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*Article*

# A low profile wideband antenna for WWAN/LTE applications

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**Abstract:** In this paper a low profile antenna is presented for wideband communication applications. The presented design is consists of an I-shape driven strip and a rectangular ground strip with an open slot in the middle and steeped lower portion. Measured result demonstrates that the achieved operating band of the proposed antenna has the potential to cover Global Star Satellite Phones (1.61-1.63 GHz, uplink), Advanced Wireless Systems (1.71-1.76 GHz, 2.11-2.17 GHz), DCS (1710-1880 MHz), GSM (1800MHz), DCP (1.88-1.90 GHz), DCS-1900/PCS/PHS (1850-1990MHz), WCDMA/IMT-2000 (1920-2170MHz), UMTS (1920-2170 MHz), LTE bands (FDD LTE bands 1-4, 9-10, 15-16, 23-25, 33-37, 39). The designed antenna possessed a very small size of $0.35\lambda_0 \times 0.027\lambda_0$ at the lowest frequency (S11 ≤ -10dB) and achieved good gain, exhibits stable radiation patterns which make it suitable for handheld communication devices.

**Keywords:** antenna; BDR; LTE; wideband; WWAN.

## 1. Introduction

The rapid advancement of mobile communication towards next generation communication systems required multiband and wideband antennas suitable to cover different wireless and mobile services. The use of wideband antenna not only lessens the number of antenna's necessary to cover different frequency bands but also reduces the system complexity, overall device size, and costs. The cellular phone antenna for wireless wide area network (WWAN) operation is usually required to cover global system for mobile communication (824 - 960 MHz), global star satellite phones (1.61-1.63 GHz, uplink), advanced wireless systems (1.71-1.76 GHz, 2.11-2.17 GHz), DCS (1710-1880 MHz), GSM (1800MHz)digital cordless phones (1.88-1.90 GHz), DCS-1900/PCS/PHS (1850-1990MHz), WCDMA/IMT-2000 (1920-2170MHz), UMTS (1920-2170 MHz) along with the recently introduced long-term evolution (LTE) bands henceforth a handset antenna needs to cover all these bands. The role of wideband and multiband antenna become more significant since the carrier aggression technique of LTE communication system was released [1]. The volumetric size of the multiband and wideband antenna inside the portable communication devices has to be as small as possible.

Various types of handset antennas have been reported to achieve wide operating band. Slot antennas can exhibit multiple resonance modes as well as it can merge the nearby resonances that results in the exhibition of wider bandwidth. However, wide slot antennas sometimes require large areas that make them difficult to integrate within the portable communication devices. To lessen the size of the multi-band/wideband antenna, numbers of design have been reported. For example, in [2] a compact antenna that comprises of a U-shaped loop, an open-end T-shaped slot and a feeding line is presented for handset applications. However, the designed antenna possesses a large volumetric size of 64.5 × 135 × 0.6 $mm^3$. For mobile phone applications, in [3] a low-profile planar monopole internal antenna having a volumetric size of 46 × 88.5 × 0.8 $mm^3$ is reported. The presented antenna can exhibit dual operating bands ranging from 848 to 1152 MHz and 1736 to 3000 MHz. In [4] a loop

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antenna is presented for WWAN/LTE smartphone applications. The desired operation in DCS/PCS/UMTS2100/LTE2300/LTE2500 bands is achieved by the high-order modes of two loops of the designed antenna. However, it requires a large system ground plane of 70 × 115 × 0.8 $mm^3$. In [5], the design of an internal printed antenna is presented for WWAN/WLAN/ISM/LTE smartphone applications. The design is comprises of a meander loop and a capacitive coupled feedline and is able to exhibits dual bands of 712 – 1078 MHz and 1757 - 2930 MHz. However, its applications in many portable devices will be restricted due to larger dimension of 120 × 60 × 1.6 $mm^3$. For LTE 13 band applications, in [6] a mobile handset MIMO antenna is presented. This design is comprises of two symmetrical inverted-F antennas in addition of a T-shaped patch. However, the reported design possesses a large footprint of 60 × 15 × 5 $mm^3$ and can only support 746-787 MHz band. In [7], a miniature-balanced antenna is presented for mobile handset application. The presented antenna is a folded structured built-in planar dipole with two arms on each half of the dipole and can tune over 1710-2485 MHz band. However, its 3D structure (48 × 15 × 9 $mm^3$) limits its applications in handheld devices. A wideband monopole mobile phone antenna is presented [8]. This design is consists of a T-shape driven strip and a dual-branch coupled parasitic ground strip and is able to demonstrate multi-resonant modes to achieve sufficient impedance band to operate at GSM/DCS/PCS/UMTS/LTE bands. However, it characterized with relatively large volumetric size of 70 × 8 × 5.8 $mm^3$. In [9] a monopole antenna is reported for LTE/WWAN application. This design is comprises of an L-shape driven branch, a parasitic branch and a band stop matching circuit. With an overall size of 117.5 × 65 × 0.8 $mm^3$, the designed antenna is able to exhibit dual operating bands. A new slim dual band microstrip antenna with a narrow ground plane is presented in [10]. The antenna consists of a simple rectangular patch, a shorting pin and a strip-like shape meander-line that can be mounted inside the portable devices. However, the antenna has an overall dimension of 76 × 3.5 × 1.524 $mm^3$. In [11], a uni-planar tablet/laptop antenna, which covers GPS/GLONASS/LTE/WWAN frequency bands, is presented. The antenna is comprised of coupled-fed, shorting strip and low frequency spiral strips and it is able to exhibit dual operating band of 870-965 MHz and 1556-2480 MHz. But, it requires a large system ground plane of 150 × 200 $mm^2$. For thin-profile laptop computer, a multiband slot internal antenna is presented in [12]. The designed antenna is formed by three monopole slots operated at their quarter-wavelength modes. A step-shaped microstrip feedline is used to excite the three slots. However, the antenna is mounted on a large ground plane of 260 × 200 $mm^2$. Despite of small sizes, the antennas reported in [13-14] have limited applications due to their 3D profile and multi-layer structure. Many reported multiband and wideband antennas achieved sufficient operating bands at the cost of large size or thickness that make them difficult to integrate within portable devices.

To alleviate the difficulties of the many reported designs, in this letter, a compact low profile handset antenna is designed for WWAN/LTE applications. Dual resonance modes at 1.70 GHz and 1.98 GHz are created by the quarter wavelength modes of the driven strip and ground plane. By combining these two modes, a wide operating bandwidth of 600 MHz (1610 – 2210 MHz) is achieved.

## 2. Wideband Antenna Design

The layout of the presented antenna with detail dimension is displayed in Figure 1. As shown in Figure 1, it comprises of an I-shape driven strip (radiator) and a rectangular shape ground strip with an open slot in the middle. The radiator with dimension of $Wp_1 \times Lp_1$ is etched on one side of a Roger's substrate material of thickness 0.5 mm, relative permittivity 3.45 and loss tangent 0.0036 as depicted in Figure 1b. The length of the radiating patch (45 mm) is about quarter wavelength at fundamental mode and controls the excitation of antenna's first resonance at about 1.70 GHz. The feeding of the proposed antenna is accomplished by a 50Ω microstrip line, which is added to the lower end of driven strip. For RF signal input, a 50Ω SMA connector is connected to the strip line. As presented in Figure 1c, the ground plane with width $G_2$ and length $Lg_1+Lg_2+d_2$ is etched on the other side of the substrate and is shorted at the feed point. To attain better coupling between the driven strip and ground, the lower portion of the open slot of the ground strip is steeped as shown in Figure

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1c. The detail dimensions of the driven strip, ground plane as well as the presented antenna are summarized in Table 1.

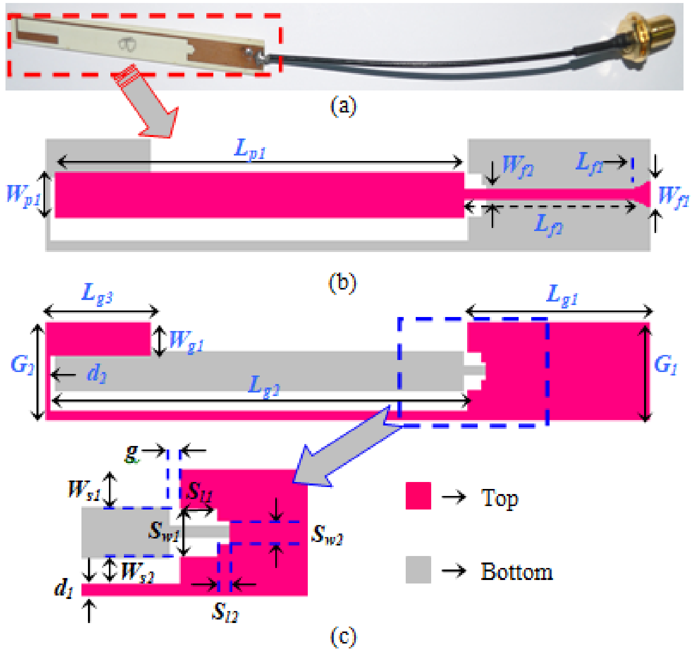


**Figure 1.** Layout of the proposed wideband antenna.

**Table 1.** Design parameters of the proposed antenna.

| Parameters | Value(mm) | Parameters | Value(mm) |
|---|---|---|---|
| $W_{f1}$ | 1.0 | $L_{g3}$ | 11.5 |
| $L_{f1}$ | 2.0 | $W_{g1}$ | 1.7 |
| $W_{f2}$ | 0.4 | $d_1$ | 0.4 |
| $L_{f2}$ | 18.5 | $d_2$ | 0.4 |
| $W_{p1}$ | 2.0 | $W_{s1}$ | 1.5 |
| $L_{p1}$ | 45 | $W_{s2}$ | 1.1 |
| $G_1$ | 5.0 | $S_{w1}$ | 2.0 |
| $G_2$ | 5.0 | $S_{l1}$ | 1.5 |
| $L_{g1}$ | 20 | $S_{w2}$ | 1.0 |
| $L_{g2}$ | 46.1 | $S_{l2}$ | 0.5 |

To investigate the antenna's resonance behavior, Figure 2 displays the surface current of the presented antenna at 1.70 GHz and 1.98 GHz. In 1.70 GHz excitation, the fundamental mode, larger surface current distributions are observed for the longer path along the microstrip line to I-shape driven strip that is corresponds to quarter wavelength of the resonance mode. For 1.98 GHz, as shown in Figure 2b, the surface current distributions are mostly along the driven strip. From Figure 2 it can be commented that, the surface current at 1.70 and 1.98 GHz are along the same path and resonance modes of the designed antenna are slightly altered by each other. Merging of these two resonance modes resulting in a wide operating band suitable for GSSP, AWS, DCS, DCP, PCS, PHS, MCDMA, UMTS and LTE bands applications.

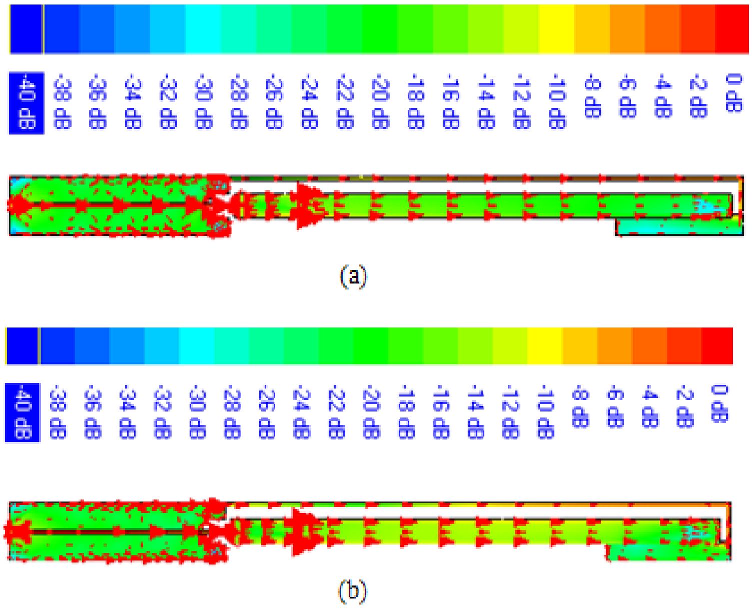


**Figure 2.** Current distributions at (a) 1.70 GHz and (b) 1.98 GHz.

To examine the compactness, the performance of the proposed antenna in-terms of bandwidth, electrical dimension and bandwidth dimension ratio (BDR) is compared with the antennas which are recently reported for the WWAN/LTE applications and that is also presented in Table 2. In the comparison, all the antennas are assumed to be planar and the differences of their dielectric constants are taken small. Although the proposed antenna achieved small operating band in comparison to the others, however, a good BDR of 3439 with small electrical size of $0.35\lambda_0 \times 0.027\lambda_0$ is achieved. Moreover, as the proposed design does not require any larger ground plane, it can directly be printed on mobile phone without any extra space. Hence, the designed antenna can offer low profile while maintaining a much smaller volumetric size.

**Table 2.** Comparison of the proposed antenna with some recently reported antennas.

| Antenna | -10dB BW (%) | $f_{low}$ (GHz) | Electrical Dimension | Size ($\lambda_0^2$) | BDR |
|---|---|---|---|---|---|
| This work | 32.5 | 1.60 | 0.35× .027 | 0.00945 | 3439 |
| [15] | 172 | 1.44 | 0.37× 0.17 | 0.0629 | 2735 |
| [16] | 181 | 2.18 | 0.23× 0.33 | 0.0759 | 2462 |
| [17] | 185 | 0.64 | 0.32× 0.34 | 0.1088 | 1730 |
| [7] | 37 | 1.71 | 0.274× 0.086 | 0.0236 | 1579 |
| [18] | 76 | 1.54 | 0.33× 0.16 | 0.0528 | 1439 |
| [6] | 5.3 | 0.746 | 0.149× 0.037 | 0.0055 | 961 |

## 3. Results and Discussion

The presented antenna is analyzed and optimized using IE3D software. All the parameters of designed antenna such as size of the driven strip, ground strip, feed-line are optimized to achieve the required operating bands. To examine the behavior of the designed antenna, a pair of antenna is prototyped as displayed in Figure 1a. Figure 3 demonstrates the simulated and measured $S_{11}$ of the fabricated prototype, which is measured with the help of network analyzer (Agilent N5227A). It can

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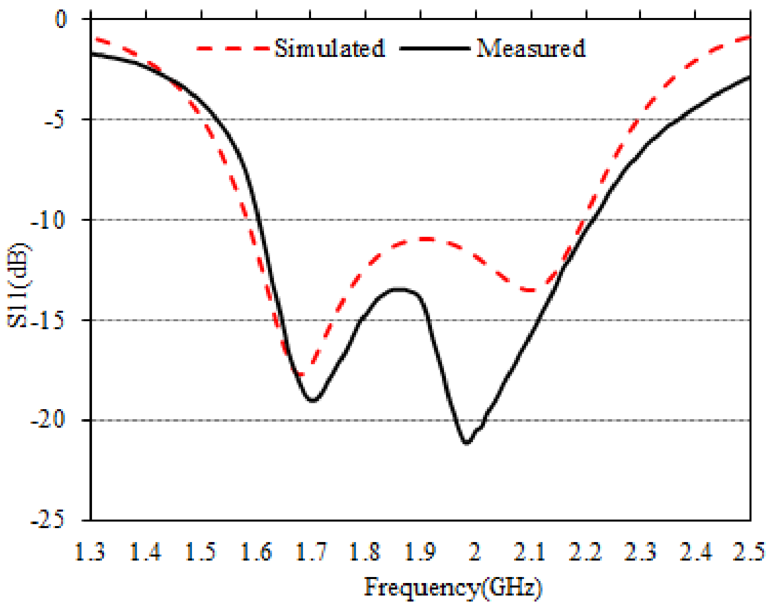


**Figure 2.** Simulated and measured $S_{11}$.

be revealed from the plot that the measured results are almost coinciding with the simulated one. The disagreement between the results is mainly caused by prototyping error and measurement error. Measured results demonstrate that two resonant modes are excited and these two nearby modes are merged to form a wider operating band. The measured -10dB bandwidth is ranged from 1610 MHz to more than 2210 MHz and almost satisfies the entire requirement of mobile phone such as Global Star Satellite Phones (uplink), Advanced Wireless Systems, DCS, Digital Cordless Phones, DCS-1900/PCS/PHS, WCDMA/IMT-2000, UMTS, LTE (Bands 1-4, 9-10, 15-16, 23-25) bands.

The radiation characteristics of the proposed antenna are measured using Satimo's StarLab near field antenna measurement system. The measured gain and efficiency of the prototype is presented in Figure 4 from where it is revealed that in the achieved operating band the gain is about 0.76 dBi to 2.45 dBi and the efficiency varies from 34 to 48% which can fulfill the requisite characteristics of many practical applications. The measured 2D radiation characteristic of the prototype is displayed in Figure 5. It is observed from the figure that the pattern in *E*-plane is almost omnidirectional. In *H*-plane, the patterns are almost dipole like with the introduction of nulls especially at higher frequencies. Despite the nulls in *H*-plane, it can be revealed from the plot that the presented design exhibits the characteristics of stable radiation throughout the operating band that is the prime requisite for mobile communication applications.

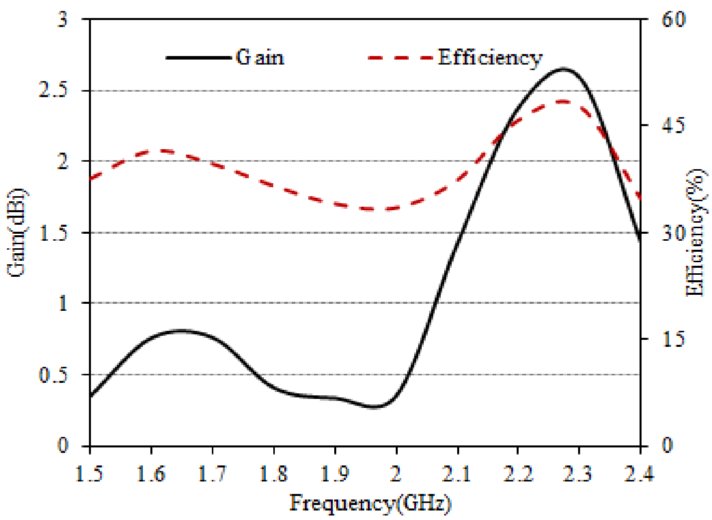


**Figure 4.** Measured gain and efficiency of the proposed antenna.

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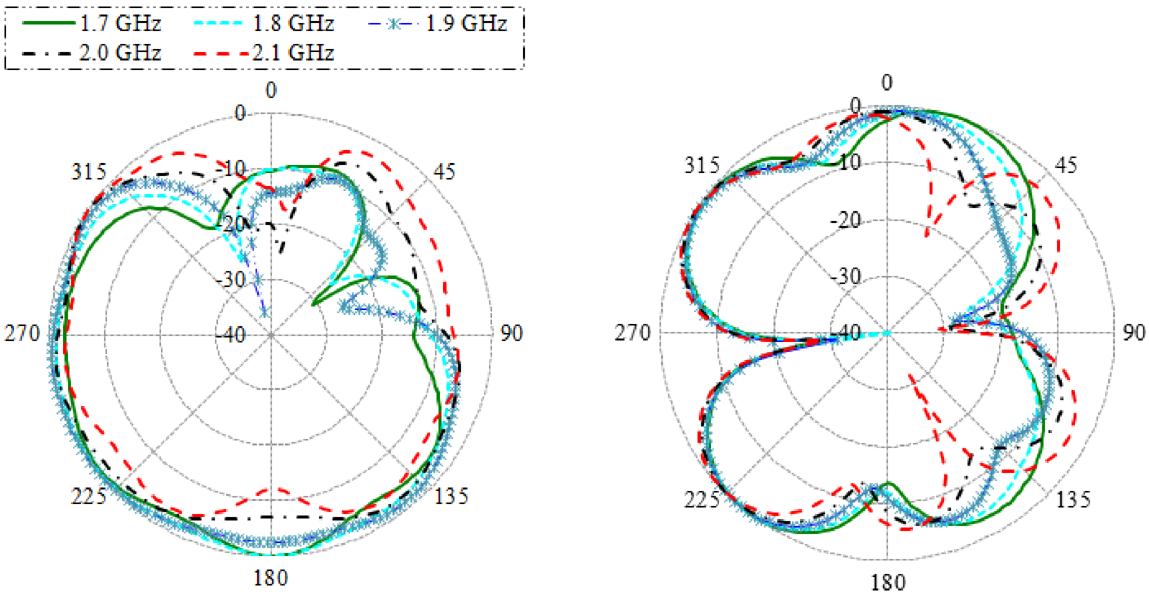


(a) (b)

**Figure 5.** Measured radiation patterns at different frequencies (a) *E*-plane, and (b) *H*-plane.

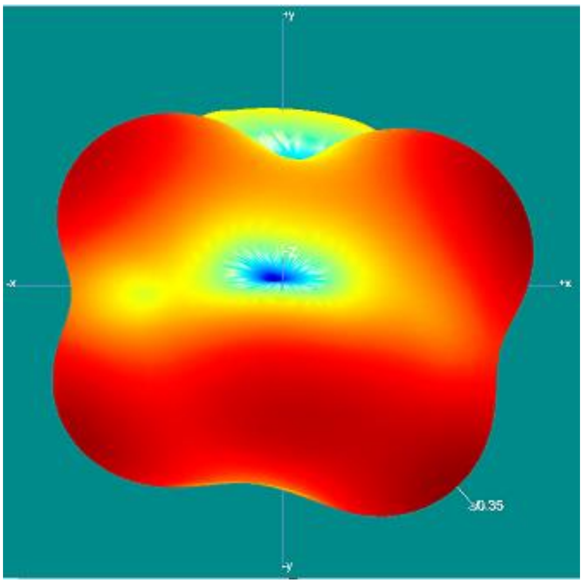

**Figure 6.** Measured 3D radiation pattern at 1.70 GHz.

Figure 6 displays the measured three dimensional radiation patterns at 1.70 GHz, which shows a dipole like omnidirectional radiation.

## 4. Conclusions

In this paper, a low profile wideband antenna covering the frequencies ranging from 1610 to 2210 MHz is reported. The antenna is made up of a driven strip and a ground strip with an open slot in the middle and steeped lower portion. The prototyped antenna exhibits an impedance bandwidth of 600 MHz (31.42%) which can address numbers of applications such as GSS Phones (uplink), AWS, DCS, DCP, DCS-1900/PCS/PHS, WCDMA/IMT-2000, UMTS, LTE bands. The designed antenna has a very small footprint and demonstrates satisfactory performance in terms of bandwidth, gain and radiation characteristics.

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**Conflicts of Interest:** The authors declare no conflict of interest.

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