A Wideband Omni Directional Antenna for 4G LTE with Dual Band Rejection

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Abstract: ***A novel planar LTE antenna with dual notched bands is proposed and investigated. The need of band rejection related to commercial issues. In certain areas, the usage of bands are restricted and decided by FCC and ITU. So the users should not get frequency bands which are restricted in a particular area provided by network operator. This design consists of a square patch and a modified grounded plane. To realize dual notched bands characteristics, a T-shaped stub embedded in the square slot of the radiation patch and a pair of U-shaped parasitic strips beside the feed line is used. The advantage of this antenna is the high rejection level in the stop band. The measured results show that the proposed dual-notched-bands planar antenna shows a very wide bandwidth from 1.8 to 11.0 GHz defined by voltage standing wave ratio , with two notched bands of 3.3-4.0 GHz (WiMAX band) and 5.05–5.90 GHz (WLAN band), respectively, and well as LTE bands. Both the experimental and simulated results of the proposed antenna are presented, indicating that the antenna is a good candidate for various 3GPP applications.***

Keywords: Horizontal polarization, Long Term Evolution (LTE), monopole-like, omnidirectional radiation pattern, wideband.

1. Introduction

Horizontally polarized (HP) omnidirectional antennas are generally used for indoor base station and wireless communication systems. To ensure the full coverage of surrounding environment, they transmit and receive the wireless signals equally in all the directions. In [1] and [2], a printed inverter F antenna (PIFA) was designed on the FR4 PCB substrate in which the horizontal polarization is the dominant antenna pattern but is not quite Omni directional as desired in the H plane. A loop antenna is a suitable choice, to achieve the HP radiation pattern. A small loop antenna with a uniform current distribution will have an omnidirectional pattern. Due to its small radiation resistance and high reactance, impedance matching is difficult. Similarly a large loop antenna will have a reasonable radiation resistance but the current distribution is non-uniform. So it could not produce the desired omnidirectional pattern. A wire structure Alford loop antenna is used to achieve an omnidirectional HP wave was designed in [3]. In this design the conductor forms the square loop type current distribution; hence the omnidirectional pattern is achieved. When compared with PIFA, Alford loop structure antenna is better to produce omnidirectional pattern. But this type of antenna design has a narrow band width(less than 10% typically) [4].

A few antenna designs were adopted to increase the operational bandwidth of HP omnidirectional antennas. Alford loop type antenna without using additional matching circuits was designed in [5], that covers the frequency range of 2.45 and 3.9 GHz, here the omnidirectional pattern is achieved by adjusting the length of the wing stub. In [6], a loop antenna with a periodical capacitive loading and a parallel strip line was reported, that has the operational bandwidth of 800 MHz (2170-2970 MHz, 31.2%). Different methods are adopted to design omnidirectional antennas with vertical and horizontal polarization. Vertical polarization is achieved by using coaxial collinear antennas [7], and by using microstrip antennas [8]. Similarly horizontal polarization is achieved by using magnetic dipoles [9] with uniform current distribution. In [10], collinear and slot antenna are used for vertical and horizontal polarization. Hence the overall dimension of the system was large and it is not suitable for volume limited systems. In [11], two orthogonally arranged collocated slots are used to provide high isolation between two polarizations, which has the frequency range of 2.4-2.48GHz. To achieve the bandwidth of 31% for 2G/3G base station applications, a broad band Omni directional planar antenna with four printed arc dipoles are designed in [12].

In recent design, to meet 4G requirements such as high data throughput and long link range for high mobility (peak speed of 100Mbps) and low mobility communications (peak speed of 1Gbps), a circular patch antenna is designed with the radiation efficiency of 83% in [13]. None of the above antenna designs are not suitable for band rejection applications.

To realize dual notched bands characteristics, a T-shaped stub embedded in the square slot of the radiation patch and a pair of U-shaped parasitic strips beside the feed line is used. This design consists of a square patch and a modified ground plane. The advantage of this antenna is the high rejection level in the stop band. Both the experimental and simulated results of the proposed antenna are presented, indicating that the antenna is a good candidate for various 3GPP applications.

2. Antenna Geometry and Design

The proposed HP antenna design is shown in Fig. 1. In the presented design, the monopole antenna and the ground plane form an equivalent dipole antenna. The current distribution on the patch affects the impedance characteristics of the antenna. By cutting the two notches of suitable dimensions at the two lower corners of the patch, it is the same with that the impedance bandwidth can be much enhanced.

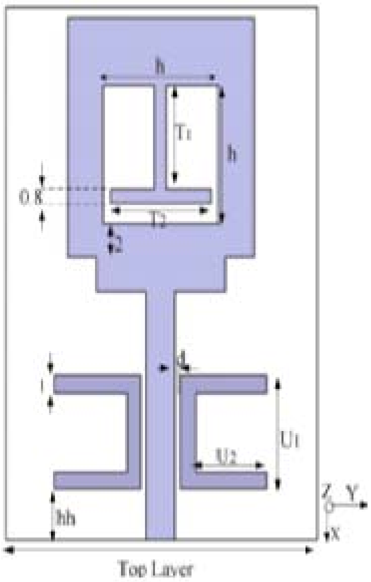

Figure 1: Geometry of the proposed Antenna

To realize dual notched bands characteristics, a T-shaped stub embedded in the square slot of the radiation patch and a pair of U-shaped parasitic strips beside the feed line is used. This design consists of a square patch and a modified ground plane. The advantage of this antenna is the high rejection level in the stop band. Both the experimental and simulated results of the proposed antenna are presented, indicating that the antenna is a good candidate for various 3GPP applications.

This phenomenon occurs because the two notches affect the electromagnetic coupling between the rectangular patch and the ground plane. The gap between the radiation patch and ground plane is denoted as, which is also an important parameter to control the impedance bandwidth. The patch and the ground plane form an equivalent dipole antenna. The ground plane is beveled, resulting in a smooth transition from one resonant mode to another and ensuring good impedance match and stable gain over a broad frequency range. The proposed antenna can achieve high gain at low and high frequency with bevel on the ground plane.

FR4 substrate is taken for this proposed design. Here the value of ε_r is chosen as 4.3 and the h value as 4.5mm. The patch antenna consists of a thin dielectric substrate, which is covered on one side by a thin layer of conducting material (ground plane), while on the other side there is a patch of conducting material. The properties of microstrip antenna are determined by the shape and dimensions of the metallic patch, as well as by the dielectric properties of the used substrate. This design has the advantage that the properties of the two layers can be chosen differently, depending on the requirement for the patch and the feed line. The length and width are calculated by using the following formulae.

$$L = \frac{c}{2f_r\sqrt{\varepsilon_r}}$$

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

After the calculation of antenna length and width, the following parameters are considered for antenna design. Table 1 describes the various geometrical parameters and their values of the proposed antenna design. The size and efficiency of the microstrip antenna are determined by the parameters of the dielectric substrate.

Table 1: Geometrical parameters of the proposed antenna

Name	*Value (mm)*
T1	6
T2	7
U1	6.6
U2	5
A	2
B	2
D	0.4
G	1
H	8
Hh	3
K	2
M	1
N	3
P	3.6
Q	2.2
R	31.6
S	5
T	2
W	1
X	2
Y	0.8

UWB Monopole antenna with two notched bands is shown in figure 1 and the table describes the geometrical parameters of the proposed system. To achieve dual notched bands, a T-shaped stub on the radiating patch and a pair of U-shaped stubs near the feeding line are adopted to generate notched bands with central frequencies of 3.6 and 5.5 GHz, respectively. The currents are mainly distributed around the filter structures and oppositely directed between the interior and exterior edges. Therefore, the resultant radiation fields can be cancelled out, and high attenuation near the resonant frequency is achieved, thus resulting in notched band.

The notched performances are mainly determined by T1, T2, U1, and U2. The first notch band is mainly decided by the dimension of T-shaped stub. Adjusting the gap between the radiation patch and ground plane, a wide impedance bandwidth is achieved. By introducing a T-shaped stub in the radiation patch and a pair of U-shaped parasitic elements beside the feed line, dual stop bands for applications of WiMAX and WLAN are created. The radiation pattern of this antenna shows good omnidirectional performance throughout the UWB frequency range and constant gain in the UWB band is realized. Accordingly, the proposed antenna is expected to be a good candidate in various UWB systems.

3. Experimental Results

Fig. 2 shows the simulated S parameter of the proposed antenna and fig. 3 “(a)” and “(b)” illustrates the port signals of i1 and o1, 1 the proposed antenna. The presence of parasitical strips significantly suppresses the reactance of the antenna and improves the return loss.

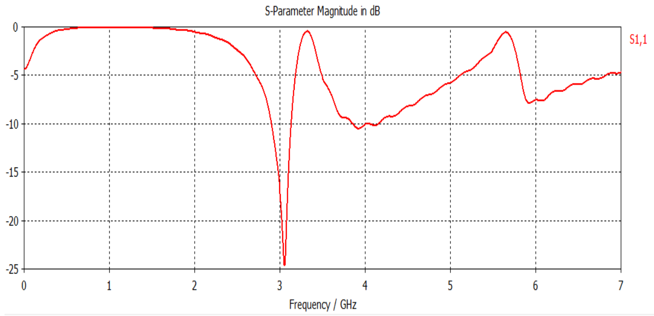

Figure 2: Simulated S-Parameter of the proposed antenna

S parameter describes the input-output relationship between ports. S11 represents how much power is reflected from the antenna, and hence known as the reflection coefficient. S parameters are the function of frequency.

Port signals in 1D results

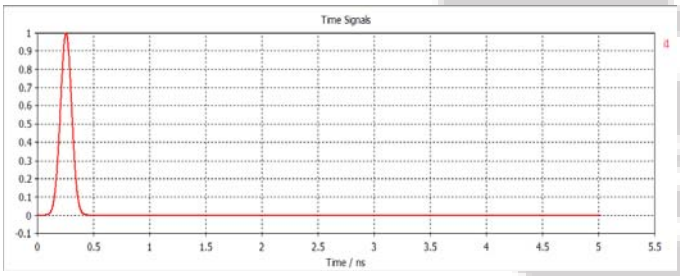

Figure 3 "(a)": Port Signal of the proposed Antenna

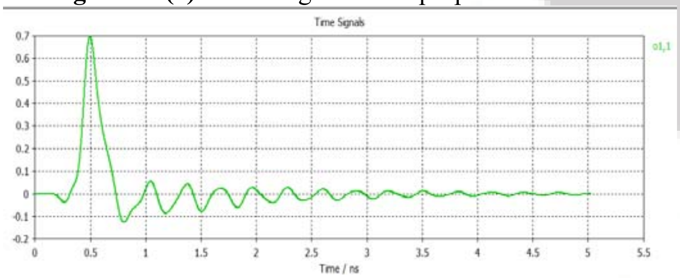

Figure 3 "(b)": Port Signal o1,1 of the proposed Antenna

Fig. 4 is the axial ratio proposed HP antenna which is fabricated on a low-cost 1.6-mm-thick FR4 board with the dielectric constant of 4.4

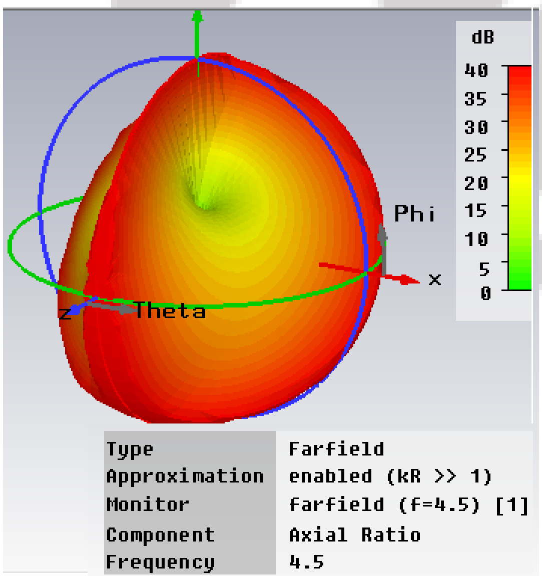

Figure 4: Axial ratio of the proposed Antenna

Axial ratio, for any structure or shape with two or more axes, is the ratio of the length (or magnitude) of those axes to each other - the longer axis divided by the shorter. The axial ratio will change over the pattern of the antenna. There will be one point where the antenna has maximum circular polarization. It is the angular range over which the field radiated by the antenna in the far-field zone is circularly polarized, with axial-ratio less than or equal to 3dB. Axial ratio by definition is the ratio of the two orthogonal components of E-field. Ideally for circular polarization where you have two equal components you will have AR 1 (or 0 dB). Its interesting to look at the AR beam width for CP based antennas because from that we can understand about the deviation from circular polarization.

Ideally CP antenna should generate circularly polarized wave, but that is not happen in real, and generate elliptical polarized wave, so 3dB of axial ratio is limit for approximation of circular polarization. Like in LP antenna, S11 parameter shows the BW of antenna that can be defined as -10dB for example. Incase of CP antenna along with impedance bandwidth the axial ratio bandwidth is required to specify the polarization purity of circular polarized antenna. The bigger axial ratio beam-width of your antenna, the bigger solid angle in which antenna radiates required (circular) polarization.

It may happen that antenna has wide beam-width but radiates circular polarization only in single direction. In other directions radiation is linear or elliptical. So, when designing circularly polarized antenna, you should optimize it for axial ratio beam-width, in opposite case antenna will not radiate desired polarization in desired directions. The axial ratio is the ratio of the two orthogonal E fields in the far field. This applies for circular polarized antennas. The E field ratio is calculated at a point where the E field is maximum, along the peak axis of Pointing vector.

Free-space path loss (FSPL) is the loss in signal strength of an electromagnetic wave that would result from a line-of-sight path through free space (usually air), with no obstacles nearby to cause reflection or diffraction. It does not include factors such as the gain of the antennas used at the transmitter and receiver, nor any loss associated with hardware imperfections. These losses may be found in the article on link budget. The FSPL is rarely used standalone, but rather as a part of the Friis transmission equation.

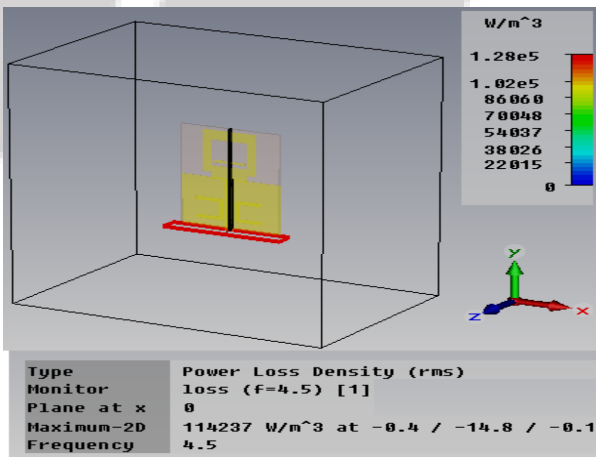

Figure 4: Power loss of the proposed Antenna

4. Conclusion

A compact, easily fabricated, and low cost wideband horizontally polarized omnidirectional antenna has been presented. The proposed antenna consists of a square plane and a modified ground plane. To realize dual notched bands characteristics, a T-shaped stub and a pair of U-shaped parasitical strips are used. The return loss, bandwidth, radiation patterns, axial ratio, and efficiency of the antenna are computed and measured, and parametric studies are performed to optimize and finalize the design. The measured results show that the proposed dual-notched-bands planar antenna shows a very wide bandwidth from 1.8 to 11.0 GHz defined by voltage standing wave ratio, with two notched bands of 3.3-4.0 GHz (WiMAX band) and 5.05–5.90 GHz (WLAN band), respectively, and well as LTE bands. Both the experimental and simulated results of the proposed antenna are presented, indicating that the antenna is a good candidate for various 3GPP applications.

Its real time implementation includes a machining work done with lathe machines. Usually at higher dimensions it is not a big criteria, but at higher dimensions, as the size of the antenna becomes very less in the order of millimetre, the fabrication process become tougher. Such millimeter ranging processes require micro-machining tools. The performance may also be evaluated with different permittivity and with different other frequencies. Beam steering process may be implemented by some techniques, in order to change the direction of the propagation through some digital controls and by changing the feed point and other relevant parameters.

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