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Compact Rectangular Microstrip Patch Antenna with Defected Ground Structure (DGS) of Swastik Shape for LTE Applications

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Abstract

In this paper a novel compact antenna suitable for long-term evolution(LTE) applications is presented. In handheld devices. The radiating elements are two planar swastik shape constructed by a meandered line and folded patch with inter digitated capacitive strips connected to the folded patch. To achieve high isolation between the two radiating elements, a defected ground plane (a combination of rectangular slot ring and inverted T-shaped slot stub) is employed. The antenna is designed to operate in the 746-787 MHz, 1850-1990 MHz, 1920-2170 MHz, and 3600-3700 MHz frequency bands. The characterization of the antenna in free-space as well as in the proximity of the user head and hand is presented. The results confirm the excellent performance of the proposed diversity antenna.

Keywords: Diversity antennas, long-term evolution (LTE), multiple-input and multiple-output (MIMO) communication, planar inverted-F antenna (PIFA), wireless fidelity (Wi-Fi).

INTRODUCTION

Several wireless applications require miniaturized and multi-band antennas, in GSM, CDMA, GPRS, ISM bands. There are several techniques to realize multi-band characteristics. The rapid development of wireless communication systems has increased the demand for compact microstrip antennas with high gain and wideband operating frequencies. Microstrip patch antenna has advantages such as low profile, conformal, light weight, simple realization process and low manufacturing cost [1-2].

Many multiband antennas have been considered to coat a wide bandwidth. However, most of them could not cover the LTE700 band because the antennas required additional space, as the electrical length of $\lambda g/4$ is more or less 700 MHz [12]. A typical solution to this problem is the coupled-feed technique [13], [14], which generates a dual resonance mode of more or less 800 MHz to cover the GSM850/900 bands and even LTE700 operation. In this technique, a coupled gap among the feeding line and the radiator element is essential. Therefore, the ground consent of the antenna should be augmented. Alternatively, the electrically deficient length can be remunerated by increasing the height of the antenna [15], [16]. However, recent mobile devices need a compact size and low profile. Therefore, antennas with a large ground consent or three-dimensional (3-D) structure are not suitable for such devices.

However, the general microstrip patch antennas have some disadvantages such as narrow bandwidth etc. Enhancement of the performance to cover the demanding bandwidth is necessary [3]. There are numerous and well-known methods to increase the bandwidth of antennas, including increase of the substrate thickness, the use of a low dielectric substrate, the use of various impedance matching and feeding techniques, and the use of multiple resonators [4-5]. To overcome the above problem, a microstrip antenna structure with a typical semicircular shaped slot is proposed which exhibits three bands with good impedance bandwidth. Due to capacity problems in the conventional GSM 900 band used in mobile phone communication systems and narrow spectral bandwidth, operators had to use additional licenses for multi-bands operating frequency such as DCS 1800 (Digital Cellular system), UMTS 2100 (Universal mobile Telecommunication system), LTE (Long term evolution) in order to overcome these problems. Microstrip antennas are the most rapidly developing field in last thirty years [6] Currently, these microstrip antennas have many salient features / merits that have made them primary candidates for mobile cellular base stations including their inherent ease of mass construction, low cost and applicability to be used into array and multi-layer in order to generate multi-bands. In this paper, it is aimed to design a multi band antenna with semicircular shapes that will resonates at 0.9GHz, 1.8 GHz and resonate at 2.4 GHz with a modified ground structures. In order to create a resonate frequency in 2.4 GHz the ground plane had been modified as partial ground plane and also had a Defected Ground Structure (DGS). DGS is realized by introducing a shape defected on a ground plane so it will disturb the shielded current distribution depending on the shape and dimension of the defect. The disturbance at the shielded current distribution will influence the input impedance and the current flow of the design. The positions and lengths of the dumbbell sections control the response and insertion loss attenuation of the design.

Long term evolution (LTE) is a new wireless standard that is able to integrate MIMO technologies, and it could be incorporated into handheld phone applications [9][10]. LTE in the fourth generation (4G) of mobile handsets employs MIMO antennas to provide high-speed data transmission and high channel capacity [11]. As is well known, achieving a lower correlation coefficient is of critical importance in portable MIMO-embedded devices. As this correlation coefficient is directly related to the mutual coupling between multiple antennas, higher isolations between surface currents and radiation patterns from the antennas are required to obtain better MIMO channel capacity [7-8].

ANTENNA DESIGN

The design is simulated on Ansoft HFSS software to view the results of simulation. The designing of micro-strip antenna requires resonant frequency(f0), dielectric material and height of substrate(h). The proposed antenna is designed for frequency band 5.2 GHz. The substrate used is FR-4 having dielectric constant ($\in r$) 4.34 and height (h) 1.6 mm. High dielectric constant is used for size reduction. The antenna is fed by 50 Ω micro-strip line feed. It has a width W and length Lf. The design formulas as given in [2] are as follows

Step 1: Calculation of the Effective dielectric constant(€r):

Equation (1) gives the effective dielectric constant as:

$$\in_{eff} = \frac{\in_r +1}{2}(1+0.3*h) \quad (1)$$

Step2: Calculation of the Length of Strip (Ls):

The length of the Microstrip Antenna given by the equation (2)

$$Ls = \frac{0.42*c}{f_r * \sqrt{\in_{eff}}} \quad (2)$$

Step 3: Calculation of the Width of Ground plane(Wg):

The width of the ground plane can be calculated by the equation (3)

$$W_g = \frac{1.38*c}{f_r * \sqrt{\in_{eff}}} \quad (3)$$

Step 4: Calculation of the Length of Ground plane (Lg):

Here the length of the ground plane is obtained by equation (4)

$$Lg = \frac{0.36*c}{f_r * \sqrt{\in_{eff}}} \quad (4)$$

Step 5: Calculation of the Resonant Frequency (fr):

Resonant frequency (fr) is given by the equation (5),

$$f_r = 3 + \frac{2}{\sqrt{\in_{ref}}}\left[\frac{21}{Ls} + \frac{65}{Wg} + \frac{18}{Lg} - 3\right] \quad (5)$$

By using the Design Equations

3. Design of Rectangular Patch Antenna

The simulation was inhibited in the 1 to 10 GHz band. The HFSS model of Rectangular patch with swastik shaped ground which is shown in Figure : 1

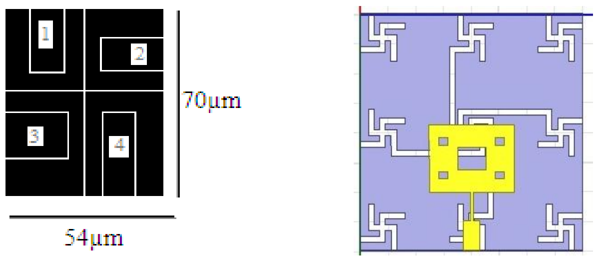

Figure 1: (a) Constructional details of swastika shape (b) designed in HFSS model of Swastik Patch 2nd iteration

The fabricated Rectangular Micro strip patch antenna with Structure slot on the ground is show in Figure : 2

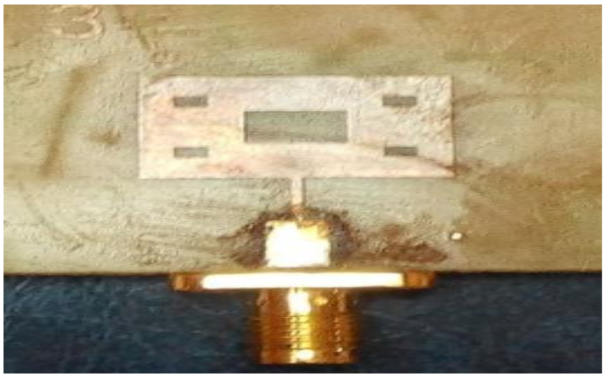

Figure 2: Ground Plane of Swastik Patch 2nd iteration

The fabricated Rectangular Micro strip patch antenna with Swastik Structure slot on the ground is shown in Figure : 3

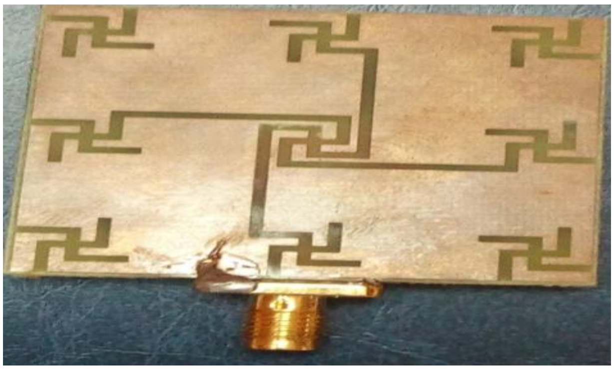

Figure 3: Fabricated prototype of the proposed Patch 2nd iteration

RESULTS

The Proposed antenna prototype is shown in Figure :3 is designed using the geometric parameters obtained by means of the parametric analysis presented above has been realized and simulated though Ansoft HFSS Software and measured various parameters using an Agilent VNA 5071 Network Analyzer.

A) Gain

Gain is nothing but the power transmitted per unit solid angle. The 3D gain of the 2nd iteration of in HFSS is shown in Figure : 4. Gain of any antenna should be more than 3dB for any applications. The Gain obtained for this antenna is 3.2133 dB.

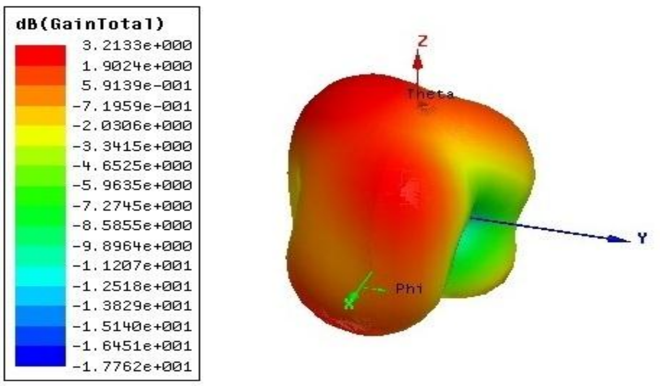

Figure 4: 3D-gain plot 2nditeration

B) Smith Chart

The antenna impedance is given as;

$$Z = \sqrt{\frac{L_{eq}}{C_{eq}}} \tag{6}$$

where , L_{eq} is the equivalent inductance and C_{eq} is the equivalent capacitance.

The smith chart explains the decrease in impedance as the capacitive reactance is indicated by the curve Thus, using equation 6, due to capacitive loading of the antenna, the impedance reduces. The smith chart for 2nd iteration Rectangular Micro strip patch antenna with Swastik Structure slot on the ground is shown in Figure : 5.

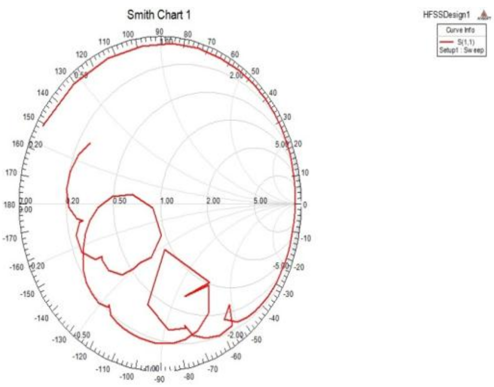

Figure 5: Smith Chart Curve of Z11 vs. frequency in the operating range of antenna by simulation

The experimental smith chart result for 2nd iteration Rectangular Micro strip patch antenna with Swastik Structure slot on the ground is shown in Figure : 6.

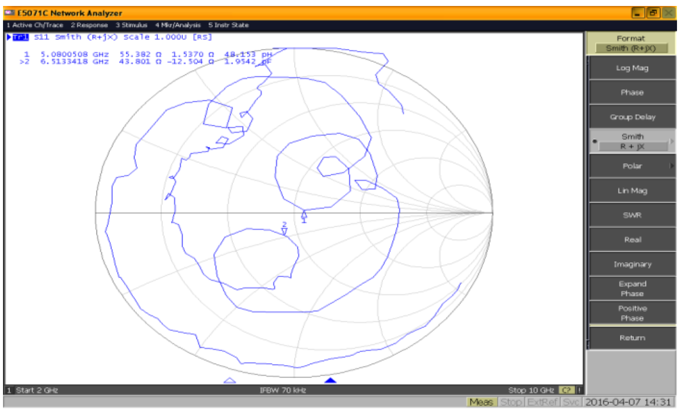

Figure 6: Smith Chart Curve of Z11 vs. frequency in the operating range of antenna on network Analyzer

C) Return Loss

The Return loss (RL) is a parameter which indicates the amount of power that is lost in the load and does not return as a reflection. The simulated result for 2nd iteration Rectangular Micro strip patch antenna with Swastik Structure slot on the ground are taken between 1 to 10GHz. The best return loss result obtained at 5.2GHz is -11.19dB and 8.1 GHz is -24.77dB and is shown in Figure : 7

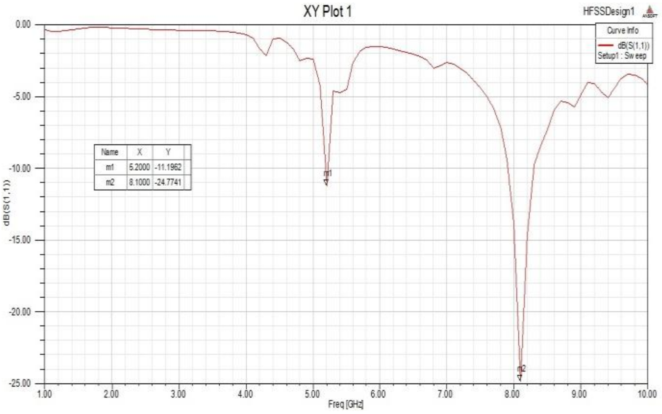

Figure 7: Return loss for 2nd iteration

The experimental results of Return Loss obtained for the antennas described above are taken between 1 to 10GHz. The best return loss obtained is -35.77dB at 5.08GHz and is -16.25dB at 6.51GHz is shown in Figure: 8

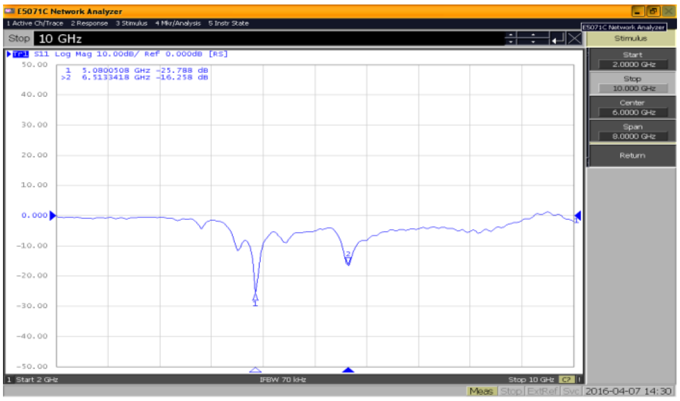

Figure 8: Return loss for 2nd iteration and is shown in Figure

D) VSWR

The VSWR is basically a measure of the impedance mismatch between the transmitters and antenna. The higher the VSWR, the greater is the mismatch. The minimum VSWR which corresponds to a perfect match is in unity. The VSWR of an antenna lies between 1 and infinity. For practical applications, it should be in between 1 and 2.As the best simulated return loss result is obtained at 8.1GHz, we took VSWR result at 8.1GHz is 1.009 and is shown in Figure :.9

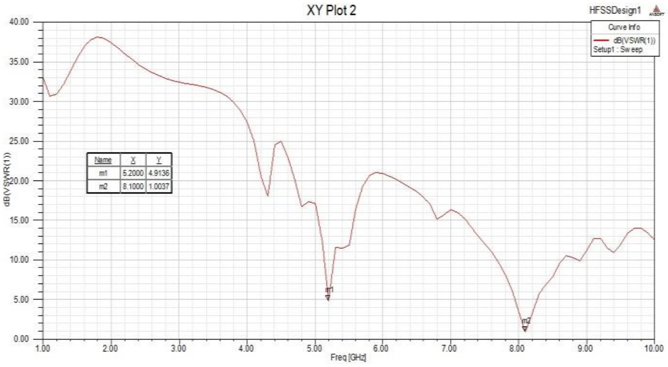

Figure 9: VSWR value for 2nd iteration

As the best experimental return loss result is obtained at 5.08GHz, we took VSWR result at 5.08GHz is 1.114 and is shown in Figure : 10

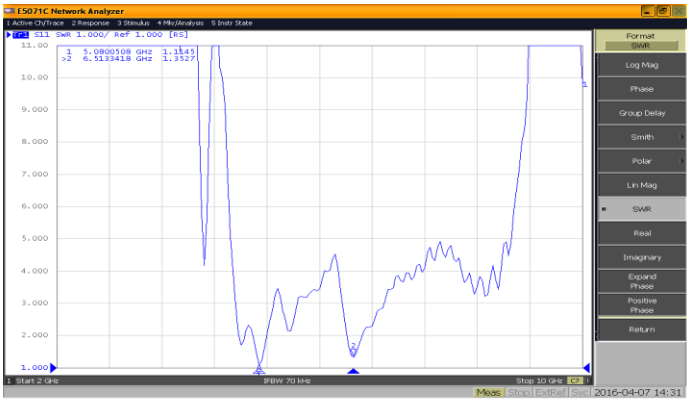

Figure 10: VSWR curve

E) Radiation Pattern

The term radiation pattern (or antenna pattern or far-field pattern) refers to the directional (angular) dependence of the strength of the radio waves from the antenna or other source. The radiation pattern for the 2nd iteration is shown in Figure: 11

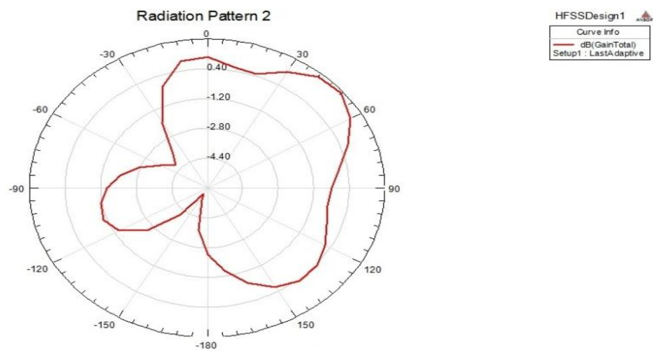

Figure 11: Radiation Pattern for 2nd iteration

Table 1: Rectangular micro strip patch antenna with swastik structure slot on the ground

	Solution frequency in GHz	Gain in dB	Return loss in dB	VSWR
Simulated results	5.20	3.2133	-11.19	1.009
Experimental results	5.08		-25.788	1.114

CONCLUSION

In this antenna, by using carpet one-third rule slots are kept on the rectangular patch and swastik shaped structure slot on the ground is designed. With this structure gain of the antenna is slightly improved when compared with other two antennas. It is used in wireless multi band applications as this antenna obtained multiband.

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