Design and Prototyping of A Compact 2S Shaped Dual Band Patch Antenna

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***Abstract*—A compact planar microstrip line fed 2S patch antenna has been designed and fabricated on the dielectric material substrate for D band applications. The proposed antenna is designed and analysed by using widely used finite element method based high frequency electromagnetic simulator HFSS. Measurement results show that the impedance bandwidths (return loss less than -10 dB) of the proposed antenna are 1.2 GHz ranges from 5.25 GHz to 6.40 GHz and 2.8 GHz from 10.9 GHz to 13.8 GHz. The simulated gain 2.09 dBi, 5.8 dBi, and 5.7 dBi with radiation efficiency 45 %, 64 % and 66 % have achieved at three minimum return loss frequencies 5.6 GHz, 11.5 GHz and 12.7 GHz respectively. The measured almost symmetric and stable radiation pattern makes the proposed antenna suitable for C, X, and Ku band applications. Furthermore, the effect of the size of cutting lots over the radiating patch on the return loss has been analysed.**

***Index Terms*—Patch antenna, finite element method, anechoic chamber, dielectric material.**

I. INTRODUCTION

In response to the increasing demand of compact, smart, lightweight, low profile multi-technology device microstrip line fed planar patch antennas receive a significant amount of research concentration to be integrated with small communication terminal [1]–[3]. The further demands of planar patch antennas are intensified due to low profile, simple structured, easy to design, manufacture and integration with circuit module [4], [5]. In order to integrate with the smart wireless communication devices, the planar patch antennas are needful to be low cost, compact and compatible for multiband applications. In literature different types of patch antennas were studied by several researchers such as circular slot antenna [6], circular ring [7], dual band dipole [8], metamaterial [9], stacked patch [10] etc. Most of these antennas are either narrow bandwidth, low gain or relatively bigger in size.

A substantial amount of research attention was focused on to design low profile, lightweight, less expensive, small patch antennas to integrate with multipurpose communication devices for more than one application. A 10 mm × 42.5 mm open ended slotted antenna for GSM900/DCS1800/PCS1900/UMTS and 2.4 GHz based WLAN applications [11]. This antenna has achieved 50 MHz (890 MHz–960 MHz), DCS1800 (1710 MHz–1880 MHz), PCS1900 (1850 MHz–1990 MHz), UMTS (1920–2170) and 80 MHz (2.40 GHz–2.48 GHz) respectively. A wideband monopole antenna proposed for multiband applications with the radiating patch dimension of 30 mm × 40 mm for GSM900, WLAN, WiMAX, SDM and WiMAX II [12]. A 22 mm × 25 mm tapered-shape slot Antenna designed on FR4 substrate for ultra wideband applications [13].

In this paper, a 20 mm x 15 mm compact 2S shaped slotted patch antenna fed by 5 mm × 1 mm microstrip line at 5.6 GHz, 11.5 GHz and 12.7 GHz respectively. The proposed antenna has measured impedance bandwidths 1.2 GHz and 2.8 GHz ranges from 5.25 GHz to 6.40 GHz and from 10.9 GHz to 13.8 GHz respectively. At three minimum return loss frequencies 5.6 GHz, 11.5 GHz and 12.7 GHz the proposed antenna achieved a peak gain 2.09 dBi, 5.8 dBi, and 5.7 dBi with radiation efficiency 45 %, 64 % and 66 % correspondingly.

II. DESIGN METHODOLOGY

Antenna design is one of the significant concerns of the increasingly growing multi-dimensional wireless technology industry. The inspiration of designing a microstrip patch antenna is electrically small, low cost, lightweight, compact and trouble-free antenna to be integrated with a wireless communication module operating for multiband applications.

TABLE I. DESIGN SPECIFICATION OF THE PROPOSED ANTENNA.

Parameter	Value	Parameter	Value
L0	20 mm	W0	15 mm
L1	4 mm	W1	2 mm
L2	2 mm	W2	4 mm
L3	2 mm	W3	4 mm
L4	4 mm	W4	2 mm
L5	5 mm	W5	1 mm

There are two methods widely used to design microstrip patch antennas such as, Finite Difference Time Domain (FDTD) based CST, Method of Moment (MoM) based IE3D

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and Finite element method (FEM) based HFSS [14]–[17]. The proposed antenna whas designed and analysed by using FEM based High Frequency Structure Simulator (HFSS).

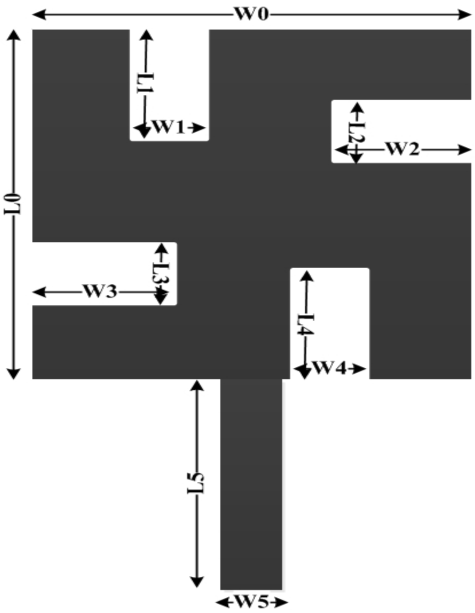


Fig. 1. Design layout of the proposed antenna.

The proposed antenna has designed with compact dimension on 1.6 mm thick low cost, market available polymer resin reinforced by fiberglass dielectric material substrate. The detail design specifications of the antenna are tabulated in Table I. Figure 1 shows the design layout of the radiating patch of proposed antenna. 2S shape of the radiating patch has obtained by cutting slots from the conventional rectangular patch. Initially, the basic idea of the overall size of the radiating patch was taken from the widely used mathematical modelling [18].

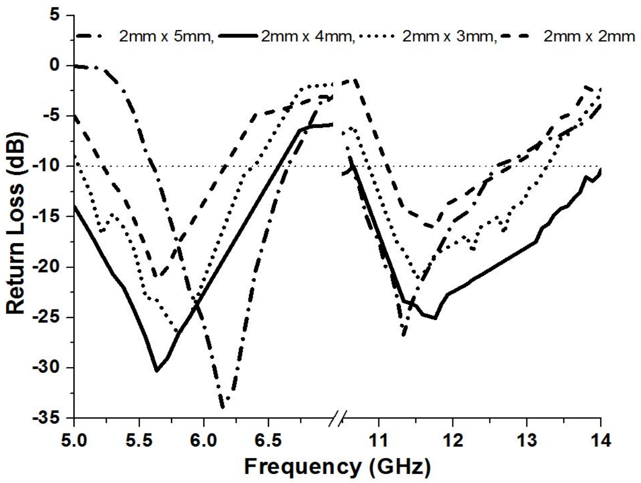


Fig. 2. Effect of the size of slots on return loss of the proposed antenna.

However, there no established mathematical formulation for slotted patch antennas, the dimension of the radiating patch and slots have determined and customized by using test and modify method. Figure 2 shows the simulated effects of different slot dimensions on return loss of the proposed antenna. It can be clearly seen that, 2 mm × 4 mm slots provide wider bandwidth and desired resonant frequency compare to others. Although, 2 mm × 5 mm slots achieved lower return loss value but the bandwidths are narrower in both upper and lower bands.

III. MEASUREMENT

Anechoic chamber is one of the most widely used Electromagnetic measurement systems [19], [20]. The results of the proposed antenna prototype have been measured in a rectangular shape 5.5 m × 5 m × 3.5 m anechoic measurement chamber. A double ridge guide horn antenna (SAS-571 from AH System Inc.) has used as reference antenna. The photograph of the anechoic measurement chamber has shown in Fig. 3.

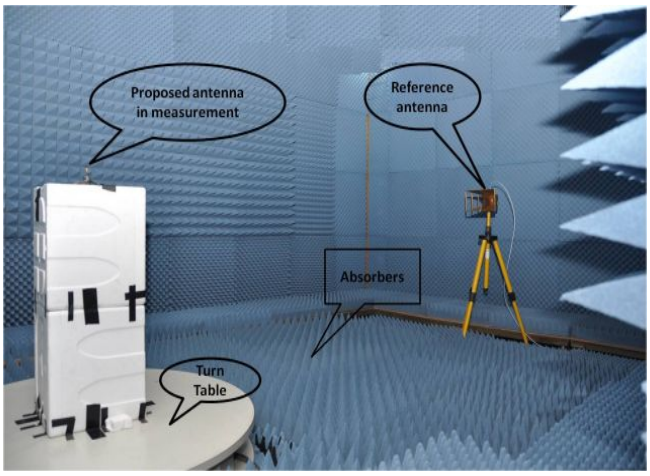
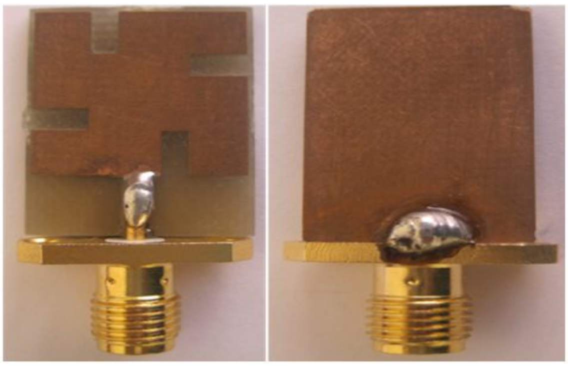


Fig. 3. Illustration of the anechoic measurement chamber.

Pyramidal shape electrically-thick foam absorber have used on the wall, ceiling and floor with less than -60 dB reflectivity at normal incidence. A turn table of 1.2 m diameter has used to rotate the measuring antenna with specification, 1 rpm rotation speed; 360° rotation angle connected with 10 meter cable between controllers. An Agilent vector network analyser (VNA E8362C) range up to 20 GHz has used for measurement procedure.

IV. RESULTS AND ANALYSIS

The performances of the proposed antenna prototype are obtained and analyzed by using Ansoft"s high frequency structure simulator HFSS v.13 and plotted in OriginPro 8.5. The proposed antenna has fabricated by using LPKF in the lab PCB fabrication machine and a standard 50 Ω SMA soldered on the end of the microstrip feed line using the handheld soldering tool. Figure 4 shows the photograph of the fabricated prototype of the proposed antenna. One of the most vital parameters of the antenna is return loss which is simulated and measured to realize the resonant frequencies, bandwidth characteristics. Figure 5 shows the simulated and measured return loss of the proposed antenna with respect to frequency. It can be clearly seen that, 1.15 GHz ranges from 5.25 GHz to 6.40 GHz and 2.8 GHz ranges from 10.9 GHz to 13.8 GHz at both lower and upper bands respectively. There is a little discrepancy occurred between simulated and measured return loss of the antenna. The possible clarification for this inconsistency can be due to the SMA soldering effect and losses introduced in the cable between antenna and controller.



(a) (b)

Fig. 4. Photograph of the proposed antenna prototype (a) radiating patch and (b) ground plane.

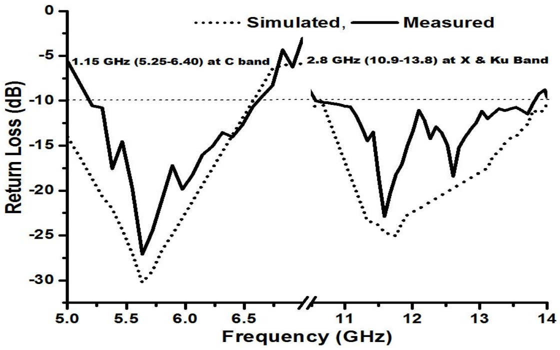


Fig. 5. Simulated and Measured Return loss of the proposed antenna.

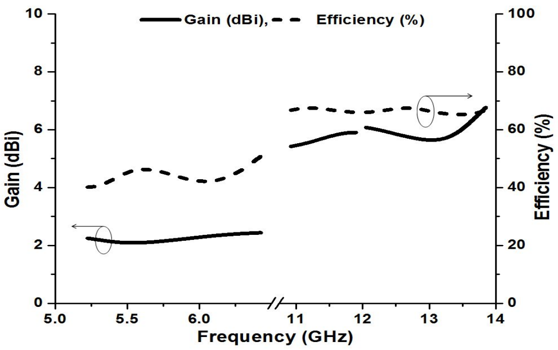


Fig. 6. Gain and radiation efficiency of the proposed antenna.

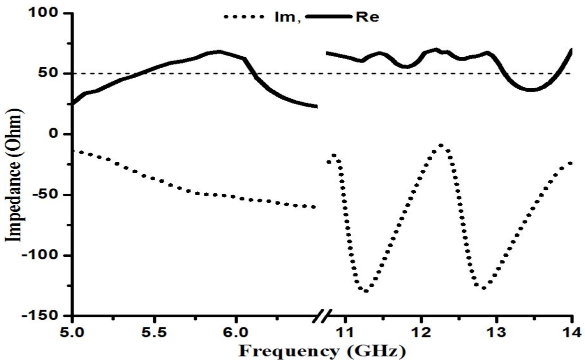


Fig. 7. Input impedance of the proposed antenna.

The simulated gain and radiation efficiency at both lower and upper bands are shown in Fig. 6. The recommended compact 2S shape antenna have achieved 2.09 dBi, 5.8 dBi and 5.7 dBi gains with 45 %, 64 % and 66 % radiation efficiencies at three minimum return loss frequencies s 5.6 GHz, 11.5 GHz and 12.7 GHz respectively. The gain and radiation efficiencies are increased at upper band compare to the lower band. The minimum variations of gain and radiation efficiencies at both upper and lower bands are realized. The input impedance characteristic of the proposed antenna is shown in Fig. 7. It can be understood from the graph that at three minimum return loss frequencies the real part of the input impedance is close to standard 50 Ohm. At the upper band the value of the real part is slightly increased that can be caused by the simulation setup and exciting port configuration. The measured E and H plane radiation pattern of the proposed antenna at three minimum return loss frequencies 5.6 GHz, 11.5 GHz and 12.7 GHz are shown in Fig. 8.

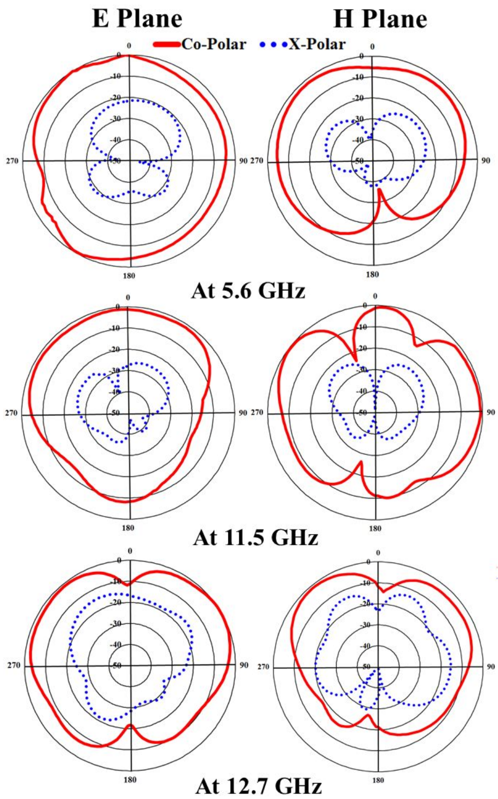


Fig. 8. Measured E and H plane radiation pattern of the proposed antenna.

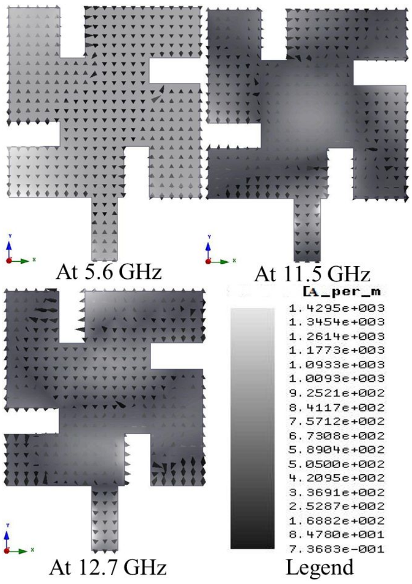


Fig. 9. Surface current distribution over the radiating patch of the proposed antenna.

The cross polar effect is minimum compared to Co polarization. At 12.7 GHz the cross polar effect slightly increased that can be caused by the instability of the dielectric properties of the substrate material at higher frequency. From the radiation pattern it can be understood that, in the lower band it is omni-directional that can be interpreted as lower gain. Whereas, in upper band the radiation characteristics are directive compare to lower band that conforms the higher gain. However, the radiation patterns are not sharply directional; the possible cause can be measurement constraints.

Surface current distribution over the radiating patch of the proposed antenna prototype is shown in Fig. 9.

It can be realized that at the lower band the intensity of the distributing current is stronger than upper band.

V. CONCLUSIONS

A dual band 20 mm × 15 mm planar 2S shape slotted patch antenna has been designed and fabricated on a ceramic material substrate. The performance results of the proposed antenna have measured in an anechoic chamber and analysed. From the measurement result it has been observed that, -10 dB return loss bandwidths 1.2 GHz (5.25 GHz–6.40 GHz) and 2.8 GHz (10.9 GHz–13.8 GHz) with peak gains 2.09 dBi, 5.8 dBi and 5.7 dBi at three minimum return loss frequencies 5.6 GHz, 11.5 GHz and 12.7 GHz respectively. The overall size of the proposed antenna is significantly reduced compared to other reported antennas and there is a scope to explore further miniaturization of the antenna by using high dielectric material substrate. Furthermore, the performance of the proposed antenna can further enhance reconfiguring the slots, shape and substrate thickness.

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