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Design of an L-Shape Slanted Dual-Band Microstrip Patch Antenna for Long-Term Evolution Wireless Application

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ABSTRACT—In this paper, an L-shape slanted dual-band microstrip patch antenna operating at the 2.1 GHz and 2.6 GHz bands for long term evolution (LTE) application is proposed. The flame-resistant type 4 (FR-4) substrate having a relative permittivity of 4.30 and loss tangent of 0.002 is considered for the design, which is probe feed by a 50-Ω microstrip, feed line. To achieve the lower band mode of 2.1 GHz and improve resonance at the upper band mode of 2.6 GHz, a slanted L-shaped slot is loaded onto the patch. Simulation results obtained using the computer simulation technology (CST) software shows that the -10 dB operation bandwidth at the 2.1 GHz and 2.6 GHz bands are 40 MHz and 110 MHz respectively. Furthermore, the gains achieved in the lower and upper resonance frequencies are 1.79 dB and 3.06 dB respectively.

KEYWORDS—microstrip patch, antenna, reflection coefficient magnitudes, radiation pattern, L-shape slot.

INTRODUCTION

Microstrip antennas are used in several wireless applications such as wireless local area network (WLAN) [1], Wi-Fi [2, 3], and Bluetooth [4, 5]. The development of wireless technology has grown to very large extent and it has been forecasted that increase in human population will lead to increase in internet access. The presence of service for higher data rate will be the solution to answer the needs. To overcome this issue, Long Term Evolution (LTE) technology was launched. The LTE will be the stride towards the fourth generation (4G) originated from radio technology, which is designed to enhance network capacity and speed [6, 7].

The 4G a successor of second generation (2G) and third generation (3G), promises a 100 Mbps data rates in mobile devices and is yet to shower its wonders on. In the case of 4G, extra features besides that 3G are included such as multimedia newspapers and the ability to watch T.V programs with the clarity as to that of an ordinary terrestrial TV. Unlike the 3G, which is based on two parallel infrastructures consisting of circuit switching and packet switching network nodes, the 4G is based on only packet switching thus, requires low latency data transmission. Furthermore, data are sent much faster than that of the previous 2G and 3G generations. It is expected to provide a comprehensive and secure all Internet Protocol (IP) based solutions [8]. The LTE provides downlink capacity of at least 100 Mbps and uplink capacity of at least 50 Mbps [4, 9]. It has been shown that through the years, since the very first mobile phone device (1G), the cellular mobile networks have had several changes to cope with user increase, system coverage, and the necessity to transfer different kind of data such as voice, video and data packets, and the desire to make the human-machine interface more amenable. At the same time, 3G technology was reaching its limit boundary and getting full of users. The necessity to create a new technology which increments the bandwidth and the data transfer rates was compulsory. The 4G technology appears as a framework established to try to accomplish new levels of user experience and multi-service capacity by integrating all the mobile technologies that exist. Even though the 4G and 3G technologies are at different frequency bands, mobile devices must be capable of working at both frequencies. This is because there is the risk of 4G signal loss at certain areas and some countries are yet to implement the 4G technology [8].

In the wireless communication system, the role of antenna is very crucial. Wireless technology application requires a small, light weighted, cheap and easy to install antenna, without compromising its performance [6, 9], the Microstrip antenna meets some of these requirements. A special quality of Microstrip antenna is its low profile and easy in realization. In this paper, a slanted L-Shaped dual band Microstrip patch antenna for LTE wireless application is proposed, the bandwidth of the propose antenna was improved by cutting away an L-shaped slot on the rectangular patch. Two resonant modes were achieved at 2.45GHz ad 2.6GHz. The antenna was design and simulated using computer simulation technology (CST).

The remainder of the paper is organized as follows: Section 2 presents the methodology for the design of the antenna while in Section 3, the simulation result and discussion is presented. Finally, the conclusion is presented in Section 4.

METHODOLOGY

In this section of the paper, the methodology for the design of the proposed antenna is presented. The rectangular Microstrip patch antennas is the commonly adopted shape in the design of a wideband antenna capable of operating in the microwave and millimeter wave frequency bands which is considered in this paper. Fig. 1 shows the structure of the proposed slanted L-shaped antenna on the rectangular Microstrip patch. The front view of the antenna contains a rectangular radiator of about 26.78 × 33.8 mm^2 in dimension which is fed through a 50 Ω feed line probe of about 11.6 × 1 mm^2 in dimension. On the back view, there is a ground plane of about 38 × 36 mm^2 in dimension with a substrate between it (ground plane) and the radiator. A flame-retardant type 4 (FR-4) substrate with a height of 1.6 mm having a dielectric constant of 4.30 and loss tangent of 0.002 is used due to its low cost and light weight. The larger dielectric constant in FR-4 helps in reducing the size of the patch.

The patch radiator is designed using closed-form equations for the fundamental mode in the following steps:

i. The width (W1) of the patch is calculated using (1).

$$W = \frac{c}{2f_o\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (1)$$

where: $\varepsilon_r =$ 4.30 is the relative permittivity of the dielectric substrate, c = speed of light in vacuum, and f_o= 2.6 GHz is the resonant frequency of the antenna.

ii. The length (L1) of the patch is determined using (2).

$$L = L_{eff} - 2\Delta L \quad (2)$$

Where: L_{eff} and ΔL are the effective length of the patch and the path length extension which are determined using (3) and (4) respectively.

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} \quad (3)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

where: ε_{eff} is the effective relative permittivity of the dielectric substrate and is determined using (5).

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\frac{1}{\sqrt{1+\frac{12h}{W}}}\right] \quad (5)$$

The h =1.6 mm in (5) is the height of the dielectric substrate.

iii. To achieve lower band of 2.1 GHz, the feed line is carefully placed at about 9 mm from the center of the patch.

iv. The length of the slanted-L slot is appropriately selected at about λ/4 of the 2.6 GHz fundamental mode, which corresponds to 7 mm (2*Ls*).

Based on the aforementioned design process, the parameters are transferred to the CST simulation software. The inclusion of the slanted-L stub can improve the upper resonant mode and by also moving the feed line of the antenna to the right-hand side (RHS) of the patch another resonance mode is achieved at 2.1 GHz. Specifically, the effects of the length *L*s on the upper resonant mode is obvious from the concept of λ/4 slot antenna. As the length is extended above the *Ls*, it results in total rejection in the upper frequency [11]. Additionally, the lower resonance mode is achieved by shifting the long narrow feed line to the RHS of the patch. The W2 in Fig. 1a provides the position of the feed line on the antenna [9].

Other parameters like *L*, *L1*, *Lf*, *W*, *W1*, *Ws*, and*Wf*, were adjusted through parameter tuning and the final sizes f the designed slanted-L Microstrip patch antenna is shown in Table I.

TABLE I. DIMENSION OF THE PROPOSED ANTENNA

Parameter	W	W_1	W_2	W_f	W_s	L	$L1$	L_s	L_f
Values (mm)	36	33.8	25.4	1	2	38	26.78	3.5	11.6

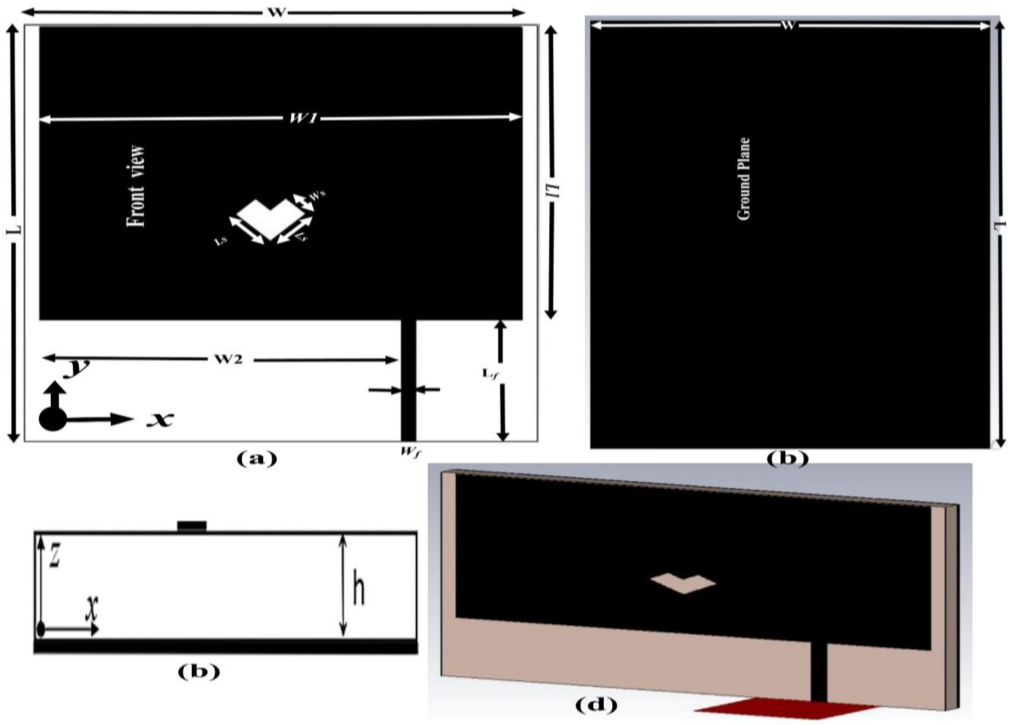
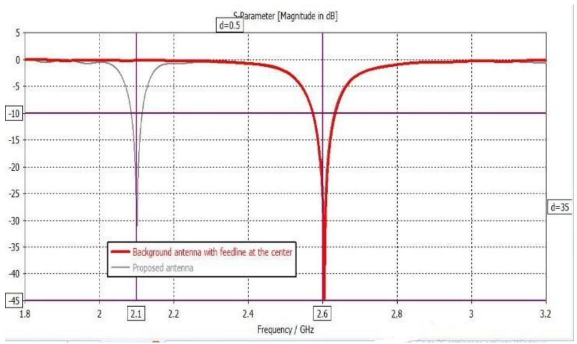


Fig. 1. Geometry of the proposed Antenna (a) Front view (b) Back View and (c) Side view. (d) Perspective view

SIMULATION RESULTS AND DISCUSSION

The initial characteristics and performance of the proposed antenna at -10 dB return loss that covers 2.08 – 2.12 GHz and 2.57 – 2.64 GHz as the lower and upper resonance frequency modes respectively, are presented in this section.

Fig. 2 shows the result of the reflection coefficient magnitude against frequency of proposed antenna and that of the background antenna obtained from the closed form model equations with its feed line at the center of the patch. The



background antenna has only one resonant mode at around 2.6 GHz that correspond to $|S_{11}|$ of about -28 dB. When the feed line is tuned to about 9 mm from the center of the patch a second lower resonance mode at about 2.1 GHz is achieved.

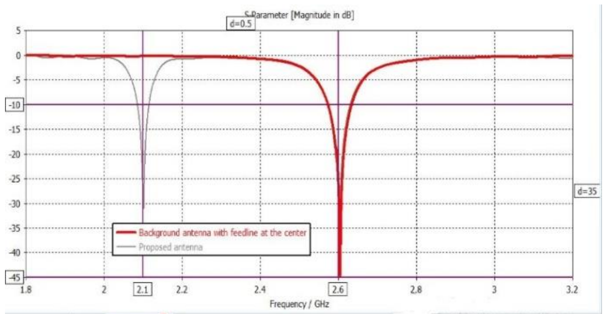


Fig. 2. Reflection coefficient magnitude against frequency for proposed and background antenna.

Fig. 3 shows the effect of the slanted-L slot cut at about λ/4 of the fundamental 2.6 GHz frequency band, and the $|S_{11}|$ increase from -28 dB to about -36.5 dB, which is presented in Fig. 4.

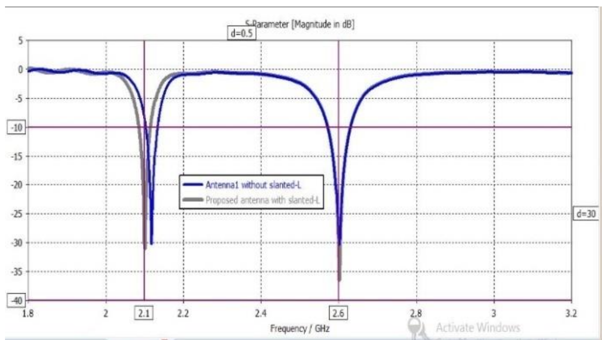


Fig. 3. Reflection coefficient magnitude against frequency showing the effects of slanted L-shape on the proposed antenna.

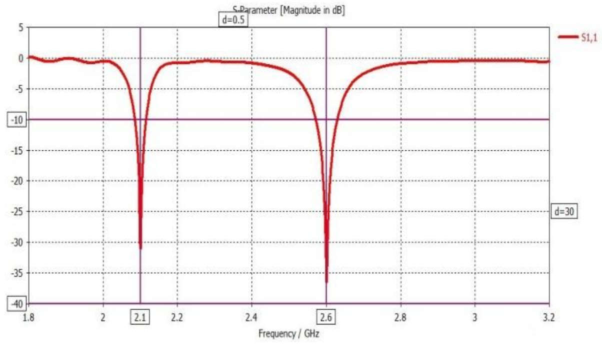
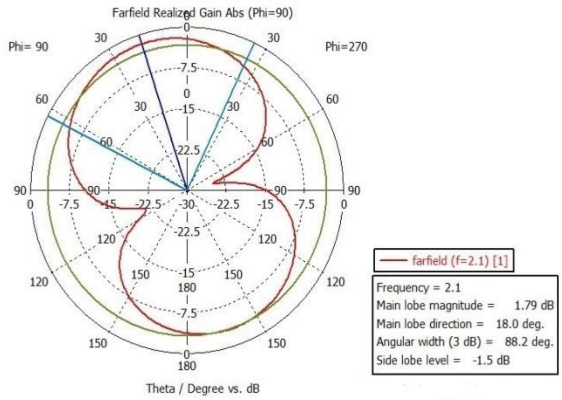
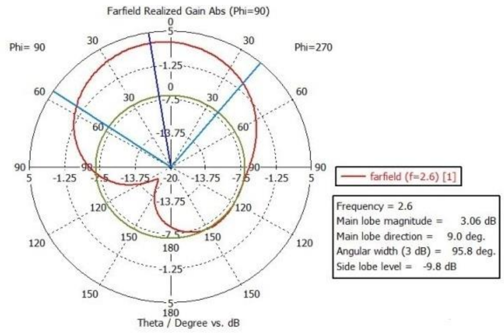


Fig. 4. Reflection coefficient magnitude against frequency for proposed antenna.

The radiation pattern shown in Fig. 5 indicate that, the proposed antenna has a maximum gain of about 1.79 dB and 3.06 dB at 2.1 GHz and 2.6 GHz respectively with a nearly omnidirectional pattern that can be used for wireless application in LTE access technology.



(a)



(b)

Fig. 5. Simulated 2-D radiation patterns (a) 2100MHZ (b) 2600MHz.

CONCLUSION

A new dual band slanted-L shaped antenna that operates at UMTS2100 and LTE2.6GHz frequency for LTE technology is proposed. The design antenna introduces a slanted L-shape at the center of the radiator to achieve the lower frequency. To improve the impedance matching, a 50 Ω feed line probe is shifted to right side of the patch. The total dimension of the proposed antenna is about 38 × 36 × 1.6 mm^3 which reasonable enough for wireless application. The proposed gain of the antenna in the lower and upper mode are around 1.79 dB and 3.06 dB respectively.

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