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Design and implementation of Novel Nine-shaped MIMO Antenna for LTE Applications

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Abstract: In this paper, a tri-band novel nine-shaped two element monopole MIMO antenna is proposed for LTE applications. The antenna has symmetrical property. It is etched on an FR4 epoxy substrate with dielectric constant of 4.4 and transmission line feed is used to excite the antenna. It radiated for 0.550-1.3 GHz, 4.3-5.1 GHz and 6.9 to 7.3 GHz LTE bands. The designed antenna is simulated using HFSS software and is fabricated and tested using network analyzer. It demonstrates that the fabricated antenna offers improved values of S_{11} and return loss. The overall size of an antenna is 50 x 100 x 1.56mm^3.

Keywords: Microstrip Antenna, MIMO (Multiple Input Multiple Output), LTE (Long Term Evolution), HFSS(High Frequency Structural Simulator) software.

I. INTRODUCTION

The microstrip antennas are increasing in demand for use in communication systems due to their compact size, light weight and cost effectiveness. They offer good compatibility for embedded antennas in handheld terminals [1]. Micro strip antennas are used in high profile applications like aircraft, space craft, and satellite where the size ,performance, weight ,installation does matter ,because micro strip antenna is one of the best contender to meet up these requirements[1].Currently this antenna is commercially tattered like mobile communication, wireless radio other than government custody. Micro strip antenna is also called patch antenna. The shape of the patch depend on the application and demand, more common shapes are square, rectangular. Most main disadvantages of patch antennas are the low profile efficiency, low power level; deprived polarization purity, narrow frequency bandwidth, and underprivileged scan.

A MIMO antenna system drastically improves the wireless communication capacity and robustness by exploiting multipath fading. MIMO, which is the acronym for multiple-input and multiple-output system, employs multiple antennas at both transmitter and receiver. A MIMO system can employ a transmit diversity scheme at the transmitter and a receive diversity at the receiver at the same time, allowing it to combine all the advantages offered by SIMO and MISO systems. The proposed MIMO antenna system goes in good terms with 4th generation by covering most of the LTE bands. The novel design of nine shape monopole MIMO antenna covers the frequency bands of 0.550-1.3 GHz, 4.4-5.1 GHz and 6.9-7.5 GHz which is LTE bands [2].

LTE (Long Term Evolution) is the trademarked project name of a high performance air interface for cellular mobile telephony. It is a project of the 3rd Generation Partnership Project (3GPP), operating under a named trademarked by one of the associations within the partnership, the European Telecommunications Standards Institute. The applications such as mobile TV, MMOG (Multimedia Online Gaming) and streaming contents have motivated the use of (LTE) standards [7]. LTE is the latest in the mobile network technology that ensures competitive edge over its existing standards [5].

The substrate chosen is FR4 epoxy material with dielectric constant 4.4 due to its ease of availability and the conducting material are of copper due to its low cost and it is a good ductile material.

In this proposed antenna a simple ground plane is used without any complicated addition structure and simple nine shaped monopole antenna is etched on the top surface which acts as radiating surface [9].

II. METHODOLOGY

A proposed methodology has been described in a simple flow chart, which comprises of a selection of simulation tool, antenna parameters to be considered, type of substrate to be chosen with proper dielectric constant. Simulation tool has been chosen to be HFSS (High Frequency Structural Simulator). 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 [4].

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. Substrate is chosen as FR4 with dielectric constant 4.4 and chosen because of its ease of availability.

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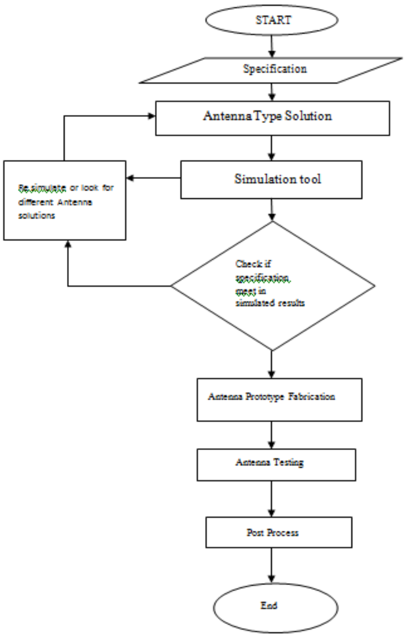

Fig 1. Complete procedure of antenna designing

The above flow chart shows the steps involved in designing, simulating, fabricating and testing of the antenna.

III. NINE-SHAPED MONOPOLE ANTENNA DESIGN

The proposed antenna geometry is shown in fig 2. The radius of the monopole antenna is 7mm, where l1, l2 and l3 are 14.5mm, 13.44mm and 28mm respectively. Design of antenna is on FR4 substrate with dimensions 50 x 100 x 156mm^3[3].

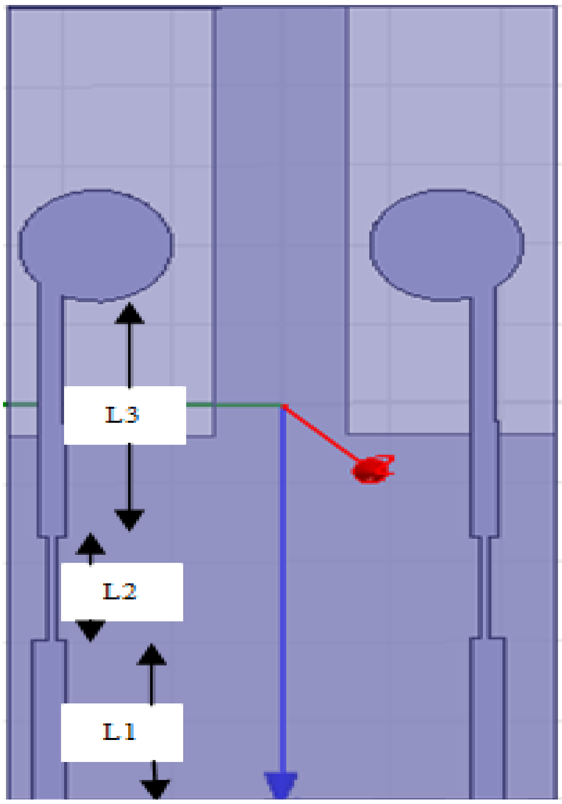

Fig 2. Proposed antenna model

MIMO antenna consists of two nine shaped symmetrical face to face dual branch monopole printed on upper part of the substrate. In order to increase the isolation between two monopole antennas a simple ground plane is etched at the bottom of substrate [2].

The antenna resonant frequency can be found using the following formula:

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

f_r =4.007 GHz

where,

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

a_e=0.0136

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.

TABLE I
DESIGN 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

IV. SIMULATION

HFSS simulator is used as an evaluation and design tool for the majority of the work carried out in this paper. HFSS utilizes a 3D full-wave Finite Element Method to compute the electrical behavior of high-frequency and high speed components [4]. Models can be created with different materials, boundaries and geometries. The basic mesh element used is a tetrahedron, which allows the user to mesh any arbitrary 3D geometry, such as complex curves and shapes. The mesh can be defined automatically by the solver, but quite often this does not give satisfactory results and the user has to define mesh operations, such as, seeding the mesh, maximum aspect ratio and curve surface approximations.

A. VSWR

The voltage standing wave ratio (VSWR) for the circular patch antenna at our design frequencies of 4.06GHz and 0.7 GHz. VSWR is a measure of impedance mismatch. As can be observed from the graph, the VSWR obtained are 1.04 and 1.5 as shown in fig 3. This is considered a good value as the level of mismatch is not very high.

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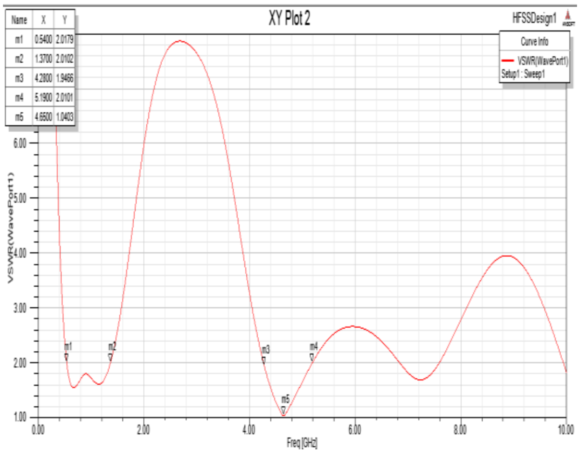

Fig 3. Variation between VSWR and Frequency

B. Radiation Pattern

Radiation pattern is defined as the power radiated or received by an antenna in a function of the angular position and radial distance from the antenna. It describes how the antenna directs the energy it radiates. The radiation pattern is obtained at two frequencies of 0.56 GHz and 0.76 GHz as shown on fig 4 and 5 respectively.

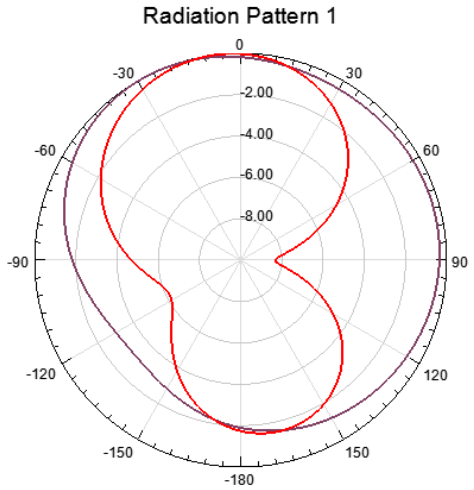

Fig 4. Radiation pattern of an antenna at 0.56 GHz frequency

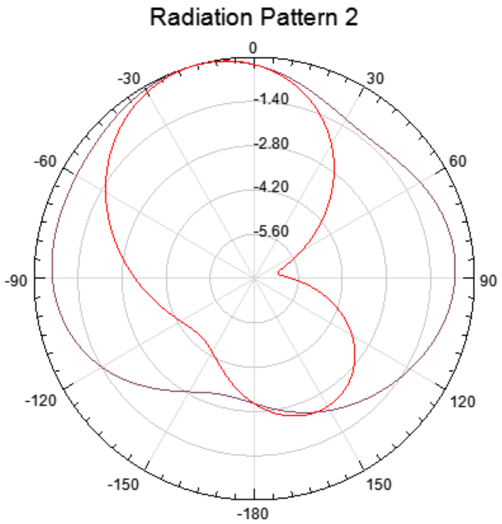

Fig 5. Radiation pattern of an antenna at 7.4 GHz

V. FABRICATION PROCEDURE

Microstrip antennas are in the form of printed circuits devices when used in the microwave range. They consist of a substrate (sheet of dielectric-PTEF glass woven web) with metallization (copper) on both sides. They fabricated like printed circuits using high-resolution photolithography process [8]. The fabrication procedure adopted for the realization of the hardware is as follows:

1. The layout of the antenna simulated and the feed network are obtained separately using CAD design.
2. Spool files are generated using CAD design.
3. Using the photo-plotting technique, a master film of the layout is obtained.
4. Copper clad laminated is used as the raw material, which basically consists of a layer of PTEF glass woven web of designed thickness sandwiched between two copper sheets.
5. The metallic layer are cleaned mechanically and chemically and dried in an oven.
6. A layer of polymer photo resist is homogeneously deposited on one metallic face by spraying or dipping techniques. The photo resist is then dried in an oven.
7. The sensitized substrate is placed in an ultraviolet (UV) exposure machine with the master film pressed against the photo resist layer. The UV reproduces the pattern of the mask on this layer. In order that an accurate reproduction is achieved, the UV source must deliver parallel radiation. Only the transparent portions exposed to the UV lighter are hardened and the rest of the photo resist remains loose.
8. The exposed substrate is developed into a chemical product, which removes the photo resist layer where it was protected by the mask. The substrate is then rinsed.
9. The developed substrate is passed through an etching machine that sprays acid to remove the metal where it is no longer protected by the photo resist. The substrate is then carefully rinsed.

The object of this unit is to give an insight into the process involved in designing, fabricating and experimentally verifying an antenna. The software used to design antennas is discussed, along with the fabrication process and the tools used to characterise the performance of antennas.

The fabricated antenna is as shown in fig 6 and fig 7, where fig 6 is the top layer or radiating part of the antenna, where l_1 is the power input of 50 ohm which is connected through SMA connector to give input from external source. L_2 is a power divider of 70 ohm to balance the input impedance and l_3 is used to maintain the input impedance to be 50 ohm. The circular patch seen in the figure is the radiating part of an antenna of radius 7mm [11].

Fig 7 is the bottom layer of the antenna which acts as ground plane, where l_4 is patch of ground plane and l_5 acts as isolation part of the two antennas. FR4 material with thickness 1.56mm is used as substrate[12].

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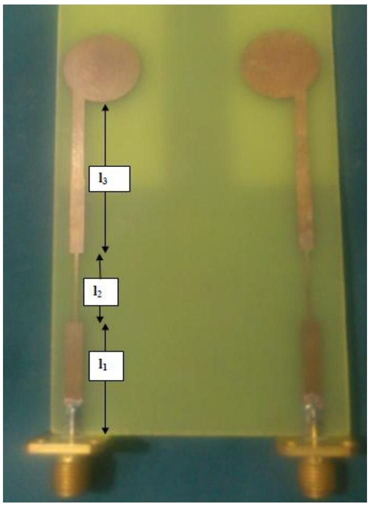

Fig 6. Top layer of fabricated antenna

TABLE II
DIMENSION OF THE TOP LAYER

Radius of circular patch	7mm
l_1	14.5 mm
l_2	13.44mm
l_3	28mm

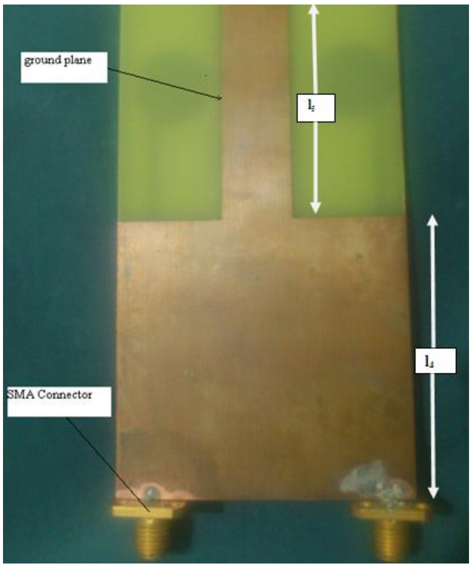

Fig 7. Bottom layer of fabricated antenna

TABLE III
DIMENSION OF ANTENNA-BOTTOM LAYER

l_4	35.9mm
l_5	64.1mm

After fabrication the actual results frequency band is 1-1.8 GHz, 4.4-4.8 GHz and 7.1-7.6 GHz which is in good match with the simulated results [10].

V. FABRICATED ANTENNA RESULTS AND DISCUSSION

The antenna has been simulated using Ansoft simulation software HFSS v13 [4]. To verify the performance of MIMO antenna, a prototype has been fabricated (Fig 6 and 7) and measured. The simulated and measured S-parameters are shown in Fig 8 and 9. It is observed that the S_{11} and S_{21} curves of overall trend between simulated and measured results are almost well matched except that the light shift in the graph. It is due to factors such as imperfection fabrication and measurement tolerances.

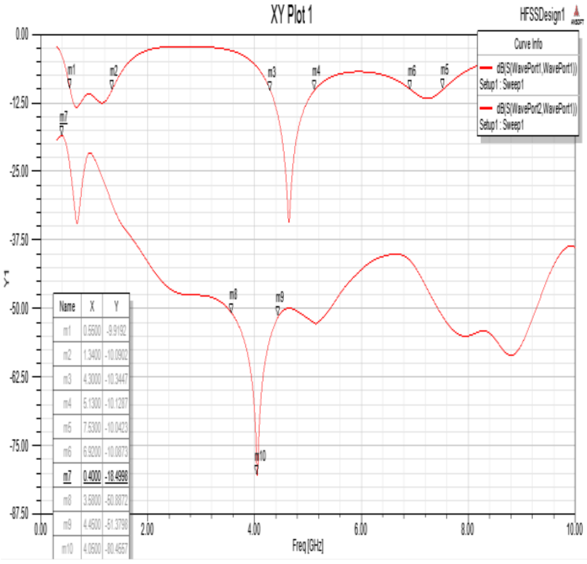

Fig 8. S_{11} and S_{21} simulated result in HFSS

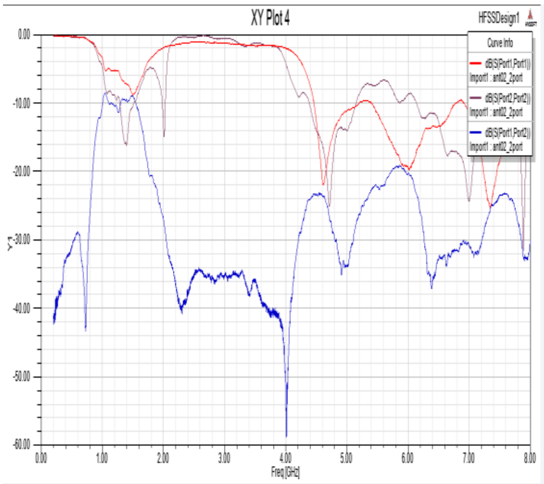

Fig 9. Fabricated ant tested antenna results of S_{11}, S_{22} and S_{21}

VI. CONCLUSION

A compact tri band novel nine-shaped two element MIMO antenna is designed and fabricated for LTE Application. The return loss is found to be -22 dB at 4.6 GHz which is tested using Network Analyzer, which is slightly shifted from simulated results. The simulation of the proposed design was done through Ansoft's HFSS simulator software. The radiation pattern at 0.56 GHz and 0.76 GHz is proposed and VSWR is 1.05.

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BIOGRAPHIES

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