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4G MIMO Antenna for Future Mobile Handsets

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***Abstract*—As we know, for the higher data rate and high quality of service, the MIMO system is widely used in mobile antennas. The proposed antenna system in this paper is a wideband antenna. This system is designed for wireless handheld devices, which are based on existing 4G standards. The principal objective is, to design a MIMO antenna which is useful to provide broadband and high data rate communication. For 4G standards, the frequency range used is 1550 MHz to 2000 MHz This antenna system is designed by using 3D antenna software. The proposed antenna is able to work for all mobile applications like Bluetooth, GSM, Wi-Fi, etc. This is the best benefit over the traditional mobile antennas. MIMO antenna is redesigned and simulated to achieve better simulation results. Parametric analysis for simulation results is done. The proposed antenna is fabricated and tested using vector network analyzer, after that simulated and measured values of antenna parameters compared with each other. The system will provide a better reflection coefficient, improved bandwidth, wide operating band, and constant gain. Operating frequency of this antenna is suitable for 4G standards.**

***Index Terms*— MIMO, Wide band antenna, reflection coefficient, parametric Analysis.**

I. INTRODUCTION

As the need of data rate requirement is increased, it caused to develop a new smart wireless device with a significant change in establishing new wireless standards for communication. The concept of '4G LTE' consists of two separate words. Term '4G' is the fourth generation of data technology for the area of wireless communication after the development of the third generation. LTE means Long Term Evolution. It is a very small technical process for high-speed data and mobile phones. The main objective to develop the 4G was to achieve improved network than 3G and to offer a data connection that is better and delivers higher speeds than 3G. Specifically, 4G LTE means fourth-generation long term evolution. LTE is a part of 4G, that provides a fast connection for a mobile internet which is having 10 times more speed than 3G. In 4G networks, the use of MIMO technology plays a very important role, it helps to enhance data throughput. This system is useful for other multiple antenna characterization, like input impedance matching, frequency, and gain of the antenna. Antenna presented for a wide band in a 4G network covering frequencies around 1.5 GHz to 2.5 GHz and includes PCS, UMTS/LTE, Bluetooth, ISM, and wireless frequency bands. A single circular antenna element of the 50mm radius is placed as an antenna but it was having a large size. In the MIMO antenna system, it is impossible to hold more antenna elements within a small handset because of the large size of the antenna element. LTE antenna of dimension 15mm by 40mm is introduced in [1], which covers two Frequency bands of 689 MHz to 960 MHz and 1710 MHz to 2690 MHz For Wi-Fi and 4G dual-band monopole antenna is used. Also, two different slot mender patch antennas were introduced for 4G standard. These all 4G antenna structures are having large dimension, thus it is not possible to integrate with the MIMO antenna system. The proposed antenna system is easy to use, not bulky, and a combination of MIMO system with multiple antennas.

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II. LITERATURE SURVEY

Hussain, Rifaqat and et al has discussed about the compact MIMO antenna which work on 4G operating frequencies and with upcoming 5G systems for broadband, they have used mm-wave for high frequency application for upcoming 5G networks. With use of mm-wave arrays and MIMO antenna system they designed this antenna [1]. Plevel Sreco, Saso Tomazic and et al these researchers studied about the MIMO system, MIMO channel capacity, improvement and benefits of MIMO, Also they have studied types of diversities and their effects [2]. Michael A Jensen, Jon W. Wallace et al studied in their research about detailed MIMO system, how the system capacity can be increased, how the system could be compatible at different antenna topologies.In this paper main issues like channel capacity,channel measurement and modeling approaches are discussed [3]. Banhijit Bhattacharya, Somdutta Bhattacharya discussed about the topic how 4G provides more efficient scalable, reliable wireless service, wide-scale availability of 4G in wireless area,in this paper. Also they studied about actual 4G Technical details, lead Features, Challenges, And how its easy to implement 4G with cost reduction for maximum use [4]. Zhang Shaui, Zhaokun studied in their research and introduced diagonal antenna chassis mode to reduce the correlation between MIMO antenna elements and hence LTE MIMO array is proposed [5]. Nassrin Ibrahim and Mohamed Elamin proposed new antenna design concept of slot mender, construction of antenna using slot meander patch (SMP) design. SMP antennas are designed for fourth-generation long-term evolution (4G LTE) portable devices [8]. M.S.Sharawi, presented multi band printed MIMO antenna for 4G wireless standards, in which he discussed some mechanisms for improvement in isolation that are used in these closely packed antennas. Purpose of designing this antenna to solve issue about demand for maximum data rates for multiple applications within the allocated bandwidth and limited power [9]. Ling Sun, Wei Huang et al., those researchers has been worked on two port pattern diversity antenna for 3G and 4G MIMO application.In that research they design a antenna which is combination of low profile monocone antenna and broadband microstrip antenna. It achieves large impedance bandwidth and covers GSM 850/900, GSM 1800/1900 and LTE 800/2300/2500 bands [10]. Rifaqat Hussain, Mohammad S. Sharawi et al., proposed an Antenna design with an ultra wideband (UWB) sensing antenna to expand a complete antenna guidelines for cognitive radio (CR) applications. In this research A reguler, compact, single substrate, multi band, frequency-reconfigurable multiple-input multiple-output (MIMO) antenna system is presented [12]. S.F.Roslan, M.R.Kamarudin et al, presented new antenna design, rectangular dielectric resonator antenna (RDRA) for 2.6GHz Long Term Evolution (LTE) applications is investigated and presented and The parameters, isolation, gain, correlation coefficient and diversity gain of the MIMO RDRA are studied [13].

III. MIMO SYSTEM

Ref. [2] MIMO is an acronym which stands for Multiple Input Multiple Output. MIMO antenna technology can be used both in transmission and receiver equipment for wireless radio communication. Multi-path propagation is the biggest advantage of the MIMO system. It uses several antennas and two parallel signals from the transmitter. Multiple signals are separated by using special signal processing or algorithm at MIMO receiving end and generate one signal that has basically transmitted data. More than one antenna signals transmitted in a single channel, at the same time multiple radios collects multipath signals and delivers same speed, coverage and reliability improvements.

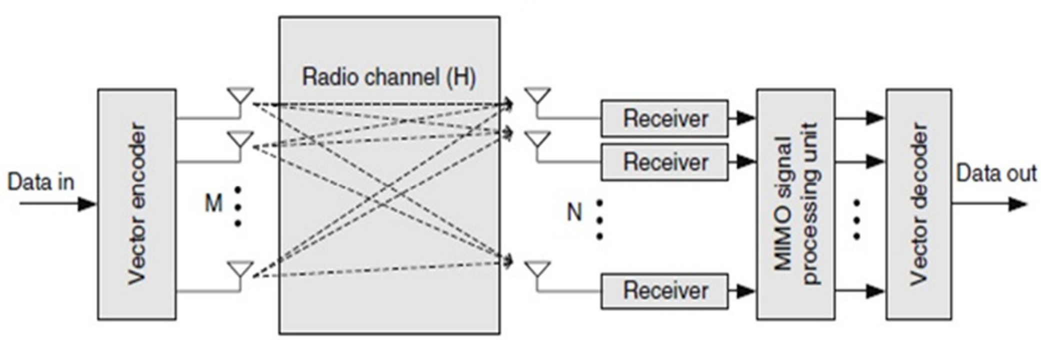

Fig. 1. MIMO system model [2]

A. MIMO system capacity & Diversity techniques

Ref[2] In the MIMO system, multiple antennas are used at both the transmitter and receiver side to improve communication performance. The improvement in the capacity of MIMO systems is linearly dependent on the number of antennas at transmitting or receiving side. By using MIMO system, several antennas can be used both at the transmitter and the receiver. The addition of more than single antennas at the transmitter combined with advanced signal processing algorithms at the transmitter and at the receiver gives a performance regarding capacity and diversity. The theoretical capacity of this system is calculated by the following equation (1) (Telatar, 1999).

$$C = log_2 \left[\det(I + \frac{\rho}{M\,HH^*})\right] \qquad (1)$$

Where

$$\rho = \frac{P}{{\sigma_n}^2} \qquad (2)$$

When the channel parameters are known at the transmitter, the water-filling algorithm can be used to maximize the channel capacity by allocating more power to the channels that are in good condition and less or none at all to the bad channels.For unknown channel matrix, uniform power distribution at the transmitter is calculated for channel capacity is assumed manually.

$$C = \sum_i^K log_2\,(1 + \lambda_i\ / M_\rho) \qquad (3)$$

$$C = \sum_i^K log_2\,(1 + \lambda_i P_i / {\sigma_n}^2) \qquad (4)$$

P_i = Power allocated to channel is calculated by waterfilling allocation.

Ref.[3] For unknown channel matrix, uniform power distribution at the transmitter is calculated for channel capacity

is assumed manually. To achieve the high channel capacity, a channel should be known to the transmitter and signal send through only good subchannel. In the case when a channel is unknown to the transmitter, transmitted power is divided equally among all the subchannels. transmitted power through bad subchannel is wested. Channel capacity can be improved by increasing number of transmitting antennas at the transmitter with the channel is known, this will work in low SNR regime also. While channel state is unknown, capacity

improvement can be compensated by increasing the number of antennas at receive side. In case of SNR greater than 0dB, when transmitting and receiving antennas are having the same ratio at both sides, capacity for known and unknown channel is almost the same.

system can be implemented using two methods, with respect to how data is transmitted across the given channel. In the MIMO system, the same data can be sent through the spatial path, so that reliability can be improved. This is called spatial diversity. In another method different portions of data should be placed on different propagation path, this is known as spatial multiplexing. This will improve the data rate. So these

two systems are listed as

1. Spatial Multiplexing - provides degrees of freedom or multiplexing gain and improvement in the data rate of systems.
2. Diversity Techniques - provides diversity gain and improving reliability

IV. PROPOSED MIMO ANTENNA DESIGN

Ref. [1] The complete antenna system is designed which is having dimensions of 60mm by 100mm by 0.965mm of a backplane. A ground plane used in the design, act as a clever co-planer reflector for the two MIMO antennas. The overall structure will be like the front view of the antenna shown in figure 3 and the bottom side is showing ground cuts with respect to upper patches like shown in figure 3. Top layer and ground

plane are connected with each other by bonding material with a thickness of 0.05mm and relative dielectric constant εr of 3 and coaxial feed are provided from the front direction of the antenna. This MIMO antenna is simulated after design process and typical antenna parameters are achieved as result

like reflection coefficient, antenna radiation pattern, 3D polar plot, etc. [1] Figure 2 shows two coaxial feeds for MIMO antenna. These feeds are having separation of distance λ/2 of the operating frequency.

MIMO antenna designing process started with a simple micro strip monopole antenna at the high-frequency band. Initially design resonating at 2.925 GHz.Microstrip line stubs were added to the optimized antenna structure for impedance matching purpose. Reflection coefficient curve measured at 2.66 GHz. As well as bidirectional antenna pattern is measured. a monopole antenna is designed using 3D antenna design software. Here two elements are separated by 42mm distance placed at the top corner of the mobile device. A single element is having a dimension of 7.9mm by 29.4mm, MIMO elements are placed at the top of the board, used dielectric constant εr =3, tanδ = 0.0013, and thickness of 0.05mm. Here we are performing antenna simulation for better results but there are some necessary changes should be done in the design of antenna and feed positions.

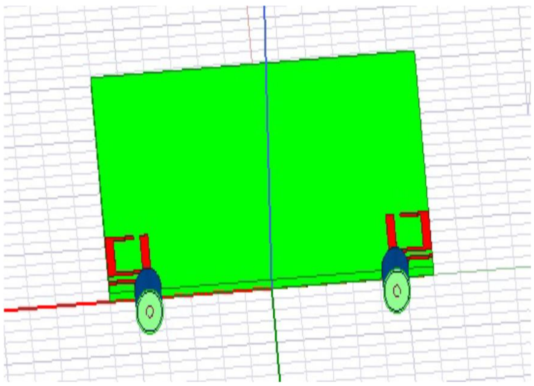

Fig. 2. MIMO antenna design- front side Coaxial connectors [1]

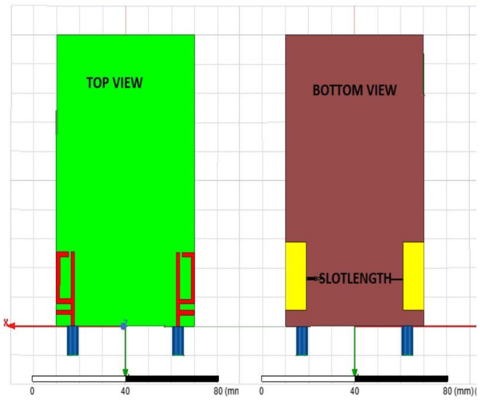

Fig 3. MIMO antenna design-Top view and Bottom view [1]

With these changes, antenna simulated with better performance and observed better results than the previous prototype. The proposed antenna designed with some of the dimensional changes, so for this antenna design, better results can be achieved after simulation. In this modified MIMO antenna, bottom kept as a complete ground plane and coaxial feeds provided from the bottom side, hence error of reflection and side radiation can be avoided and total radiation pattern achieved is purely single lobe radiation pattern. Strong radiation field indicates upward direction. After the simulation, the more improved reflection coefficient achieved. Figure 4 and 5 are a front view and bottom view of the proposed MIMO antenna design. This antenna designed using two cross monopole antennas. Coaxial connectors connected at the bottom side. The distance between the two connectors maintained is λ/2. Radiating patches are consist of copper material. bottom of antenna design is a copper sheet, which acts as a complete ground. FR-4 epoxy used as a substrate. In this design, vertical patch length is λ/2 according to resonating frequency.values for horizontal and vertical patch line is chosen 36mm and 29mm respectively, so the antenna resonates very well at a 1.89GHz frequency.

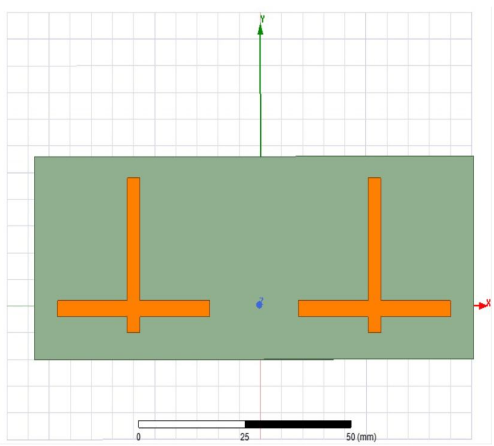

Fig. 4. Proposed antenna design-Top view

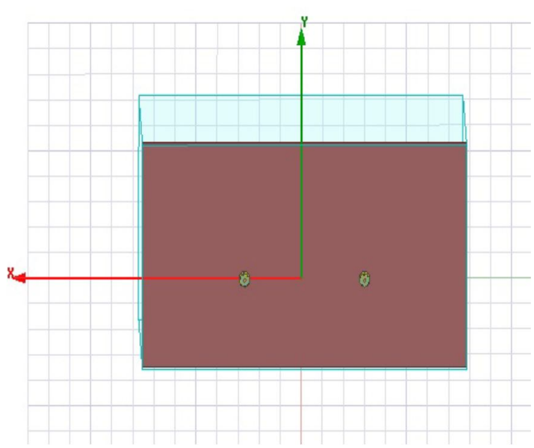

Fig. 5. Proposed antenna design- bottom view

V. ANTENNA PERFORMANCE AND SIMULATION RESULTS

Proposed MIMO antenna is fabricated for measurements, which is shown in figure 6. Two antennas are fabricated with the operating frequency of 1.85GHZ and 2.5GHz respectively shown in figure 6, it's the top view of the antenna. A bottom of the antenna is designed with the complete ground plane of copper and input coaxial feeds are connected at the bottom. After the simulation, radiation pattern for prototype MIMO antenna which we used to design, is shown in figure 8, this radiation view looks like a bidirectional pattern, two main lobs are observed, which is not expected. Proposed MIMO antenna works better than the previous antenna, as per the observation, radiation pattern and 3D polar plot are achieved as per required pattern which is single lobe and strong radiated field is observed at the upward direction. Reflection coefficient S11= 28.37 dB is achieved at 1.85GHz, which is much better. Figure 7 shows the 2D radiation pattern for the proposed antenna in H and E plane. From the graph shown in figure 16, VSWR value is observed 1.17, and the transmission coefficient value for S12 = 45.66 dB observed from the graph, to achieve better impedance matching and improved reflection coefficient, parametric analysis is done shown in figure 10, antenna tuned with resonant frequency by applying variant values for vertical and horizontal patch lines, after then as the graph, values for horizontal and vertical patch line is chosen 36mm and 29mm respectively so the reflection coefficient is achieved -28.37 dB at the resonating frequency of 1.85GHz.

Fig. 6. Proposed MIMO antenna prototype for measurement (top view)

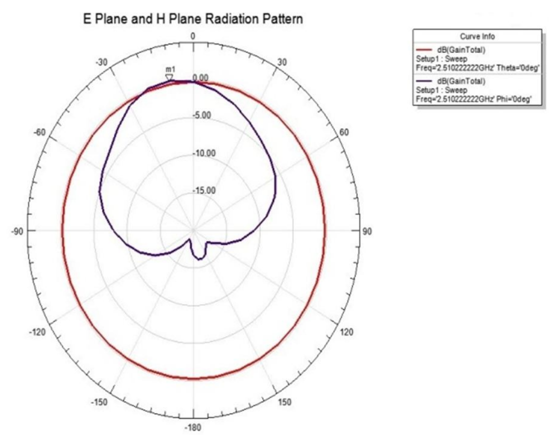

Fig. 7. Radiation pattern in H plane

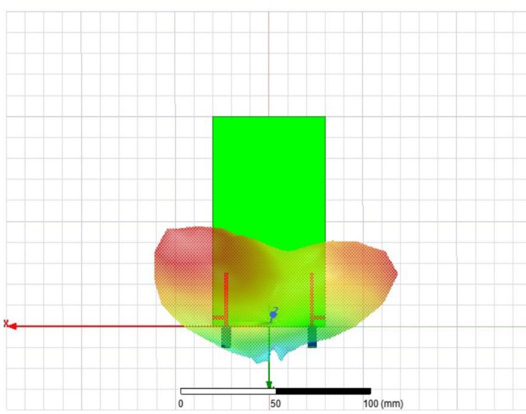

Fig. 8. MIMO antenna radiation view

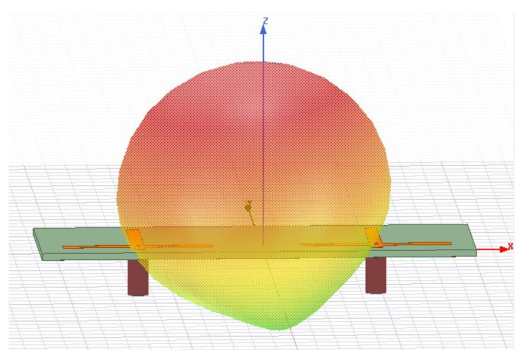

Fig. 9. Proposed antenna radiation view

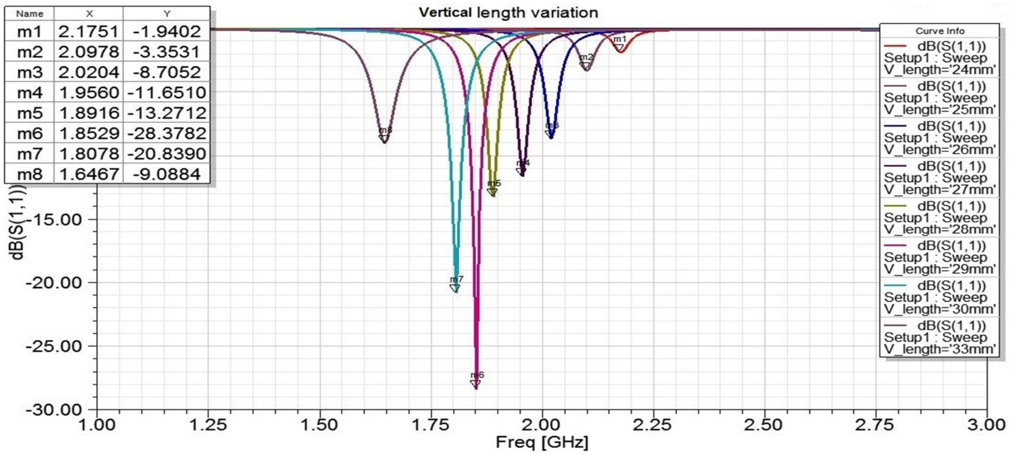

Fig. 10. Parametric analysis with variable length of vertical plane

Figure 11shown bellow is radiation patterns in 3D, the pattern showed the strongest radiation field in an upward direction. The graph shown in figure 10 is a parametric study of frequency tuning of antenna, using variable values of vertical and horizontal cross monopole antenna. The graph shown in figure 10 describes parametric study for a variable length of vertical patch of the cross monopole, length varies from 24mm to 33mm, as the length is varied, a graph of frequency shifts towards the lower band. The same situation observed parametric study for a variable length of a horizontal patch of a cross monopole. At certain value, the antenna is tuned with proper impedance matching at the resonating frequency of 1.85 GHz. Value obtained for S11 is -28.37 dB. Parametric study for variable positions of input feeds is done. These positions vary from 6mm to13mm, but in this case frequency shifts towards the upper band. It shows increasing and decreasing nature of impedance matching. Figure 8 shows the radiation view on the antenna surface for MIMO antenna, which is bidirectional patterns, two main lobes are created here, this radiation field is not acceptable. Proposed antenna radiated like shown in figure 9, the strongest radiation is observed in an upward direction. The single main lobe is created and strong field pattern is observed. when the fabricated antenna is tested, the measured values are observed for S11 is -23.1556 dB, VSWR is 1.16 and impedance is 49.94 . Figure 18 shows the graph for simulated versus measured values of reflection coefficient S11, simulated value for S11 was -28.37 dB and the measured value -23.15 dB is observed.

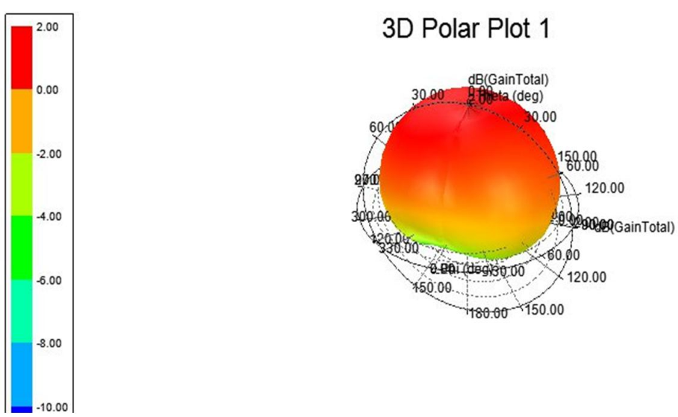

Fig. 11. 3D radiation pattern

VI. Conclusion

The Proposed antenna system is consistent with existing 4G standards for broadband operation. An antenna is designed using MIMO (Multiple Input Multiple Output) antennas with the feed network. The proposed MIMO antenna system is designed to obtain better reflection coefficient, more bandwidth and wide operating band without any change in gain as well as antenna resonating frequency. Parametric analysis is done

for proper frequency tuning of the antenna. From Parametric analysis, it is clear that, when verticle and horizontal length of cross monopole antenna kept variable, frequency shifts towards the lower band and at certain point antenna tuned to resonating frequency with proper impedance match. Different values for input feed positions result in increasing and decreasing nature of frequency shift, at resonating frequency exact impedance matching value is achieved. Use of complete ground plain at the bottom helps to avoid side radiations and reflections. Value for maximum reflection coefficient at 1.85 GHz is -28.37 dB after simulation and -23.15 dB after an antenna is tested on the vector network analyzer. When the

variation is done in vertical and horizontal patches, Maximum gain value is 3.92 dB.VSWR is observed 1.17 after simulation and 1.165 after antenna testing. Transmission coefficient value for S12 is -45.66 dB. Antenna Impedance is obtained 49.94. This antenna will surely provide benefits of high data rates and high bandwidth with better antenna results. The proposed antenna system is well-designed and suited for mobile terminals and future development in the communication area.

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