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Design of a Novel Nine Shaped Tri-Band MIMO Antenna for LTE Applications

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Abstract

LTE(Long Term Evolution) is considered to be the most promising 4th generation(4G) mobile standard to increase the capacity and speed of the mobile and other handheld terminals. Multiple-antenna systems, also known as multiple-input multiple-output radio, can improve the capacity and reliability of radio communication. In this paper, we propose a novel nine shaped microstrip MIMO antenna which is designed using HFSS software. The proposed MIMO antenna covers frequency band of 0.550-1.3GHz, 4.3-5.1 GHz and 6.93-7.5GHz. The return loss of the antenna is found to be -34dB for all the resonant frequency bands. The designed antenna provides satisfactory isolation and de-coupling. Substrate is chosen to be FR4-epoxy with dielectric constant of 4.4 due to its ease of availability. The overall size of the antenna is 50 x100 x 156mm^3.

Introduction

The LTE standard has made tremendous gains in the efficient use of Multiple-Input Multiple-Output (MIMO) and general smart antenna schemes, many of which have been increasingly applied to HSPA (High Speed Packet Access) systems [5]. LTE is unique in requiring as a minimum that all terminals include a second receive antenna for receive diversity and downlink MIMO support [10]. In choosing an antenna topology for LTE design, several factors must be taken into account including physical characteristics, compatibility, impedance bandwidth, radiation efficiency, and radiation pattern. Within the framework of antenna, there are two challenges for the LTE handset application. The first challenge is to design a small antenna fitting in the limited space of the hand size terminals. The second challenge, the antenna should be mostly available within the wider bandwidth as well as the multiple communication standards covering from the whole 3G to LTE schemes. And this broadband performance requires the expansion of physical antenna dimensions [5].

Multiple-Input Multiple-Output (MIMO) systems are a pivotal solution for the significant enhancement of the band-limited wireless channels' communication capacity. MIMO system is essentially a wireless system with multiple antennas at both the transmitter and receiver ends.

As compared to the conventional wireless systems, the main advantages of the MIMO systems are the higher system capacity, more bit rates, more link reliability, and wider coverage area. All of these features are currently considered as crucial performance requirements in wireless communications. Additionally, the emerging new services in wireless applications have created a great motivation to utilize the MIMO systems to fulfill the demands these applications create. The MIMO systems can be combined with other intelligent techniques to achieve these benefits by employing a higher spectral efficiency. The use of multiple antenna technique has gained overwhelming interest throughout the last decade. The idea of using multiple antenna configuration instead of a single one has proven to be successful in enhancing data transfer rate, coverage, security and overall the performance of radio networks. MIMO schemes are characterized by the number of antennas transmitting into the air, and the number of antennas receiving those same signals at the receiver [8].

Microstrip antenna is popular due to their light weight, low cost and multiband capabilities [1] as shown in Fig 1. In this paper first a microstrip line feed antenna have been modeled, designed and simulated [6]. The analysis of nine shaped antenna is the realized using Ansoft HFSS v13 software [4] which works on the principle of Finite Element Method. It is a high performance full wave electromagnetic field simulator for 3D volumetric passive device modeling. It puts together simulation, visualization, solid modeling, and automation in a setting that makes easy learning and where solutions to 3D electromagnetic (EM) problems are swiftly and correctly achieved. HFSS build use of the well-known Microsoft Windows graphical user interface and employs the Finite Element Method (FEM); FEM is a numerical technique for estimating the solution of partial differential equations and integral equations, adaptive meshing, and brilliant graphics to furnish users matchless performance and accomplished insight to all their 3D EM problems. HFSS is an interactive simulation system whose basic mesh element is tetrahedron Ansoft HFSS has developed over a time of years through input as of numerous users and industries, in industry; Ansoft HFSS is the tool of preference for high-productivity research, improvement, and virtual prototyping [4].

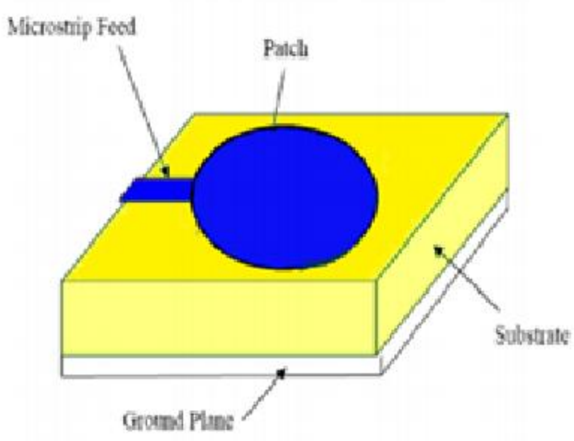

Figure 1. Microstrip Circular patch antenna

Design and Analysis

In this design procedure, thickness and dielectric constant of the substrate are selected initially. The radius of a monopole microstrip antenna is designed keeping the resonant frequency in observation for LTE band, FR4 is used as substrate with dielectric constant of ε_r =4.4 and with loss tangent of 0.02 and substrate height (h) 1.56mm[9]. The resonant frequency of an antenna can be found using following formula [1][3].

$$f_r = \frac{(1.8412 * C)}{2\pi * \ a_e \sqrt{\varepsilon_r}} \qquad (1)$$

where,

$$a_e = a * [\left\{1 + \frac{2h}{a\pi\varepsilon_r}\right\} \{\ln\frac{a\pi}{2h}\} + 1.7726]^{\frac{1}{2}} \qquad (2)$$

where,

a_e=effective radius of the patch
f_r=resonating frequency
a=radius of the circular patch
a_e=effective radius of the patch
h=height of the substrate
c=speed of the light
ε_r=dielectric constant of the substrate.

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Table I. Design Parameters specifications of Antenna

Parameter	***Measurements***
Radius of circular patch	7mm
Substrate	FR4-epoxy
Input impedance	50 ohm
Dielectric constant of FR4	4.4
Height of substrate	1.56mm
Conducting material	copper
Feeding Technique	Transmission Line method

The measured values for the given specification are,

$$a_e = 0.0136$$

Resonant Frequency,

$$f_r = 4.007 \text{ GHz}$$

Thus the antenna was designed for the above said resonant frequency. The simulated antenna has two element of novel nine shaped monopole antenna. Each of which antenna resonating at each resonant frequencies obtained at 0.550-1.3GHz, 4.3-5.1 GHz and 6.93-7.5GHz.

Results and Discussion

The novel nine shape monopole patch antenna is simulated using Ansoft HFSS v13. Fig.2 shows the design of an antenna model, Fig 3 shows the S-parameters and Fig 4 shows the VSWR of the antenna. It can be seen from S_{11}-parameter that the frequency coverage of 0.550-1.3 GHz, 4.3-5.1 GHz and 6.9-7.3 GHz. And also VSWR is found to be 1.04 between the bands 4.5-5.1 GHz [11].

A. Antenna Model [2]

These above parameters are analysed and used in designing microstrip patch antenna in HFSS simulator. And all the resultant parameters return loss; VSWR, input impedance etc. are achieved [7]. Some of the design factors which have to be taken into consideration before designing are:

- Frequency of operation (f_o): The resonant frequency of the antenna must be selected appropriately.
- Dielectric constant of the substrate (ε_r): The dielectric material selected for my design is FR4 which has a dielectric constant of 4.4.
- Height of dielectric substrate (h): For the microstrip patch antenna to be used in cellular phones, it is essential that the antenna is not bulky. Hence, the dielectric substrate height is selected as 1.56mm in our model.

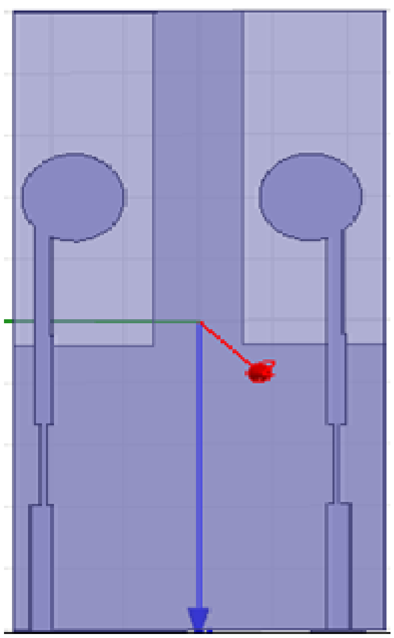

Figure 2. Proposed antenna model

B. S-parameter

This antenna shows -13 dB return loss at frequency band of 0.550-1.3 GHz, -34 dB return loss at frequency band of 4.3-5.1 GHz and -11 dB return loss at frequency band of 6.9-7.3 GHz. At the resonant frequencies antenna radiates with maximum power.

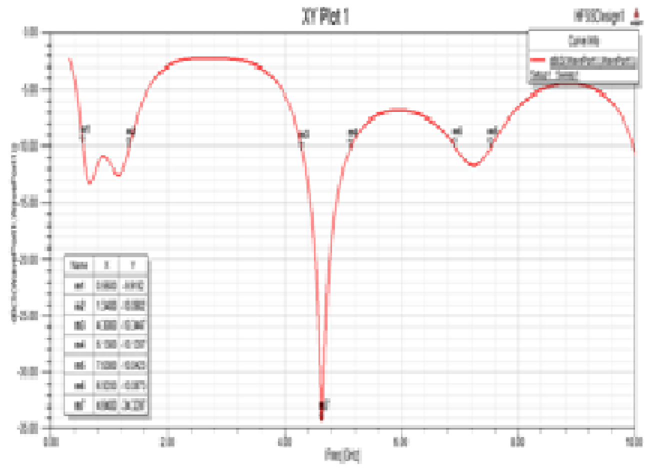

Figure 3. S (1, 1) v/s frequency plot

C. VSWR

The voltage standing wave ratio (VSWR) for the circular patch antenna at our design frequencies of 4.65 GHz and 7.2GHz is shown in fig 4. VSWR is a measure of impedance mismatch. As can be observed from the graph, the VSWR obtained are 1.04 and 1.5 for the above said frequencies. This is considered a good value as the level of mismatch is not very high [12].

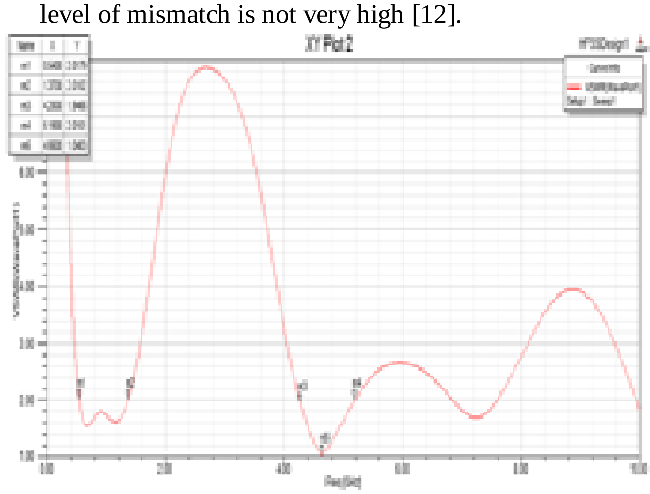

Figure 4. Variation between VSWR and Frequency

D. Smith Chart

Impedance matching at the design frequencies of 4.3-5.1 GHz has a value of approximately 50Ω impedance. To match an antenna, the impedance locus needs to be shifted as near as possible to the centre of the smith chart (matching point). As can be observed impedance matching point is

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very close to the centre of the smith chart.

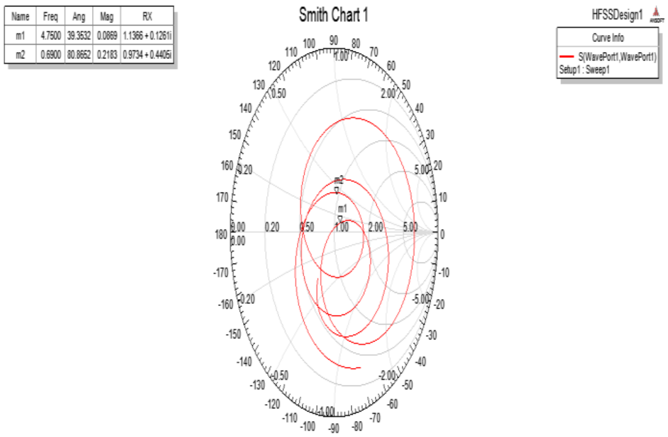

Figure 5. Smith chart to determine input impedance

E. Radiation pattern

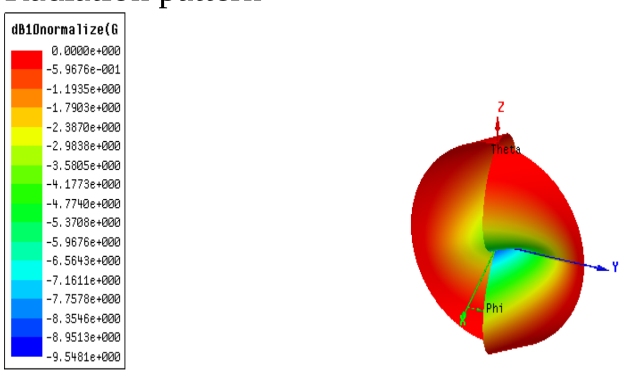

Figure 6. 3D polar plot of an antenna radiation

Table 2: Result of the designed nine shape antenna

Parameter	Lower Band	Middle Band	Upper Band
Frequency	0.550-1.34 GHz	4.3-5.13 GHz	6.9-7.5 GHz
Return loss	-13	-34	-11
VSWR	1.56	1.04	1.6

Conclusion

A novel compact and printed MIMO antenna system for 4th generation is designed. The MIMO system based novel nine shaped antenna geometry was designed to work for LTE application. The antenna with good isolation and return loss was obtained at 4.3-5.13 GHz frequency. The simulation of proposed design is done using Ansoft HFSS v13 software. The simulated results are in good terms with standard values.

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Biographies

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