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Design and Implementation of Compact Coax Fed Multi Band MIMO Antenna for 4G Applications

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Abstract

Background/Objectives: In multimedia data communication environment a trade-off shall be opted between power, spectrum needs and wireless channel capacity in Global System for Mobile, Long Term Evaluation, and Wireless Local Area Networks applications. Multi-Input Multi-Output antenna elements display a high degree of similarity and it leads to efficacy reduction in multi user milieu. **Methods:** This paper investigates and presents a condensed 2-port coax fed multiband MIMO antenna for 4G applications. The proposed MIMO antenna possesses dimensions of 45mm×50mm×0.4mm^3 and comprises two layers, a rectangular patch, a pair of small-N shaped strips, two G-shaped monopole structures and L-shaped slots. An array of three resonant frequencies is opted for exciting the proposed design with the values of 1.8GHz, 2.5GHz and 5GHz. The methodology exhibits an adaptable frequency selecting with the ability to neutralize the impact of the other frequency. **Findings:** The implemented design accomplishes a high efficiency rates for LTE-Advanced, WiMAX and Wi-Fi applications 71.80%, 72.28% and 85.74%. **Applications/Improvements:** Fabrication with a suitable FR4 substrate material is used in the design of the coax fed multiband MIMO antenna. For future enhancements, the radiation pattern and reflection coefficient of an antenna shall be assessed.

Keywords: Global System for Mobile, Multi-Input Multi-Output Antenna, Long Term Evaluation, Wireless Local Area Networks

1. Introduction

The applications of the wireless communication have different type of antennas. The size of antenna is mainly decided by which frequency the antenna is supposed to radiate. When the frequency becomes high the size of antenna reduces. Thus noticing for mobile networks the antennas are made smaller since they have higher carrier frequencies. In the present mobile phones the antennas are hidden inside the phones because they usually use micro strip antennas, a thin metal strip on a dielectric sheet.

GSM, UMTS (3G) and LTE, WiMAX (4G) and Wi-Fi are the most common network technologies which are used today. As different frequency bands are used in these technologies, they need an antenna supporting all three in order to transmit and receive signals at three different frequencies. Different spectrum laws and policies are followed in different countries and so the actual amount of different frequencies the antenna needs to support in order to support these three technologies in all countries are eight. In fact LTE, WiMAX and Wi-Fi have many more different bands, but this report will try to support three of the most common LTE, WiMAX and Wi-Fi bands. Still now LTE is a new technology, these kinds of antennas are very uncommon and open up research opportunities. LTE has opened up for the possibility to send with multiple antennas and this increases the data rate of the connection. The goal with this paper is to design a small size mobile phone coax feed MIMO antenna supporting triple frequency bands for LTE, WiMAX and Wi-Fi.

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1.1 Importance of Good Handset Antenna Design

Mobile phone includes antenna which is one of its major hardware parts. The cost of antenna may be low but it plays a major impact on the performance and design of the mobile phone. The performance of the antenna decides the cell phone reception. Clear signal can't be received from a base station because of a badly designed antenna and hence cripple the usage of the cell phone as mobile phones turn off the screen during voice conversations. Hence the mobile phone antennas efficiency decides the energy consumption.

As the antennas are mounted externally the mobile phones visual design depends on them in olden days. But now a day they are placed internally and so the dependency becomes less obvious. But the antenna plays a major role in visual design. A metal casing is used in many mobile phones like computers and tablets. This metal case has a pair of plastic areas for the antenna through which the transmission and reception of signals take place. The size of the antenna decides the visual design. For example, a smaller antenna leaves a smaller constrain. The design constraint plays important role as the mobile phones have thinner designs with bigger screens.

Also the antenna design plays a major role in radiation safety. Like microwave ovens, mobile phones radiate microwaves in frequencies and thus have a heating effect in the head while using the phone. So while designing mobile phones the design of antenna plays an important factor and should satisfy allowed radiation limits put up by organizations such as IEEE and ITU.

Antennas supporting all bands have been achieved by LTE, WiMAX and Wi-Fi frequencies used in different countries. LTE, WiMAX and Wi-Fi has been separated in more than 20 different bands ranging from 600MHz to 6000MHz. Thus to design a smaller antenna supporting all these frequency bands might require tuning, one of the techniques that is used in this project.

A small size triple band antenna is designed with a handset antenna that can cover LTE, WiMAX and Wi-Fi operation. The antenna will be connected to the perfect two port coax feeding with suitable substrate when the LTE, WiMAX and Wi-Fi operation are required, so that the antenna can cover the LTE band at 1800 MHz, WiMAX band at 2500 MHz and WiFi band at 5000 MHz. Without increasing the antenna size, the handset antenna can be switched to perform as an LTE, WiMAX and Wi-Fi antenna. Thus a small-size triple band (LTE, WiMAX and Wi-Fi) handset antenna is designed with better radiation characteristics. The 4G mobile terminals use the proposed coax feed MIMO antenna which can perform triple band operation. The two main goals of this paper are, to design a tunable WiMAX, LTE and WiFi handset antenna and to measure the performance of an MIMO antenna for triple operation.

2. Previous Studies

LTE, WiMAX and WiFi systems have been used extensively in telecommunication and other commercial applications. To design an antenna for these applications, various types of antennas have been reported[1]. A compact low-profile single element two-port planar inverted-F antenna (PIFA) and its uses were investigated by previous researchers[2]. According to the authors[3], application of 2.6-GHz Long Term Evolution is observed using multiple-input–multiple-output[3]. There is proposal made for the mobile handset application using the principle of a planar coupled-fed monopole antenna with eight-band LTE/WWAN (LTE700/2300/2500/GSM850/900/1800/1900/UMTS)[4]. The application of LTE/WWAN in a shorted monopole antenna have been described[5]. In addition, an inverted-F antenna with multiband operations, wireless wide area network GPS, WiMAX and WLAN applications have been presented[6]. The previous studies described for wireless terminals using wideband built-in antenna with a new crossed C-shaped coupling feed structure[7]. The application of LTE MIMO antenna array was studied for the effects on the user's body[8] and MIMO antenna operation for LTE 13 band applications was proposed[9]. Further, multi operation functionality of LTE smart mobile antenna with multiband operation has been proposed[10] and cellular systems is presented[11].

Two symmetric monopoles with 2.5 GHz edge-to-edge separation compact wideband multiple-input-multiple-output antenna is studied and novel MIMO antenna system has also been developed[12,13]. The MIMO antenna system consists of an outer loop and an inner loop[14,15]. Furthermore, LTE/WWAN operation in the tablet computer is proposed[16].

3. Proposed Antenna Design

3.1 Design of Coax Feed MIMO Antenna

The proposed antenna geometry for 4G applications with its measurement is designed to accomplish optimal performance as shown in Figure 1. It consists of substrate layer with single layer metallic structure on one side and other side no metallization.

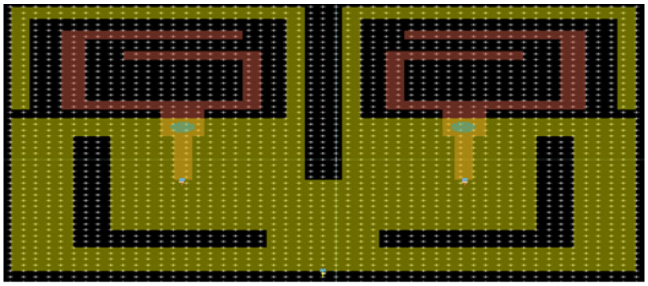


Figure 1. Layout design after simulation.

The slot in the projected antenna geometry is fed by a micro strip line and 2 mm widt was fixed for micro strip feed line. It consists of a square radiating patch, a feed line connected with patch and a ground plane. Conducting ground plane is provided on one side of substrate with 50Ω connector for signal transmission. Based on electromagnetic coupling, the modified two layered antenna structure impedance matching element is used to control the impedance bandwidth of the proposed antenna. To achieve the triple resonant mode for LTE, WiMAX and WiFi operations, the proposed antenna contains various structures such as G-shaped strip, L-shaped slot and small N-shaped strips at top and bottom layer.

3.2 Proposed MIMO

Step 1: A new layout is created.

Step 2: A substrate is designed with the suitable dimension.

Step 3: A MIMO antenna structure is created and placed over the substrate.

Step 4: A radiating feed section consisting of micro strip feed strip is designed and connected to the antenna design.

Step 5: The pin P_3 is plotted to provide ground and feeding point.

Step 6: The layout is saved and the EM setup is performed the substrate specifications are given and frequency plan is also done.

Step 7: S Parameter simulation is performed.

Step 8: Graphs are plotted for different frequency band.

3.3 EM Simulation

3.3.1 Layout Design

Layout design after simulation is presented in Figure 1. The production of the planned antenna is done using a conventional FR4 substrate, often used to make printed circuit boards with thickness *(h)* of 0.4 mm and relative permittivity of 3.0, which makes it easy and inexpensive to manufacture.

3.3.2 Substrate Design

There are few key parameters which help in deciding right substrate for the RF/Microwave designs

3.3.3 Substrate Height

The substrate height depends on the frequency of operation, as it can cause Surface wave radiation. Higher the frequency of operation lower should be the height of substrate.

3.3.3.1 Relative Permittivity / Dielectric Constant

The measure of opposition placed by Dielectric substrate towards any electric field is usually referred to as the dielectric constant.

3.3.3.2 Loss Tangent

It is the quality measure of dielectric purity (depicts loss nature of dielectric). Dielectric becomes lossless for lowest possible values.

3.3.3.3Conductor Material

Figure 2 shows the conductor used in Micro strip design contribute to the transmission losses. Substrate performance can be controlled or optimized with proper selection of Height and Er.

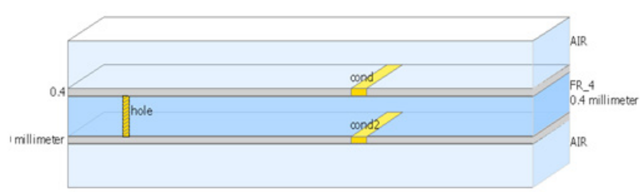


Figure 2. Substrate design of coax fed MIMO antenna.

4. Results and Discussions

Figure 3 indicates the simulated reflection coefficient of a single G-shaped monopole antenna. The Figure 3 can be observed that the monopole structure can produce return loss of -23.24 dB at 1.8 GHz for advanced LTE. To improve the performance of WiMAX (IEEE 802.16m) operation at 2.5 GHz, another monopole antenna (mirror of G-shape) could be added on right side of the structure 3 shown in Figure 1.

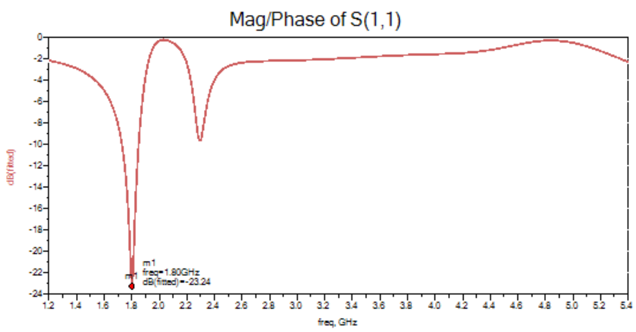
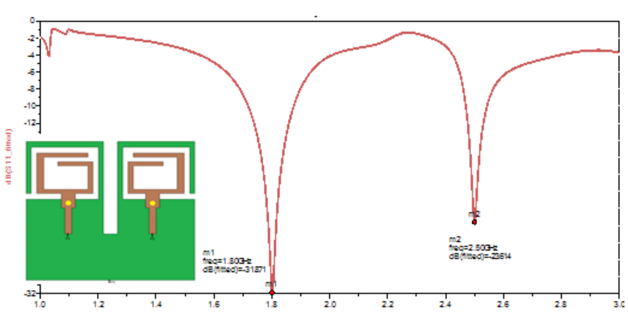


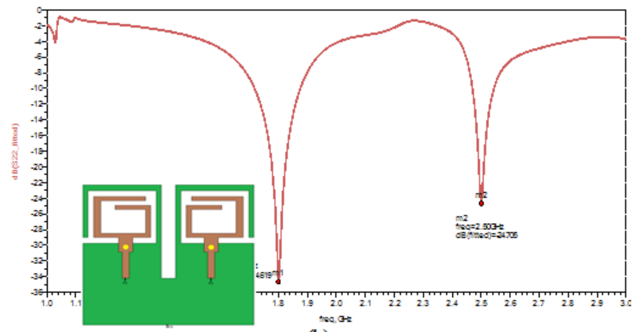
Figure 3. S-Parameter calculation of proposed antenna with single G-shape structure.

4.1 S-Parameter Calculation with single G-shape

Figure 4 shows the return loss analysis of dual branch monopole antenna (G-shape and its mirror), which provides dual band operations at 1.8 GHz and 2.5 GHz for LTE-Advanced and WiMAX (IEEE 802.16m). The reflect coefficient of 1.8 GHz and 2.5 GHz is -31.87 dB and -23.614 dB in port-1, -34.619 dB and -24.705 in port-2.



(a)



(b)

Figure 4. S-Parameter calculation of proposed MIMO antenna with out L-slot (**a**) at port-1 and (**b**) at port-2.

4.2 S-Parameter Calculation with G-shape and its mirror (without L-slot)

The simulated *S*-parameters of proposed coax fed MIMO antenna at port 1 and port 2 respectively are shown in Figure 5 and Figure 6. It is observed from Figure 5 and Figure 6 the simulated results are almost well accepted for the S11 and S22 curves. This is due to factors such as perfect design and suitable substrate. In addition, it can be seen from Figure 3, that the proposed antenna with L-slot produces the three resonant modes, which is around 1.8, 2.5 and 5 GHz for advanced LTE, WiMAX (IEEE 802.16m) and WiFi (IEEE 802.11ac). Here, reflect coefficients of 1.8/2.5/5GHz is -36.94dB/-19.16dB/-30.91dB in port-1 and -38.10dB/-19.33dB/-29.60dB in port-2.

4.3 S-Parameter calculation of proposed MIMO antenna

S-Parameter calculation of proposed coax fed MIMO antenna at port-1 and port-2 are presented in Figures 5 and 6 respectively.

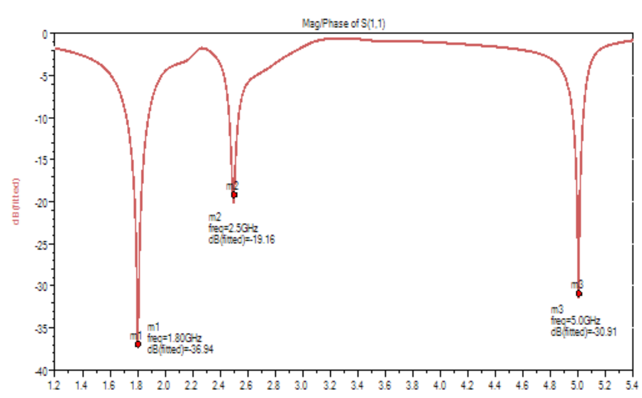


Figure 5. S-Parameter calculation of proposed coax fed MIMO antenna at port-1.

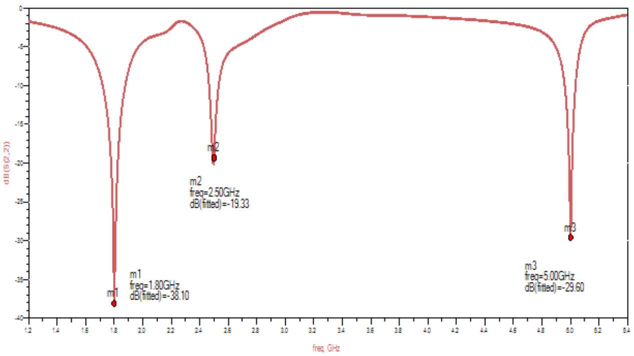


Figure 6. S-Parameter calculation of proposed coax fed MIMO antenna at port-2.

5. Conclusions

A new coax fed multi band MIMO antenna for LTE-Advanced, WiMAX (IEEE 802.16m) and WiFi (IEEE 802.11ac) operations has been proposed. To achieve the expected multi band operation, various types of resonant antenna structures have been reported for design the proposed antenna. The arrangement of the small N-shaped strip, G-shaped monopole structure and L-shaped slot etched in the ground to increase the reflection coefficient (S11 and S22). The designed effective MIMO antenna to be simulated and it produce the triple band operation at 1.8GHz, 2.5GHz and 5GHz for LTE-Advanced, WiMAX and WiFi. The observed result shows the reasonable agreement due to the better radiation characteristics. Hence, proposed antenna could be most suitable competent for 4G applications.

In future, the simulated coax fed multiband MIMO antenna design to be fabricated with the suitable FR4 substrate material. After fabrication, the radiation pattern and reflection coefficient of an antenna measured by using network simulator. The comparison between simulated and measured results indicated that the proposed antenna how much effective for 4G applications.

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