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Wine Glass Shaped CPW Fed Slotted Patch Antenna With DGS For 5G Communication

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Abstract – Due to high demand for wireless communication a wideband Microstrip antenna with compact size is designed for 5G Communication. In this paper a wideband patch antenna is designed and simulated using Ansoft HFSS software and modeled for experimental verification. The design is proposed with a Coplanar Waveguide fed and with a modified ground plane for 5G communication. Extending ground plane, the same antenna can be used for multifrequency operation. The proposed wideband antenna provides a bandwidth of 90.4% ranged from 1.28 GHz to 4.4 GHz, which is useful for 5G communication. The second proposed structure provides tetra frequency response with good reflection coefficient of 18.6 dB, -28.1 dB, -29.3 dB and -32.5dB at 3.96 GHz, 6.45 GHz, 8.29 GHz and 10.4 GHz respectively. Both the simulated and experimental results are found in good agreement.

Keywords - Microstrip patch antenna, Coplanar Waveguide fed, DGS, 5G communication, WiMAX.

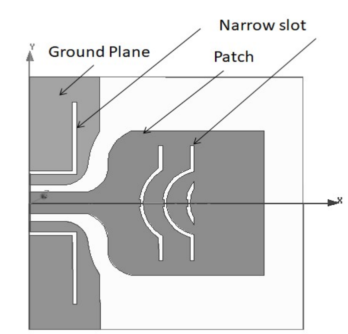
Introduction

There is a need of compact patch antenna to meet the frequency requirements of various wireless communications such as, GSM frequency band (800 MHz, 900 MHz, 1800 MHz, and 1900 MHz), WLAN (2.4-2.48 GHz, 5.49-6.45 GHz), UMTS (1.92-2.17 GHz), PCS standards (1.85-1.88 GHz) and also L- band (1-2 GHz), S- band (2-4 GHz) wireless application, X-band (8-12 GHz) application. Also these antennas are suitable for SHF Super High Frequency (10.4-10.64 GHz) application like Radars, Mobile phones, and commercial application. Researchers are carried out on the patches to produce multifrequency performance and also for wideband operation.

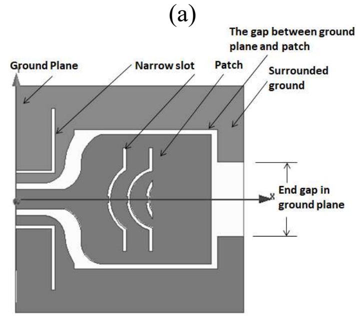
A CPW fed small monopole antenna is presented for 5G application [1]. To improve the bandwidth two square slots are inserted on the feed line and a spiral stub is inserted on one of the slots. A wideband microstrip antenna with truncated corners is presented [2]. To improve the antenna performances like reflection coefficient, bandwidth and gain, some L-shaped and T-shaped slots are inserted in the ground plane. A dual wideband CPW fed slotted square patch antenna is modelled for wireless and satellite applications [3]. An L strip, a rectangular slot and a pair of spiral slots are embedded in ground plane to obtain circular polarization and to enhance the bandwidth. A microstrip feed miniature multiband antenna is designed for WLAN and X-band application [4]. The antenna is designed with two arc-shaped strips and L-shaped parasitic stubs and a par- tial ground plane. A reconfigurable miniaturized multiband antenna with fractal slot is proposed [5]. This antenna consists of a Koch fractal and slotted ground loaded with Complementary Split Ring Resonator (CSRR). The antenna can be operated for switch- able PS/GNSS/ Bluetooth/ WiMax/X-Band. By using a PIN diode in the ground plane frequency reconfiguration is done. A circular CPW fed Microstrip patch antenna with modified ground plane is proposed for triple band operation [6]. An inset fed rectangular patch antenna with modified ground plane is presented for 5G application [7]. A triple band CPW fed antenna is proposed. For triple band operation three nested loop elements are there [8]. By adjusting the dimensions of these nested loops center frequencies can be controlled. The can be used for Bluetooth, WiMAX and WLAN application. A wineglass shaped CPW fed wideband Microstrip ntenna is described having DGS with woodpile structure [9]. This antenna produces three resonant frequencies with maximum present bandwidth of 3 GHz.A coaxial feed E-shaped patch antenna is presented [10]. By using a washer, the probe inductor is compensated and 40% bandwidth is achieved. A semicircle fed flower-shaped patch antenna is presented [11]. At the four sides of a rectangular patch by introducing some flower petals the antenna can be used for wideband operation and 63% bandwidth is achieved. A CPW fed eye-shaped UWB antenna reported [12]. The antenna can be used for GPS bands, Wireless Medical Telemetry Service, WLAN applications. A G-shaped with coaxial probe feed tri-band rectangular patch antenna is presented [13].This antenna can be used for Microwave application. A dual band Microstrip antenna with inset feed is proposed here for 5G Millimeter-Wave application [14]. An overview of microstrip antenna which can be used for 5G broadband communication is discussed [15]. At the time of designing these types of antenna different issues, like fabrication restrictions, connector problems are faced. Here two antennas are reported those can be used for practical implementation. A circular ring patch antenna for triple-band operation [16]. Some small rectangular slots are introduced to improve antenna performances. This is suitable for X-band, Ku-band, and K-band applications. A planar CPW fed dual-band antenna for DCS/PCS, WCDMA/IMT, and WLAN application is presented [17]. Mainly the antenna is of a flared monopole antenna. Additionally, two sleeves are added for dual-band operation. In this paper, a wine glass shaped patch antenna with CPW fed is described which is shown in Figure 1. The slots are introduced on patch and ground plane to increase the bandwidth. Firstly CPW feed is used (Figure 1 (a)) with introduction of slots on the patch and the ground plane. With these configurations the antenna performs at two frequency bands (1.28-4.4 GHz, 8.2-9.8 GHz). The first frequency range indicates a wideband covering L and S bands with 90% bandwidth between -10 dB reflection coefficients. Finally, the ground plane is extended around the patch as shown in Figure 1 (b). With this configuration four resonant frequencies are obtained at 3.96 GHz, 6.45 GHz, 8.29 GHz and 10.4 GHz with reflection coefficient of-18.6 dB, -28.1 dB, -29.3 dB and -32.5dB, respectively, for the proposed structure. The simulated and measured reflection coefficient is shown. But bandwidth is decreased for the final structure from the previous designs. The bandwidth is 90.4 % of the lower band which is ranged from 1.28 GHz to 4.4 GHz. The bandwidth is 18% of the upper band which is ranged from 8.24 GHz to 9.82 GHz. The proposed antenna can be used for WLAN standards and WiMAX standards.

Antenna Design optimization of the Proposed Antenna using the Ansoft HFSS tool

The basic design consists of a wine shaped patch on a FR4 epoxy thin dielectric substrate (h=1.6mm,ε_r=4.4, and low loss tangent tan δ=0.02) as shown in Fig.1. The antenna is fed by a fan shaped coplanar ground plane as shown in Fig.1a. L-shaped narrow slots are introduced in the ground plane. Three non-linear narrow slots are cut on the patch. The centers of the slots are indented at the center by 0.5 mm. The structure is simulated using Ansoft HFSS software. The mouth of the feed is tapered for better impedance matching. The antennas shown in Fig.6.1 are designed with the Ansoft HFSS tools where dimensions of the antenna, width and length of the slots, position and spacing between the slots, number of slots, and also DGS are iteratively altered and best performances are obtained with the present design and reported in this thesis. Subsequently the ground plane is modified which partially embraces the patch as shown in fig 1b.The optimization of the design for multifrequency operation and reasonable bandwidth are obtained using the Ansoft HFSS software by changing the gap between the ground plane and the patch and also changing the end gap in ground plane[Fig.1b]. Typical optimum width of the slots is 1mm.



(a)



(b)

Figure 1 The slotted wine glass shaped structureSimple slotted CPW feed (a) (b) slotted CPW feed with surrounded ground

Experimental evaluation

The final structure is experimentally evaluated using a Network Analyzer. The radiation pattern is measured using a laboratory setup shown in Fig 2. The gain of the antenna is measured using three antenna method. The results of simulation and modelling using HFSS and those of experimentation are shown in Figs.3-5.

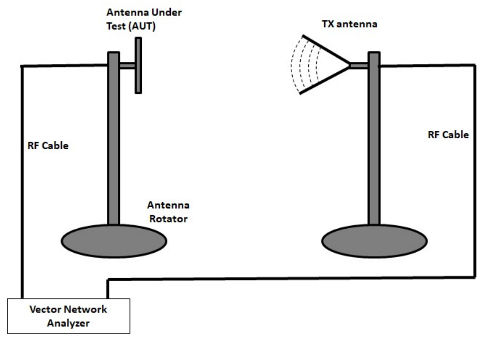


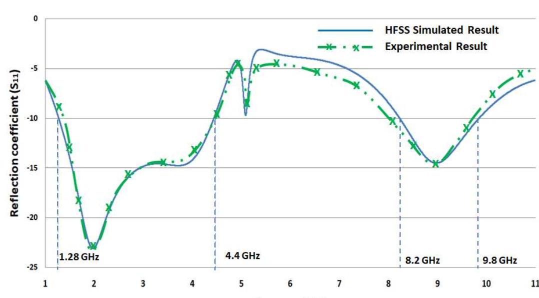
Figure 2 Radiation pattern measurement setup

Results and Discussion

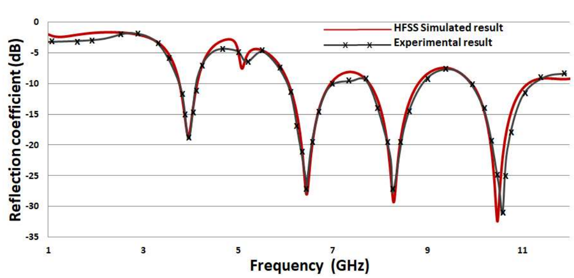
Fig.3 shows the reflection characteristics at the feed point in the HFSS platform along with the measurement results. Both the results agreed well within a maximum deviation f less than 2 dB at few points only. This shows good impedance matching of the antennas with the feed.

The antenna shown in Fig 1a operates at two resonant frequencies 1.96 and 8.9 GHz with reflection coefficient of -23.1dB and -14.8dB respectively. The impedance bandwidths at the corresponding frequencies are 90.4% and 18% respectively. The gain of the antenna at these frequencies is 3.8 and 2.1 respectively.

For the design of Fig b, there are four resonant frequencies 3.96GHz, 6.45GHz, 8.29GHz, and10.4GHz with reflection coefficient of -18.6dB, -28.1dB, -29.3dB, -32.5dB respectively. This shows that the second design exhibits quadruple resonant frequencies with bandwidth in the range of 9% to 12%. The experimental results match well with the results of simulation and modelling. The gain of the antenna at different frequencies is 0.6, 0.8, 1.5, and 2.3 GHz, respectively. Therefore the first antenna can be used at dual frequencies with large bandwidth. Whereas the second antenna can be used at our frequencies with smaller bandwidth for different wireless communication such as WLAN, UMTS, S-Band and X-Band.



(a)

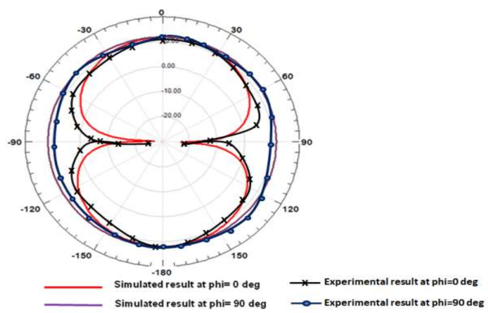


(b)

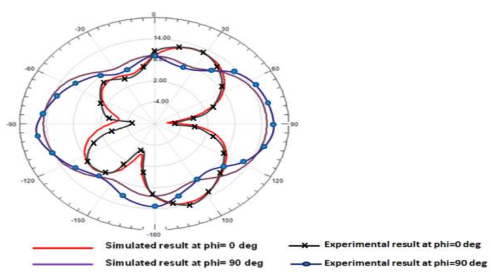
Figure 3 Simulated and measured reflection coefficient (S11) vs. Frequency (GHz) response for design of Fig.1(a) S_{11} for design of Fig.1 (a)

(b) S_{11} for design of Fig.1 (b)

The radiation patterns of these antennas are shown in Fig,4. Both the HFSS simulated and also the measured results are presented graphically. Experimentations are conducted with a Network Analyzer. The gain of the antennas is measured in three antenna method. Although the simulation and experimental patterns have a good match, there are some deviations due to experimental errors caused by ambient reflections. Omnidirectional pattern is obtained in y-z plane (phi=90 deg) and bidirectional pattern in x-z plane (phi =0 deg) as shown in Fig 4 and 5.

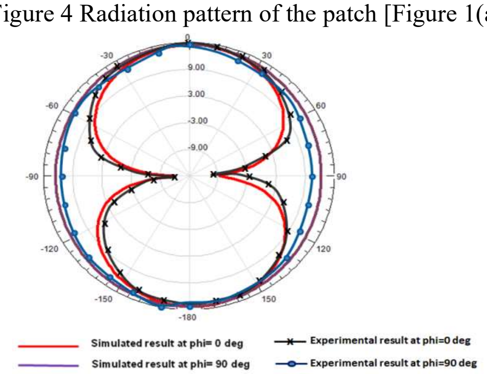


(a) f=1.9GHz

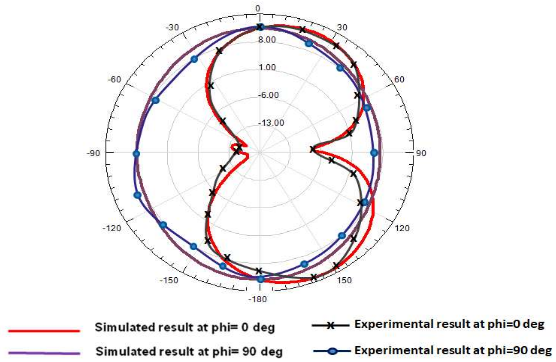


(b) f=8.9 GHz

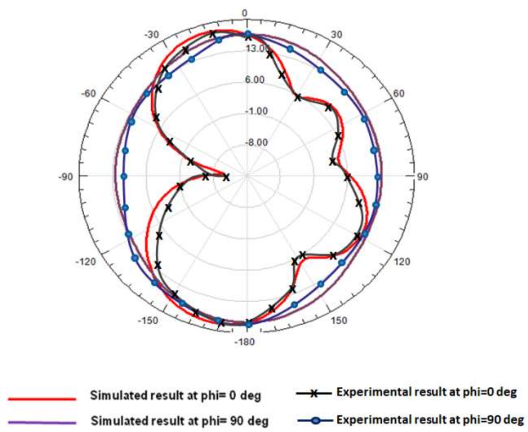
Figure 4 Radiation pattern of the patch [Figure 1(a)]



(a) f=3.96 GHz

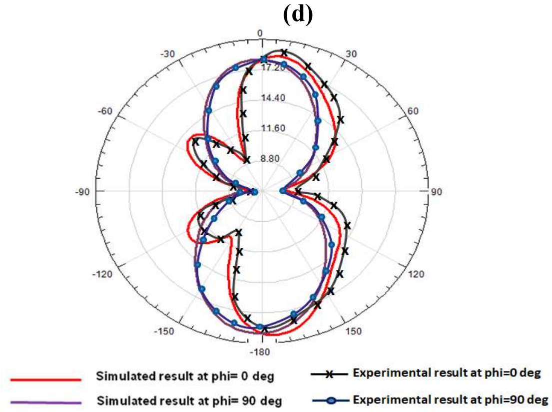


(b) f=6.45 GHz



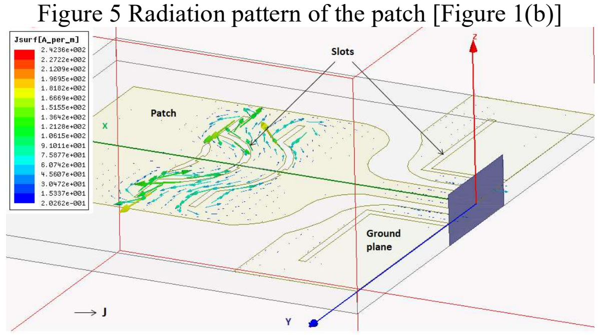
(c) f=8.29 GHz

(d)

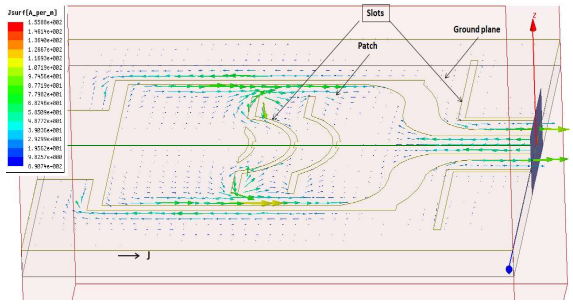


(d) f=10.4 GHz

Figure 5 Radiation pattern of the patch [Figure 1(b)]



(a)



(b)

Figure 6 Electric current distributions on the patch(a) Antenna of Fig.1 (a) (b) Antenna of Fig.1 (b)

To understand the effect of the slots at resonant frequencies the electric current distributions on the conductors are shown in Fig 6. It is observed that the direction of the currents along the inner and outer side of the slots are opposite, thus current cancelled by each other. Therefore the slots are not the radiator but behave like tuning elements producing multi frequency resonances.

Table 1 **Reflection coefficient (S_{11}), Bandwidth, and Gain**

Configuration		Operating Frequency (GHz)	Reflection coefficient (dB)	Band-width (%)	Gain (dB)
Fig1 (a)	**Simulated**	**1.96** **8.9**	**-23.1** **-14.5**	**90.4%** **18%**	**3.8** **2.1**
	Measured	**1.94** **8.8**	**-22.9** **-14.7**	**92%** **19%**	**2.9** **1.8**
Fig1 (b)	**Simulated**	**3.96** **6.45** **8.29** **10.4**	**-18.6** **-28.1** **-29.3** **-32.5**	**9%** **13%** **14%** **12%**	**0.6** **0.8** **1.5** **2.3**
	Measured	**3.95** **6.47** **8.32** **10.6**	**-17.1** **-28** **-27.8** **-31**	**9.1%** **12%** **13.4%** **11.3%**	**0.5** **0.7** **1.2** **2.1**

Table 1 shows Reflection coefficient (dB), % BW, and Gain of the antenna at specific frequencies where the return losses are minimum. These are the corresponding impedance matching points.

Figure 7 Hardware Design**Table 2 gives a comparative study between some wideband antennas and the proposed antenna. From the comparative report, is can be observed that the proposed antenna gives the satisfactory gain with wide bandwidth. Also, compared to the other antennas the proposed structure is also small in size.**

Table 2. Comparison between the proposed antenna and some other reported wideband antenna

Reference	**Operable band**	**Bandwidth (GHz)**	**Gain (dBi)**	**Application**
[7]	**Wideband**	**2.9042**	**9**	**Sensor application in wireless**

				communication
[8]	**Dual band**	**3.575**	**7.4 6.4 4**	**Wireless communication**
[10]	**Wideband**	**3.3**	**2.2**	**General**
Proposed antenna [Figure 1b]	**wideband**	**3.12**	**3.8 2.1**	**5G application, UMTS, PCS, L-Band wireless application, X-band application**

Conclusion

A wine glass shaped, CPW fed slotted patch antenna is designed and dimensions are optimized using the Ansoft HFSS Software tool. Antenna is fabricated on a FR4 glass epoxy substrate of height 1.6 mm, dielectric constant 4.4, loss tangent 0.02. Two design structures are reported. One design produces dual band operation with large bandwidth and other one exhibits multiband operation with reasonable bandwidth for application to wireless communication. Experimental evaluation of both the antennas is carried out using a Network Analyzer to verify the simulated results of reflection coefficients, bandwidth, radiation pattern and gain. A good match between the simulation results and the experimental one are found. The antennas are useful to wireless communication systems.

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