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A Survey on Design of Compact LTE/ WWAN Antenna for Tablet Computers

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ABSTRACT: Long Term Evolution (LTE), is also known as 4G is a rapidly growing common global technology and it becomes attractive for modern mobile devices such as the smart phones, laptop computers a tablet computers. The internal antennas embedded in these modern mobile devices are smaller in size and hence they are usually demanding for practical applications. In this paper review of several promising LTE/WWAN antennas for tablet computers is given.

KEYWORDS: Tablet Computer Antennas, LTE antennas, mobile antennas, wideband antennas.

I. INTRODUCTION

Now a days, advanced handheld communication devices are looking forward to more compact antennas that cover all their imperative frequency bands. Almost all modern portable devices have a Wi-Fi capability for wireless connectivity. The new long term evaluation (LTE) band in 4G wireless communication has attracted considerations due to greater amount and higher speed of transmission. The LTE operating bands include wide lower band of 698-960 MHz, wide middle band of 1710-2690 MHz, and wide higher band of 3400- 3800 MHz. In this survey paper we discuss different LTE antennas for tablet computers.

II. LITERATURE SURVEY

Various multiband antennas for portable devices such as Laptop computers, Tablet Computers and mobile handsets have been proposed in literature recently. In [1] Jiu-Han Lu et al proposed a small-size uniplanar antenna with eight-band LTE/GSM/UMTS operation in the tablet computer with the use of an internal printed loop matching circuit. The antenna has a size of 45x15x0.8 $mm^{3.}$ The operating bands can reach about 262/1610 MHz for the LTE/ GSM/UMTS bands, respectively. In [3] Jiu-Han Lu et al proposed a novel design of a planar multiband monopole antenna with dual parasitic shorted strips for LTE/WWAN operation in the tablet computer with the antenna size of 45x15x 0.8mm^3 . The operating bands can reach about 255/980 MHz for the LTE/WWAN bands, respectively. In [4] Navid Amani et al proposed an internal uniplanar small size multiband antenna for tablet/laptop computer applications. The proposed antenna in addition to common LTE/WWAN channels covers commercial GPS/GLONASS frequency bands. The antenna has a size of 50x11x0.8 mm^3. In [5] Ting Zhang et al proposed a new multi band planar antenna with a compact size. The proposed antenna consists of a two-strip monopole and a meandered strip antenna which occupy a compact area of only15 mm x 42 mm^2. In [6] Wen-Shan Chen et al, proposed a Wireless Wide Area Network (WWAN) and Long Term Evolution (LTE) eight-band antenna for portable wireless devices. The two wide operating bands can be employed in LTE 700/GSM 850/900/1800/1900/UMTS/LTE 2300/2500 applications. The antenna occupies a volume of 75x 10x 0.8 mm^3. In [7] Y.L.Ban et al proposed novel eight band LTE/WWAN frequency reconfigurable antenna for tablet computer applications. The antenna has a small dimensions of 40x12x4mm^3. In [8] Y.K.Park et al proposed a reconfigurable antenna using two PIN diodes for quad-band (GSM900/GSM1800/GSM1900/UMTS) mobile handset applications. The proposed antenna has a size of 45x11x6 mm^3. In [9] Yue Li et al proposed a folded loop-inverted F reconfigurable antenna for mobile phone applications. . In a compact volume of 60x5x5mm^3 , the

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proposed antenna operates in hepta-band, including GSM850, GSM900, GPS, DCS, PCS, UMTS and WLAN, with the return loss lower than 6 dB.

III. PLANAR SMALL-SIZE EIGHT-BAND LTE/WWAN MONOPOLE ANTENNA FOR TABLET COMPUTERS

The geometrical configuration of the planar compact multiband antenna for LTE/WWAN operations in a tablet computer is illustrated in Fig. 1. The monopole antenna (MA) is printed on the same side of an FR4 substrate with the dimensions of 35x10x0.8 mm^3 and mounted on the top-right corner of the display ground with a distance of 37.15 mm to the centre line of the ground plane. A 0.2-mm-thick copper plate is used as the display ground, which is commercially available for a 9.7-inch tablet computer. The small-size monopole antenna (MA) consists of a G-shaped driven monopole and an inverted L-shaped parasitic strip shorted at point E. A 50-Ω mini coaxial line is connected to the feeding point (point A) of the G-shaped driven and the display grounding point (point B) to excite this monopole antenna.

First the upper meandered arm of the inverted L-shaped parasitic shorted strip (i.e., section EFG) contributes to its fundamental (0.25-wavelength) resonant mode at around 750 MHz with a higher-order resonant mode at approximately 2460 MHz. Then, to widen the impedance bandwidth for the lower operating band (LTE700/GSM900 MHz), another inverted L-shaped parasitic shorted strip (section EFH) is introduced and coupled by the G-shaped feeding strip with the gap of G1 to generate the fundamental (0.25-wavelength) resonant mode at approximately 940 MHz band.

Next, by introducing the lower/upper strips (section AC and AD) of the G-shaped driven monopole, 1695/2148 MHz modes are then excited as the first and second operating modes of the upper band. The MA is optimized by using Ansoft HFSS, a commercially available software package based on the finite element method. Fig. 1 displays the design parameter values obtained by the above strategy. Moreover, the reflection coefficient and input impedance of the proposed MA are measured using an Agilent N5230A vector network analyzer.

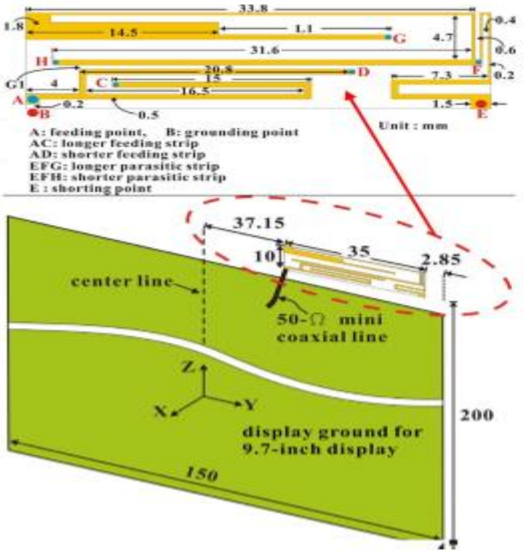

Fig. 1 Geometry of the planar small size eight band monopole antenna

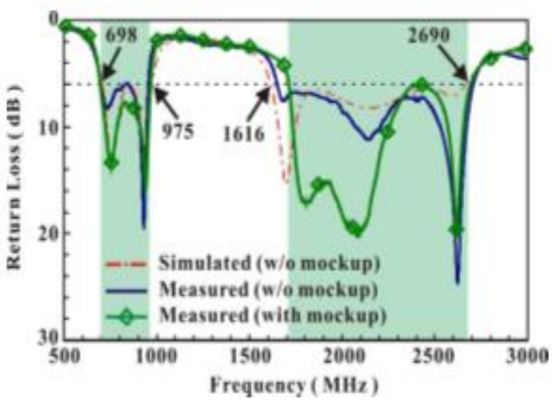

Fig.2 Simulated and Measured Return Loss Results

Fig. 2 summarizes the simulation and experimental results of return loss in the proposed monopole antenna The MA provides the measured 3:1 VSWR (6-dB return loss) bandwidth of 264 MHz (698–962 MHz) and 1046 MHz (1650–2696 MHz) for the lower and higher operating bands, respectively. Dual wide bands comply with the bandwidth

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requirements of the desired eight-band LTE/WWAN (LTE700/GSM850 /900/GSM1800 /1900 /UMTS /LTE2300/ 2500) operations.

IV. SMALL- SIZE TRIPLE WIDEBAND LTE / WWAN TABLET DEVICE ANTENNA

Fig.3 shows the proposed antenna printed on a 0.8-mm-thick FR4 substrate of size 10x45 mm^2 and relative permittivity of 4.4. To test the antenna, it is mounted along the top edge of the device ground plane of a typical tablet computer with a 10-in display panel, wherein the device ground plane has a size 150x200 of mm^2 .In the experiment, a 0.2-mm-thick copper plate issued to simulate the device ground plane. When the antenna is mounted to the device ground plane, the antenna's small ground pad is connected to the device ground plane. To feed the antenna, a 50-Ω coaxial line is applied.

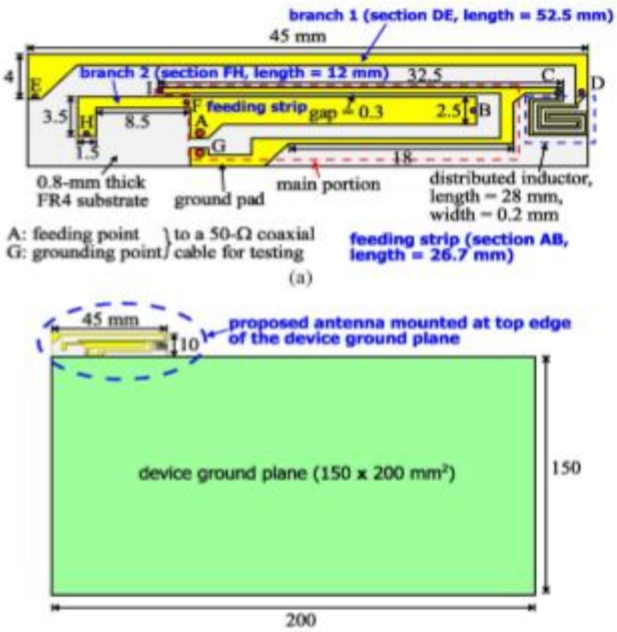

Fig.3 Geometry of the triple wide band LTE/WWAN tablet device antenna

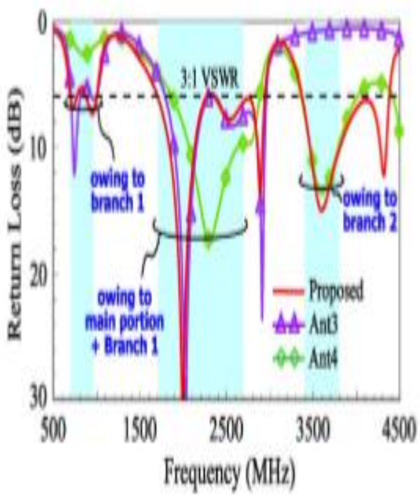

Fig.4 Simulated Return Loss

The antenna comprises three parts including main portion, branch 1, and branch 2. The main portion is a coupled-fed shorted strip antenna. The main portion includes an inverted-L feeding strip (section AB) of length 26.7mm and a shorted folded strip (section GI) of length about 57 mm. The folded strip is short-circuited to the ground pad and closely encircles the feeding strip to achieve a compact structure. Through a coupling gap of 0.3 mm between the feeding strip and shorted folded strip, good excitation of the coupled-fed shorted strip antenna can be obtained, which can generate wide resonant modes in the middle wideband of 1710- 2690 MHz.

Branch 1 is a branch strip (section DE) of length 52.5 mm inductively coupled to the main portion through a distributed inductor disposed between point C and D, while branch 2 is a simple strip (section FH) of length 12 mm connected to the main portion at point F. With the adding of branches 1 and 2, the lower wideband of 698 - 960 MHz and higher wideband of 3400- 3800MHz can be generated. To analyze the antenna's operating principle, Fig. 4 shows the simulated return loss for the proposed antenna. The three shaded frequency ranges in the figure are 698 – 960 MHz (lower band), 1710 – 2690 MHz (middle band), and 3400 - 3800 MHz (higher band). The simulated results are obtained using HFSS ver. 14. For frequencies over the three wide bands, although a small fraction of frequencies in the lower band is slightly less than 6 dB.

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V. PLANAR COMPACT LTE/WWAN MONOPOLE ANTENNA FOR TABLET COMPUTER APPLICATION

Fig. 5 shows the geometry and photograph of the multiband monopole antenna for the LTE/WWAN operation in the tablet computer. The antenna is printed on the same side of an FR4 substrate with the dimensions of 45x 15mm^2, relative permittivity 4.3, and loss tangent 0.02, and it is mounted to the top-right corner of the display ground with a distance of 7 mm to the right edge. In the study, the display ground is made by 0.2-mm-thick copper plate, and a 7-in tablet computer is considered, which is commercially available for the present product. The antenna comprises an inverted-L driven monopole and dual parasitic shorted strips. This antenna is fed by a 50-Ω mini coaxial line connected to the feeding point (point A) of the driven monopole and the display grounding point (point B).

First, we start with arranging the inverted-L monopole strip (section AH) as a quarter-wave length resonant structure to generate the fundamental resonant mode at about 195 MHz in this study The shorter parasitic shorted strip (section BCFG) is with the length of 75 mm, which is close to a 0.24 wavelength at about 925 MHz and is shorted at point B in the antenna display ground. To widen the impedance bandwidth for the lower operating band (LTE700/GSM900 MHz), the longer shorted strip (section BCDE) with a length of 96.7 mm is introduced and mainly contributes to its fundamental (0.25-wavelength) resonant mode at about720 MHz with a higher-order resonant mode close to 2530 MHz band. Then, by insetting the L-shaped slit into in the ground plane or the supporting metal frame of the display panel, the impedance bandwidth for the lower operating band (LTE700/GSM900MHz) can be improved to meet the required bandwidth for the LTE/WWAN operation in the tablet computer. The return loss is measured by using an Agilent E5071C vector network analyzer.

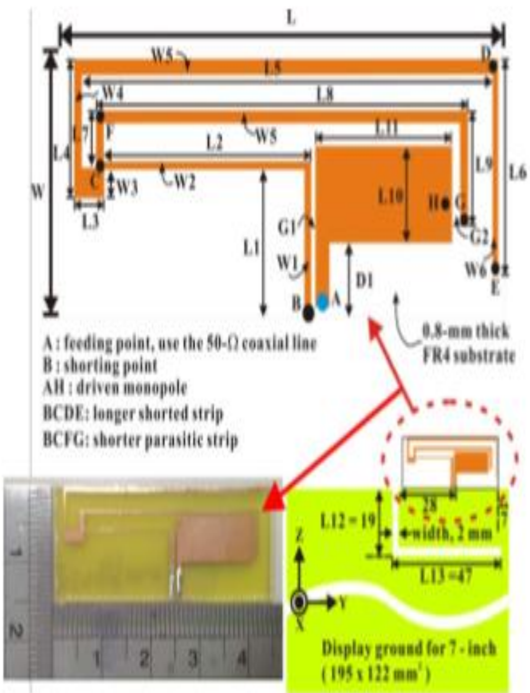

Fig.5. Geometry of the planar monopole antenna for LTE/WWAN tablet computer

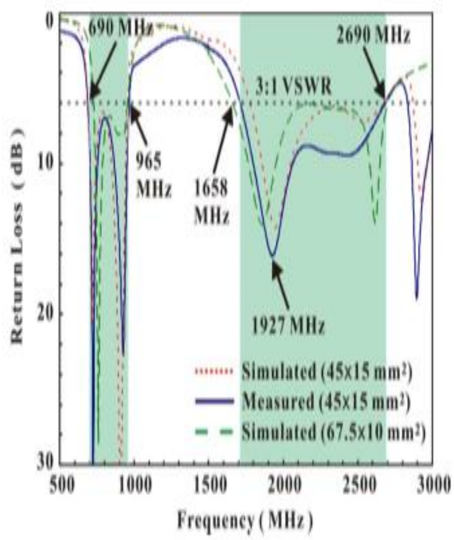

Fig .6 Measured and simulated return loss

As a result, Fig. 5 shows the calculated values of design parameters throughout the presented strategy above. Particularly, from those results, we are simultaneously optimizing them by using Ansoft HFSS as we set L=45mm,

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W=15mm, L1=9.1mm, L2=18.5mm, L3=4mm, L4=7mm, L5=41.7mm, L6=12.6mm, L7=2.9mm, L8=37mm, L9=6.4mm, L10=6mm, L11=16.3mm, W1=1mm, W2=0.3mm, W3=1.5mm, W4=0.4mm, W5=0.5mm, W6=0.3mm, G1=0.4mm, G2=0.3mm, D1=5mm.

Fig. 6 shows the measured and simulated return loss of the constructed prototype. Results show the satisfactory agreement for the proposed compact multiband monopole antenna operating at the LTE/WWAN bands in a tablet computer. The lower band shows a measured 3:1 VSWR (6-dB return loss) bandwidth of 255 MHz (690–965MHz), whereas the upper band has a bandwidth of 980 MHz (1710–2690 MHz). Dual wide bands can meet the required bandwidth of the desired eight-band LTE/WWAN operation. Due to the dielectric constant and loss tangent of FR4 substrate varied with the operating frequency, the measured resonant frequency and input impedance for this proposed compact monopole antenna are a little different from the related simulated results by setting the constant substrate parameters across the operating bands to have slight discrepancy between the measured and simulated bandwidths. Moreover, under the condition of the same antenna size, the study of this proposed antenna with the dimensions of 67.5 x 10 mm^2 is also provided with less operating bandwidth for the lower operating band (LTE700/GSM900 MHz) as shown in Fig. 6. However, that for the higher operating band can meet the bandwidth requirement for LTE/WWAN operation.

VI. PASSIVE RECONFIGURABLE TRIPLE-WIDEBAND ANTENNA FOR LTE TABLET COMPUTER

A passive reconfigurable triple-wide band tablet computer antenna for the LTE operation in the low band of 698-960 MHz, middle band of 1710-2690 MHz, and high band of 3400-3800 MHz is presented in this paper. Fig. 7 shows the geometry of the passive reconfigurable inverted-F/loop antenna for the LTE triple-wideband operation in the tablet computer.

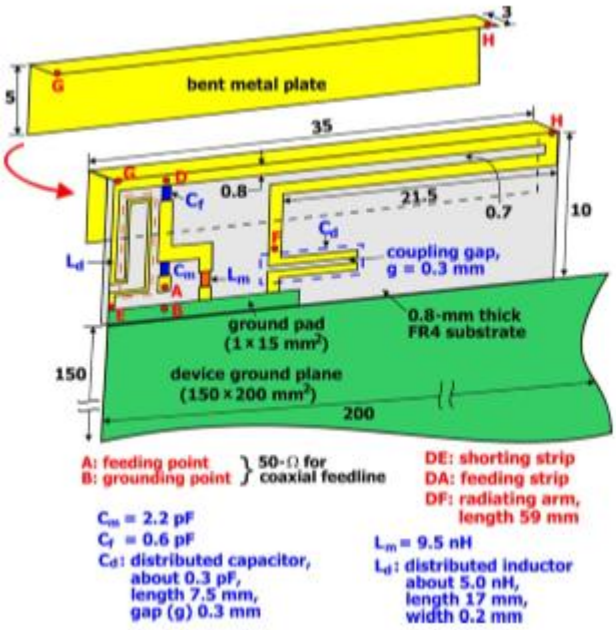

Fig.7. Geometry of the passive reconfigurable inverted-F/loop antenna for the LTE triple-wideband operation in the tablet computer

The antenna mainly acts like an inverted-F antenna (IFA) at frequencies in the LTE low and middle bands and like a loop antenna at frequencies in the LTE high band. The reconfigurable IFA/loop antenna is achieved without active switch circuits and occupies a small volume of 10x35x0.8mm^3. The antenna is mounted along and at one corner of the long edge of a device ground plane of dimensions. The selected dimensions of the device ground plane are for a 9.7-

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inch tablet computer. The antenna is formed by two parts, including a bent metal plate cut from a 0.2-mm thick copper plate and a printed metal pattern on a thin FR4 substrate of thickness 0.8 mm, relative permittivity 4.4, and loss tangent 0.024. The bent metal plate is connected to the printed metal pattern at point G and H so as to widen the strip width of the antenna to improve the achievable bandwidth.

The antenna comprises a radiating arm (section DF), a shorting strip (section DE), and a feeding strip (section DA). The radiating arm is folded to achieve a compact structure. The open end of the radiating arm is also connected to the ground pad through a distributed capacitor. Note that the ground pad is printed on the FR4 substrate and electrically connected to the device ground plane in this study. The capacitor shows an equivalent capacitance of about 0.3 pF and has a length of 7.5 mm and a coupling gap of 0.3 mm. However, when a chip capacitor of 0.3 pF is used to replace the capacitor in the proposed design, the obtained impedance matching of the antenna will be slightly degraded. The shorting strip is embedded with a distributed inductor, which has a length of 17 mm and a width of 0.2 mm. The inductor has an equivalent inductance of about 5 nH. Similarly, when the inductor is replaced by a chip inductor of 5 nH, the obtained impedance matching of the antenna will also be slightly degraded. In the feeding strip, a chip capacitor of 0.6 pF is loaded near point D, and a high-pass matching circuit consisting of a shunt inductor and a series capacitor is embedded near the feeding point A. A coaxial line with its central conductor and outer grounding sheath respectively connected to point A at the feeding strip and point B at the ground pad is used to feed the antenna.

A simplified model of the antenna with the circuit elements of C_d, L_d, C_f, C_m, L_m is shown in Fig.8. In this design, the radiating arm has a length of 59 mm, which is about 0.16 wavelength at 829 MHz (centre frequency in the LTE low band) and is about 0.71 wave length at 3600MHz (centre frequency in the LTE high band).Note that although the length of the radiating arm is much less than a quarter-wavelength at 829 MHz, the capacitor C_d and inductor L_d together can lead to a resonant mode generated in the LTE low band. With the high-pass matching circuit (C_m, L_m) further added, enhanced bandwidth for the antenna's low operating band can be obtained. On the other hand, owing to small capacitive reactance provided by C_d at frequencies in the LTE high band, the radiating arm can be treated to be switched to connect with the ground pad to provide a closed resonant path. In this case, the closed resonant path formed from point A through section DF to point B at the ground pad is close to about one wavelength at 3.6 GHz. A one-wavelength loop resonant mode can hence be excited, which covers the LTE high band in this study. In addition, the antenna can contribute two higher-order resonant modes in the LTE middle band. The presence of the capacitor C_d can also lead to improved impedance matching of the two higher-order modes, so that the antenna can provide a wide operating band to cover the LTE middle band.

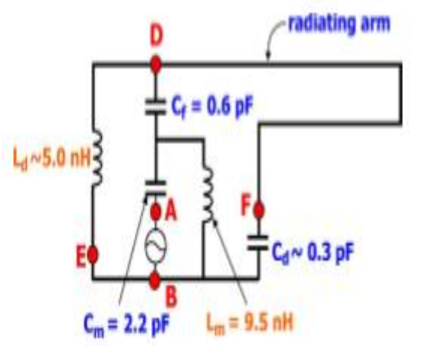

Fig. 8. Simplified model of the proposed antenna with embedded circuit elements

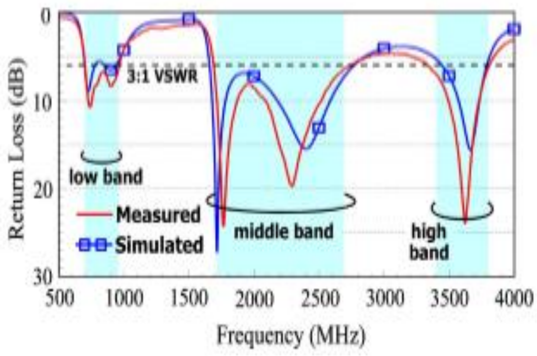

Fig.9.Measured and simulated return losses of the fabricated antenna

Similar improved impedance matching for the antenna's low band can also be obtained by the added capacitor C_d. The proposed antenna was fabricated and tested. The measured and simulated return losses of the fabricated antenna are presented in Fig.9. The measured results agree with the measured data.

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VII. CONCLUSION

Bandwidth enhancement and size reduction are becoming major design considerations for practical applications of microstrip antenna. Many techniques have been used to achieve wideband and to reduce the size of microstrip antennas. This paper shows the survey of various such techniques. Out of all techniques shown above in this paper Passive Reconfigurable Triple-Wideband Antenna for LTE Tablet Computer occupies a small volume of 10x35x0.8mm^3. Good radiation characteristics have also been obtained for the antenna's three wide operating bands.

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