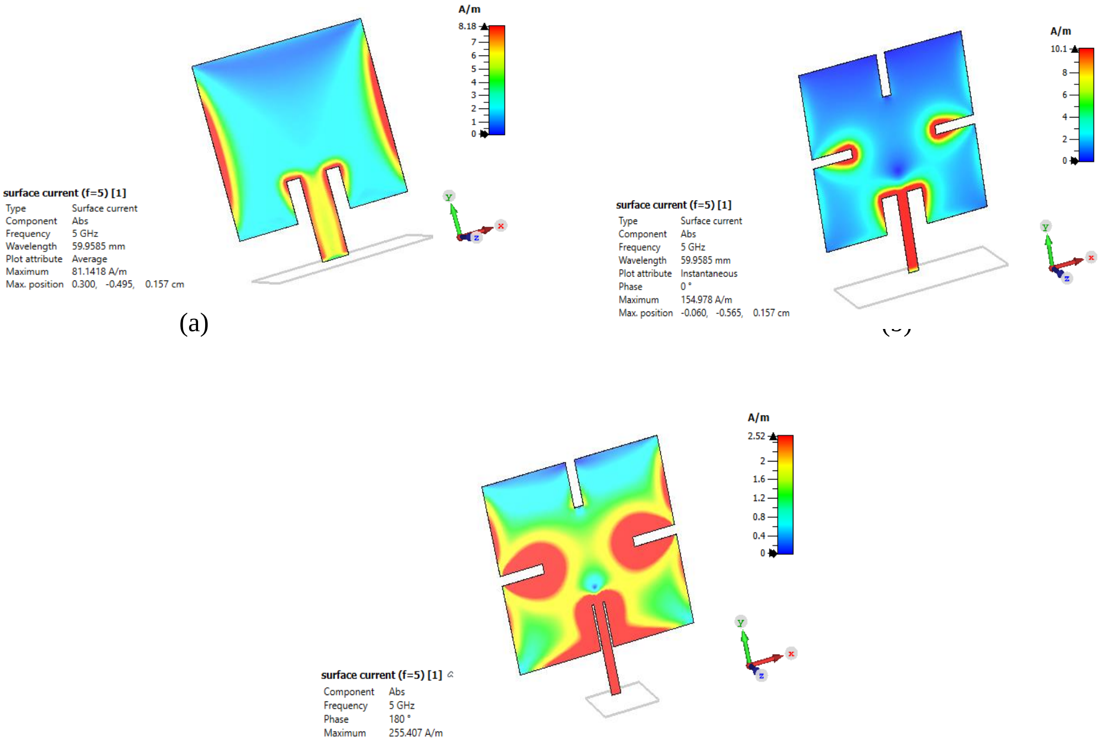
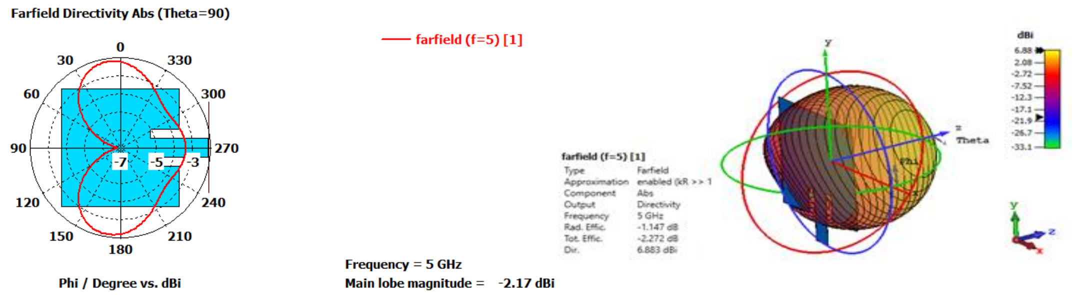


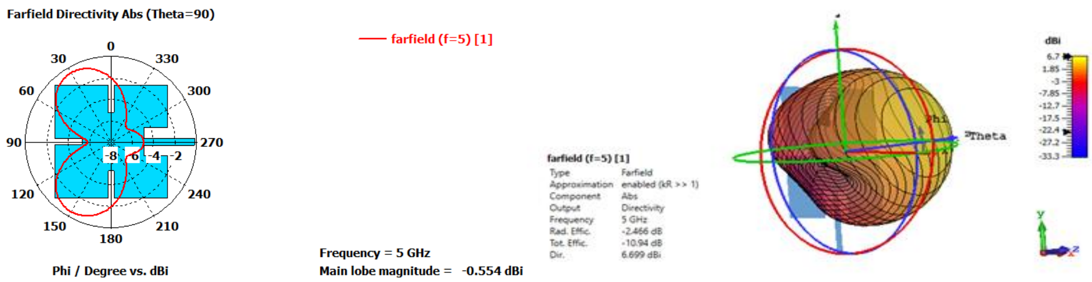
Fig. 3: Surface Current View (SCV) at 5GHz. a) Conventional design, b) Design 1, and c) Design 2

The design 2 shows the patch with four slits which are cut on the patch surface but now the width of the inset gap of the feed is decreased by retaining similar patch dimensions as that of conventional design which is as shown in the figure 1.(c). With this configuration, the proposed antenna i.e., design 2, resonates for dual band response with the reduced return loss up to -23 dB at fr_1 = 4.5 GHz having bandwidth 1.5% and fr_2 = 12.5 GHz with return loss up to -17 dB having bandwidth of 14%. The proposed antenna i.e., design 2 has achieved the maximum bandwidth of 14% suitable for wireless applications.

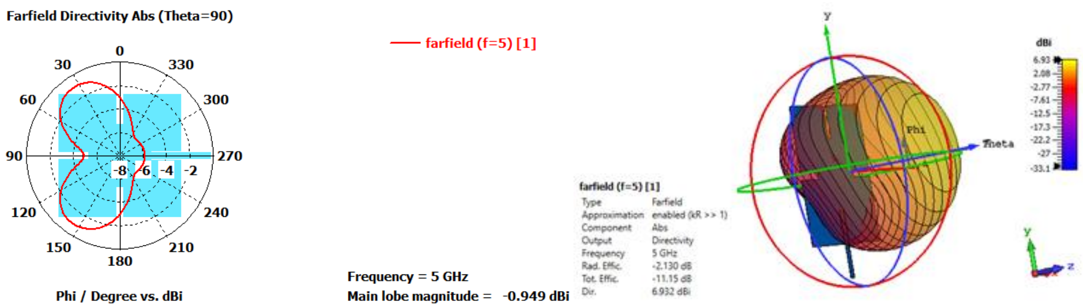
The Surface Current View (SCV) designs for conventional design, design 1, design 2 are shown in Figure 3. The surface currents are found to be more near the feed and along the patch-width as shown in figure 3(a). The surface currents slightly diminish near the feed with as the inset gap between the feed is increased but notably the currents also get excited on the portion of slits which are cut along the width of patch surface as shown in fig.3(b). The surface currents get more accumulated when the inset feed width gap is decreased to a minimum value (wf=0.1mm) and also along the slits cut on the width of patch surface making it a wide bandwidth antenna resonating at low frequency useful for wireless applications.



(a)



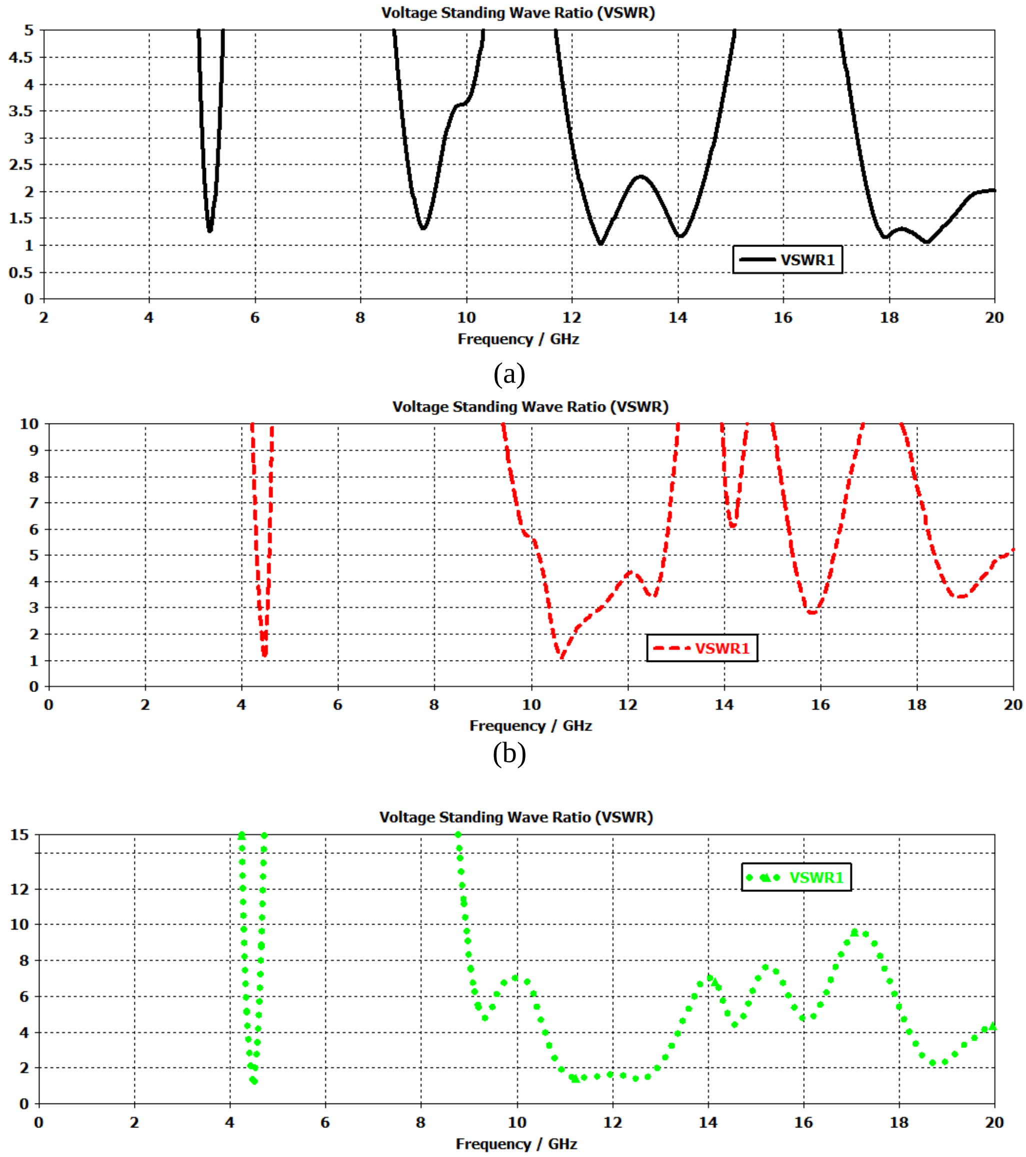
(b)



(c)

Fig. 4: 2D and 3D radiation patterns at 5GHz. a) Conventional design, b) Design 1, and c) Design 2

It is quite clear that, the all the three radiation plots as depicted in 2D and 3D nature at their respective resonance are nearly broadsided in nature with less cross polar levels for the proposed design as shown in figure 4. Figure 5 shows the plots of SWR which are less than 1.5 at respective resonant frequencies of all the three designs of the antenna which signifies less reflected power back to the antenna and also it is quite clear that the resonant frequency point which confirms a better match of input and load properties.



(c)

Fig. 5: SWR curve. a) Conventional design, b) Design 1, and c) Design 2

5. CONCLUSION :

The dual band characteristics of the slit-based patch antennas are proposed in this study. The design 1 has dual resonances at fr_1 = 4.5 GHz (RL= -30 dB) having bandwidth of 1.5 % and fr_2 = 10.5 GHz (RL= -26 dB) having bandwidth of 2.2 % and the design 2 includes two resonances at lower and higher frequency bands, with reduced return loss up to -23 dB at fr1 = 4.5 GHz and bandwidth of 1.5 %, and return loss up to -17 dB at fr2 = 12.5 GHz and bandwidth of 14 % for VSWR less than 1.5.

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