CAD Model and Simulation of T-Shaped Microstrip Antenna for LTE 1800MHz Applications

S. Malisuwan, J. Sivaraks, P. Promkladpanao, and Y. Thamachareon

***Abstract*—In this paper, the simulation of proposed T-shaped microstrip antenna is presented. The proposed procedure in this research includes frequency-dependent characteristic impedance in GHz frequency range in the standard microstip patch antenna design methods. The proposed antenna in this paper is designed for broadband 1800MHz LTE applications in the E-UTRAN band of 1, 2, 3, 4, 9, 10 and 11. The proposed procedure and designed formulas in this research are used to construct in-house MATLAB program software which is compatible with Computer Aided Design (CAD) with fast and user-friendly implementations.**

***Index Terms*—Microstrip antenna, T-shaped, frequency-dependent, LTE, 1800MHz, CAD.**

I. INTRODUCTION

In the modern day, mobile phones sizes have decreased in size and are light-weight. Due to this trend, components within the mobile phones are required to be small, light-weight and have low profile. Therefore, antennas used in mobile phones for personal communications are required to be small as well as are crucial as it can either improve or limit system preference due to the bandwidth and efficiency it provides. To carefully design a handset with superior performance, engineers must focus on the design of the antenna system of the mobile phone. The microstrip patch antenna is slim, light weight, easy for manufacturing and is suitable for small and light weight handsets.

"The microstrip patch antenna is a narrowband antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane" [1].. Narrow bandwidth is a serious limitation of the microstrip patch antennas. There are many successful attempts to improve the bandwidth, gain and efficiency of the microstrip antenna. These methods include variation in antenna dimensions, dielectric constant, substrate thickness and using parasitic patches [2]-[6].

The objective of this research is to design microstrip patch antenna suitable for using within LTE mobile terminals. In this paper, we present the design of T-shape patch microstrip antenna by cutting four notches in rectangular patch. By cutting the slots from a patch; gain, return loss and bandwidth of microstrip antenna can be improved [6]. The methods presented in this research are "fully compatible with the needs and trends of modern computer-aided design (CAD) [7].

Large numbers of radio spectrum bands have been reserved for FDD (Frequency Division Duplex) LTE use. Table I shows the 14 E-UTRAN band used by the LTE standard for each downlink and uplink for both UE (User Equipment) and eNB (evolved NodeB) with the minimum and maximum frequencies for downlink and uplink for every band [8]. Also it shows more than 18000 channels divided to these bands.

The proposed antenna in this paper will be utilized in broadband 1800MHz LTE applications. The 1800MHz frequency band is considered the prime option for LTE international roaming as 1800MHz band is widely available throughout Europe, APAC, MEA and some regions of South America-thus having the potential to be a core and global band for LTE deployments.

TABLE I: LTE FDD FREQUENCY BANDS

E-UTRAN Band	Downlink (DL) (UE Receive, eNB Transmit)		Uplink (DL) (UE Receive, eNB Transmit)	
	fDL_Low (NUL) (MHz)	fDL_High (MHz)	FUL_Low (MHz)	FUL_High (MHz)
1.	2110	2170	1920	1980
2.	1930	1990	1850	1910
3.	1805	1880	1710	1785
4.	2110	2155	1710	1755
5.	869	894	824	849
6.	875	885	830	840
7.	2620	2690	2500	2570
8.	925	960	880	915
9.	1844.9	1879.9	1749.9	1784.9
10.	2110	2170	1710	1770
11.	1475.9	1500.9	1427.9	1452.9
12.	728	746	698	716
13.	746	756	777	787
14.	758	768	788	798

II. ANTENNA DESIGN

To achieve the design objective in this research, first a rectangular microstrip patch antenna is constructed based on the standard designing procedure. For an efficient radiation a practical width of the rectangular patch element becomes [3]

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$$w = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} \tag{1}$$

And the length of the antenna becomes [8]-[10]

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{eff}}\sqrt{\varepsilon_0\mu_0}} - 2\Delta \tag{2}$$

where

$$\Delta L = 0.41h\frac{\varepsilon_{eff}+0.3}{\varepsilon_{eff}-0.258}\frac{\left(\frac{w}{h}+0.264\right)}{\left(\frac{w}{h}+0.8\right)} \tag{3}$$

And [11]

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+10\frac{h}{w}\right)^{-B} \tag{4}$$

where B is given by:

$$B = 0.564\left\{1+\frac{1}{49}\ln\left(\frac{\left(w/h\right)^4+\left(w/52h\right)^2}{\left(w/h\right)^4+.432}\right)+\frac{1}{18.7}\ln\left[1+\left(\frac{w}{18.1h}\right)^3\right]\right\}\left(\frac{\varepsilon_r-0.9}{\varepsilon_r+3}\right)^{0.053} \tag{5}$$

where, λ is the wave length, f_r (in Hz) is the resonant frequency, L and W are the length and width of the patch element, in cm, respectively and ε_r is the relative dielectric constant.

Prior to analyzing the frequency-dependent variables, the capacitance parameter in microstrip-line system should be analyzed.

A microstrip antenna consist of a dielectric substrate which is in between the radiating patch which is on top and the ground plane which is on the other side as illustrated in Fig. 1 material) and the shape varies. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

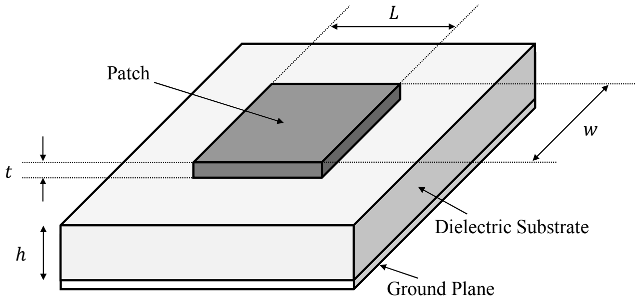

Fig. 1. Structure of a microstrip patch antenna.

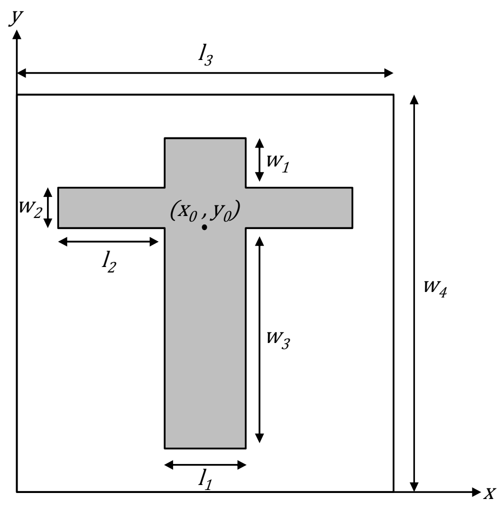

Fig. 2. Dimensions of designed antenna.

The capacitance per unit length of the classical parallel-plate capacitor is [9]:

$$C = \varepsilon\frac{w}{h} \tag{6}$$

A simple frequency-dependent capacitance of the parallel-plate capacitor can be expressed in any frequency-dependent attributes of ε which is

$$C(\omega) = \varepsilon_0\varepsilon^*(\omega)\frac{w}{h} \tag{7}$$

where $\varepsilon^*(\omega)$ is a complex permittivity is expressed as $\varepsilon'(\omega) - j\varepsilon''(\omega)$. Therefore,

$$C(\omega) = \varepsilon_0\varepsilon'(\omega)\frac{w}{h} - j\varepsilon_0\varepsilon''(\omega)\frac{w}{h} \tag{8}$$

Referring to the equivalent Cole-Cole diagram deduced for a parallel-plate microstrip line in is substitute into Eqn.(8). Hence,

$$C(\omega) = C\left(\frac{1}{1+Q(\omega)}\left[Q(\omega)+\frac{\varepsilon_{eff}}{\varepsilon_r}\right]\right) - j\frac{C}{\varepsilon_r}\left[\varepsilon''_u(\omega)+\varepsilon''_c(\omega)+\varepsilon''_d(\omega)\right] \tag{9}$$

where $C = \varepsilon_0\varepsilon_r(w/h)$.

For simplicity, the coefficients of Eqn.(9) are defined as follows:

$$A(\omega) = \frac{1}{1+Q(\omega)}\left[Q(\omega)+\frac{\varepsilon_{eff}}{\varepsilon_r}\right] \tag{10}$$

$$B(\omega) = \frac{1}{\varepsilon_r}\left[\varepsilon''_u(\omega)+\varepsilon''_c(\omega)+\varepsilon''_d(\omega)\right] \tag{11}$$

In general, the characteristic impedance of a transmission line is given by

$$Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}} \tag{12}$$

where R, L, G, C are per unit length quantities defined as follows:

R = resistance per unit length in Ω/m.
L = inductance per unit length in H/m.
G = conductance per unit length in S/m.
C = capacitance per unit length in F/m.

If G and C are neglected, the characteristic impedance can be written as:

$$Z_0 = \sqrt{\frac{L}{C}} \tag{13}$$

Frequency-dependent characteristic impedance is derived $\left(Z_0'(\omega)\right)$, the frequency-dependent capacitance $\left(C(\omega)\right)$of Eqn.(9) is replaced into the capacitance (C) in Eqn.(13). Therefore, frequency-dependent characteristic impedance is

$$Z_0'(\omega) = \sqrt{\frac{L}{C[A(\omega)-jB(\omega)]}} = \frac{Z_0}{\sqrt{A(\omega)-jB(\omega)}} \tag{14}$$

Now, the frequency-dependent (lossy) impedance can be derived through input of $Z_0'(\omega)$ in Eqn.(14) into the normalized terminal impedance expression as done in traditional Smith-chart model [10]. Therefore the normalized terminal impedance Z_L' is

$$Z_L' = \frac{Z_L}{Z_0'(\omega)} = br + jbx \quad (Dimensionless) \tag{15}$$

As r and x are the normalized resistance and normalized reactance, and $b = \sqrt{A(\omega) - jb(\omega)}$.

The voltage reflection coefficient of present Smith chart is

$$\Gamma' = \Gamma_r' + j\Gamma_i' = \frac{Z_L'-1}{Z_L'+1} \qquad (16)$$

Or

$$Z_L' = \frac{Z_L}{Z_0'(\omega)} = br + jbx = \frac{(1+\Gamma_r')+j\Gamma_i'}{(1-\Gamma_r')-j\Gamma_i'} \qquad (17)$$

The T-shaped microstrip antenna is fed by a coaxial probe. The advantage of using probe feeding is very easy to fabricate and relatively simple to model. Fig. 2 shows the designed dimensions of the proposed T-shaped microstrip patch antenna [6].

The procedure and formulas described above are used to construct in-house MATLAB program software. The calculated parameters are transferred to the software for simulation.

III. RESULT AND DISCUSSION

From Fig. 2, the designed specification for proposed T-shaped microstrip antenna is 53 × 53mm, patch size 42.5×42.5mm, dielectric constant (ε_r) of 4.2 and substrate thickness (h) 1.6mm as shown in Table II.

The final stage of the design process is to find the sub-optimum position where the required bandwidth is obtained. Finally, the feed point is at (28.45, 32.55). The return loss of the proposed antenna is shown in Fig. 3.

TABLE II: DIMENSIONS OF THE PROPOSED ANTENNA

Parameter	Value	
$l_3 \times w_4$	53×53	mm^2
patch size	42.5×42.5	mm^2
ε_r	4.2	
substrate thickness	1.6	mm
l_1	10.5	mm
l_2	16	mm
w_1	5.5	mm
w_2	5.5	mm
w_3	31.5	mm

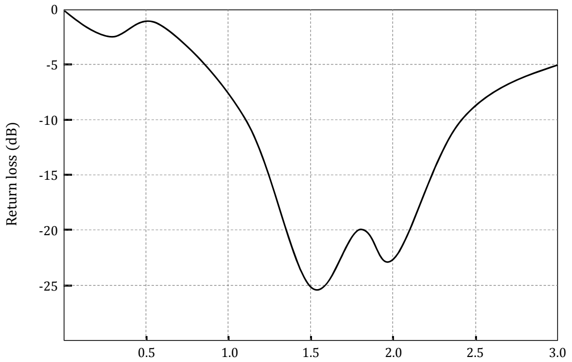

Fig. 3. Return loss of the proposed antenna.

The return loss is a way of expressing mismatch. It is a logarithmic ratio of reflected power to the power fed to the antenna. A bandwidth can be calculated from the return loss at -10dB. From Fig. 3, the bandwidth of the proposed antenna is 1.3GHz. The results indicate that the proposed T-shaped microstrip antenna can operate at the range of 1800MHz LTE communication systems.

As shown in Table I, it can be observed that the proposed antenna in this paper operates in the E-UTRAN band of 1, 2, 3, 4, 9, 10 and 11 thereby making it suitable for LTE applications.

IV. CONCLUSION

The results of this paper indicates that T-Shaped Microstrip Antenna is suitable for LTE deployment operating on 1800 MHz. 1800 MHz is a widely used throughout the world to be a core and global band for LTE deployments. In this research it can be observed that the proposed antenna in this paper operates in the E-UTRAN band of 1, 2, 3, 4, 9, 10 and 11 thereby making it suitable for LTE applications. The proposed procedure and designed formulas in this research are used to construct in-house MATLAB program software hence it is compatible with Computer Aided Design (CAD) and is fast and user-friendly for implementation.

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