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Designing of a Dual-Band MIMO Antenna for 5g Smart Phone Applications

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Abstract-A dual band MIMO antenna is used for the 5G connectivity for smart phones. The antenna built is different from conventional 5G antenna. The antenna is perpendicular to the edge of the circuit board of the device it can be applied to the famous full screen cell phone. According to the simulation tests, the module's reflection coefficient is less than 6 db, and the insulation is higher than 12 db over the 3300-3600 MHz and 4800-5000 MHz frequencies which satisfy the needs of future 5G applications. The design of printed slot antenna is available for low cost FR-4 material. The proposed antenna consist of four for smart phone antennas operating at two frequencies setups to access for lower frequencies upto 3300 to 3600 MHz and for higher frequencies access upto 4800 to 5000 MHz.Similarly we can use this antenna setup for gps and wimax we can replace it by this antenna. The design of antenna is quite peculiar as it is mounted normally through the base of the PCB making which is easier to be applied in smart phones for 5G communications. The dielectric material FR-4 with relative permittivity of 4.4 and loss tangent (d) 0.02 was used as a substrate material for the design of the antenna proposed. The thickness of the substrate material is 1.6mm which is used to construct the antenna due to lossy properties. The technique of microstrip line feeling with patch insertion was used to feed the power to the antenna with a suitable impedance match of 50.This means full power can be transferred. The MIMO dual- band antenna for smart phones with parameters shows different tested results for return loss, gain, and VSWR etc. The simulation tool test is CST 2021 microwave studio for simulations and study.

Keywords- MIMO antenna,Fading problems, total gain, radiation pattern, VSWR

I. INTRODUCTION

The advancement of telecommunication technology has brought many challenges in the design of mobile devices in recent years, particularly in the area of antennas. There are many ways for the telecommunication network and it keeps evolving very repialy. Nowadays dual band and multi channel are among the most frequently used. Many studies have implemented dual-band and multi-band antennas for GSM, UMTS and Wi-fi on cell phones, but as now the LTE standard is announced and it is now important to cover frequency 1 bands. Because of the low frequency used by this standard, it becomes a challenge to build an antenna that can work over a wider frequency band and be incorporated in a cell phone [1].

The smart phone MIMO antenna system requires that antenna unit should have the characteristics such as broadband for long communications and working in the epidemic communication frequency band by which we can communicate far places. Miniaturization of MIMO antenna it should have small size and be easy to be carried with. It should be very convenient while using as long as possible and also be convenient for the different users. The purposes for integrated wireless electronics have a very high demand at compact volume and wide bandwidth. There is an immense market for commercial applications for antennas with multiband performance attributes. If the frequency is given, all is set.

The advantages of a MIMO system provides better signal strength even without clear line-of-site as they utilize the bounced and reflected RF transmissions. The higher throughput allows better quality and quantity of video sent over the network. Multiple data streams reduce the number of lost data packets, which results in better video or audio quality.

The main disadvantage of MIMO system is that the multiple antennas required extra high cost RF modules. The extra RF modules increase the cost of wireless communication systems. In this research, the antenna selection techniques are proposed to minimize the cost of MIMO systems. The purpose of MIMO communication sends the same data as several signals simultaneously through multiple antennas, while still utilizing a single radio channel. This is a form of antenna diversity, which uses multiple antennas to improve signal quality and strength of an RF link. The data is split into multiple data streams at the transmission point and recombined on the receive side by another MIMO radio configured with the same number of antennas.

A large number of research papers focused on the design of multiband antennas, the most common techniques of which were etching slots on the radiating patch or ground plane. Steps must be taken when etching patch slots as it reduces the effective aperture of the radiation resulting in lower gain values. Alternatively, the antennas can operate on the10.5 and 12Mhz frequency bands in all mobile phone application frequency bands with a return loss of less than -10db.

The pentagonal patch antenna is most common used antenna in smart phones now days, due to its less cost and most efficient antenna for smart phones. The pentagonal patch antenna is simulated at 5.8GHz frequency which is useful for WI-MAX applications.

The pentagonal antennas are considered as the most common types of antennas due to their obvious advantages of light weight, low cost, low profile, planar configuration, easy of conformal, superior portability, suitable for arrays, easy for fabrication, and easy integration with microwave [2].

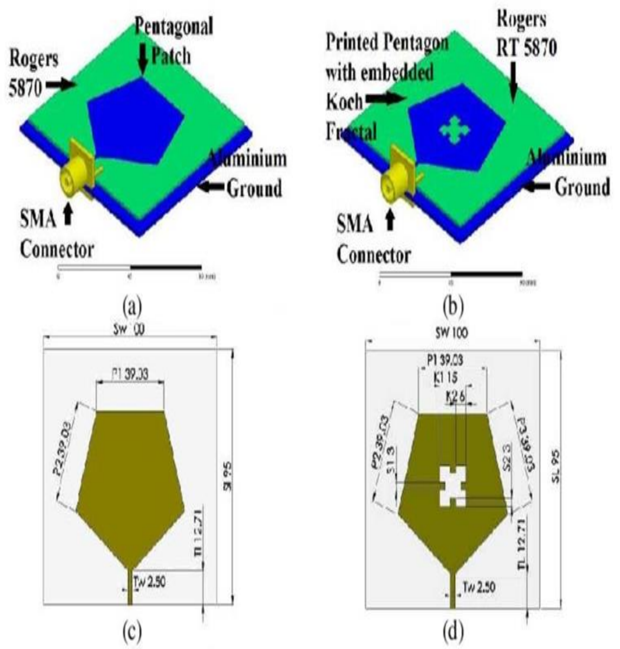

Fig 1. Pentagonal antenna

This is the figure of mostly used pentagonal antenna in smart phones. It also used in high- speed digital PCB designs, where signals need to be routed from one part of the assembly to another with minimal distortion, and avoiding high cross-talk and radiation.

II. EXISTING SYSTEM

Antennas used before are capable of working in the unique application of frequency. MIMO systems focused on basic spatial diversity - here the MIMO system was used to limit the degradation caused by multipath propagation. However this was only the first step as system then started to utilize the multipath propagation to advantage, turning the additional signal paths into what might effectively be considered as additional channels to carry additional data.

III. PROPOSED SYSTEM

The telecommunication technology is moving in very fast track due to which most of world is moving through the age of connectivity, new technologies and apps and games evolving each day, connecting people with help of technologies and artifacts. The amount of data collected is growing along with the demands of a rising innovative society, smarter and better services. The exponential increase of the number of connected devices, as well as the amount of data traffic generated, is anticipated in the coming years.

The fifth generation of mobile communications (5G) is aimed at adapting to this technological change, offering an improvement in capability, coverage, accessibility, energy efficiency, and cost savings as opposed to the 4G. The 5G networks would allow connectivity from the most densely populated to the most remote locations everywhere, stationary or moving, and its implementations can be grouped. MIMO is effectively a radio antenna technology as it uses multiple antennas at the transmitter and receiver to enable a variety of signal paths to carry the data, choosing separate paths for each antenna to enable multiple signal paths to be used. MIMO antenna can be used as low-power and low-cost communications, usually includes connecting hundreds of small sensors, and has common applications in agriculture, robotics, smart homes or smart cities.

Mission- critical services include high performance, low latency, high reliability and safety features and have application in autonomous vehicles, drones, and other critical applications. Enhanced Wireless Broadband applies to systems with high latency, broad coverage and quicker internet access. This is capable of operating in 4 frequency bands and as built in by one antenna, for 3 applications. Miniaturization is performed in pentagon shaped, optimistically constructed to achieve the minimum return loss over the frequency.

To use multiple antenna at same time many problems occurs these problems are as follows:

- **Fading problems**Caused by Caused by constructive and destructive waves can be removed by adding more antennas with different signal levels.

- **Maximum ratio combining** Gives a combining effect reducing destructive wave. The waves are formed in Digital environment
- **Deep wave covering** More antennas can be added, incase two antennas are in deep wave, the third will cover. Maximum ratio combining can also be taken as a factor.
- **Mutual coupling** Adding more antennas increases planes but also start to fade each other.
- **Radiation pattern distortion** Radiation pattern maybe distorted by the current induced in 2nd antenna

1. Factors affecting MIMO base stations:
Space-division multiple accesses (SDMA) uses directional or smart antennas to communicate on the same frequency with users in different locations within range of the same base station. To reduce millimeter effects, massive MIMO – Base Station are used. The small antennas transmit bits of data simultaneously in a process called beam forming. This is more efficient than 4G-Base Station as signal is not transmitted over a large area which consumes more power. The Base Station server will calculate the best route to reach each wireless device. Multiple antennas will work together beams to reach that device.

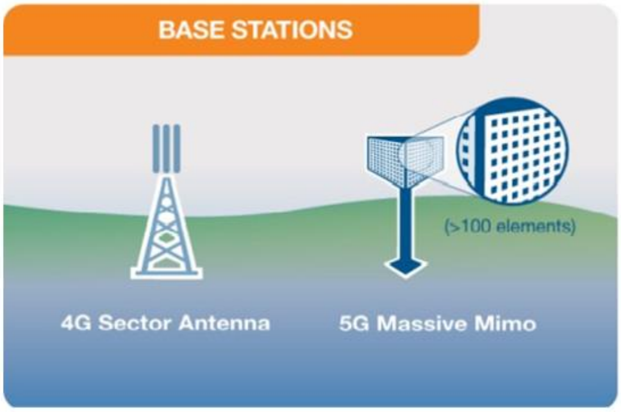

Fig 2. Base Station

IV. DESIGN PARAMETERS

1. Antenna size:
The Chu-Harrington limit (In electrical engineering and telecommunications the Chu– Harrington limit or Chu limit sets a lower limit on the Q factor for a small radio antenna. The theorem was developed in several papers between 1948 and 1960 by Lan Jen Chu, Harold Wheeler, and later by Roger F. Harrington) sets the minimum size of an antenna. A little smaller than 1⁄3 wavelength in its widest dimension.

For a small antenna the Q is proportional to the reciprocal of the volume of a sphere that encloses it. For any given frequency, bandwidth and efficiency the Chu-Harrington limit gives the minimum size of the antenna Part of this theory deal with polarization. It is stated that orthogonal polarizations are independent, so restricting ourselves to only one polarization will increases the size of the antenna.

2. Separation &Power Pattern:
When two antennas as are very widely separated the coupling between them is given by the path loss equation:

$$\textbf{Coupling} = L + G1 + G2 \text{ (dB)}$$

G1 is the gain of antenna 1 in the direction of antenna 2
G2 is the gain of antenna 2 in the direction of antenna 1
L is the path loss between them, given by 32.4 + 20log10 (f MHz) + 20log10 (D KM)

- The proposed antenna is designed on the side of the PCB to meet the trend of modern ultra smart phones.
- The single antenna designed can be operated at the bands of 3300 - 3600 MHz and 4800 - 5000 MHz
- The height of the edge frame is kept 5mm.
- The area of the side frames is 3.9 mm x 17 mm.
- The system circuit board is selected to have an area of 130mm x 74mm.
- The substrate is FR-4 lossy with a thickness of only 0.8mm (loss tangent 0.02).
- The radiation part is L-shape stub at the back.
- Used for high frequency impedance matching.
- The expected S-parameters are under -6 dB.

V. SOFTWARE DESCRIPTION

CST Studio Suite® is a high-performance 3D EM analysis software package for designing, analyzing and optimizing electromagnetic (EM) components and systems. Electromagnetic field solvers for applications across the EM spectrum are contained within a single user interface in CST Studio Suite. The solvers can be coupled to perform hybrid simulations, giving engineers the flexibility to analyze whole systems made up of multiple components in an efficient and straightforward way.

Co-design with other SIMULIA products allows EM simulation to be integrated into the design flow and drives the development process from the earliest stages. Common subjects of EM analysis include the performance and efficiency of antennas and filters, electromagnetic compatibility and interference (EMC/EMI), exposure of the human body to EM fields, electro-mechanical effects in motors and generators, and thermal effects in high-power devices.

CST Studio Suite is used in leading technology and engineering companies around the world. It offers considerable product to market advantages, facilitating shorter development cycles and reduced costs. Simulation enables the use of virtual prototyping. Device performance can be optimized, potential compliance issues identified and mitigated early in the design process, the number of physical prototypes required can be reduced, and the risk of test failures and recalls minimized.

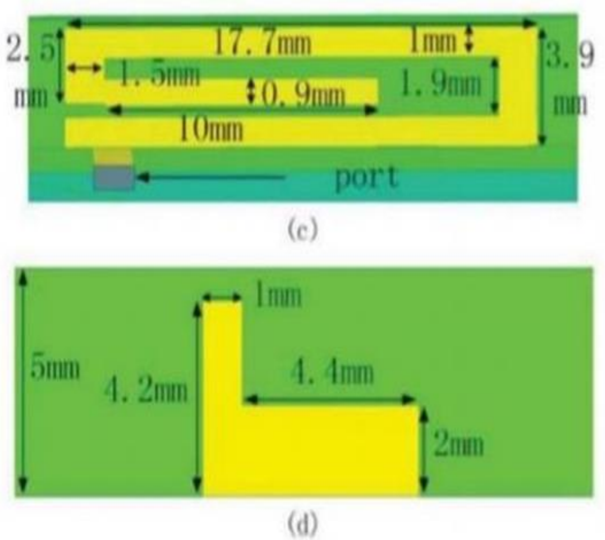

Fig 3. Design and Characteristics of Antenna.

VI. SIMULATION RESULTS

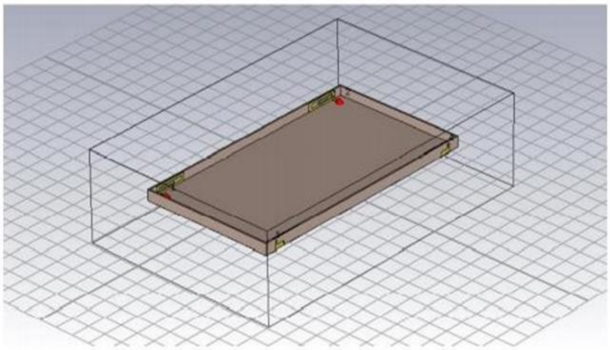

Fig 4. CST Design.

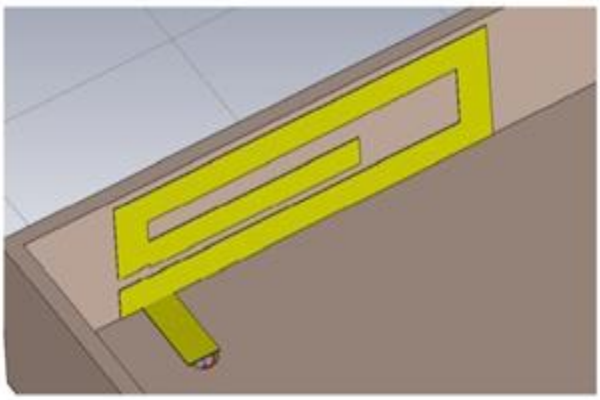

Fig 5. CST Design (Antenna).

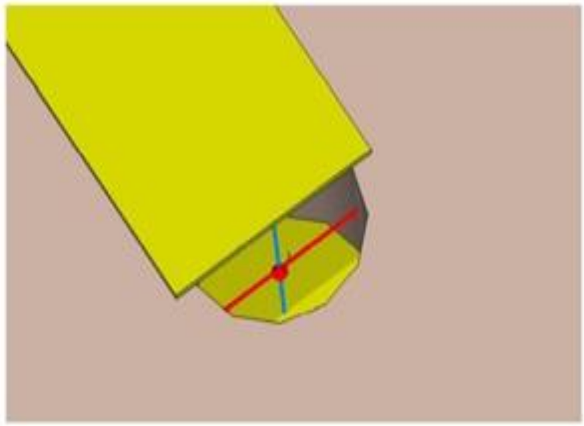

Fig 6. CST – Discrete Edge Port.

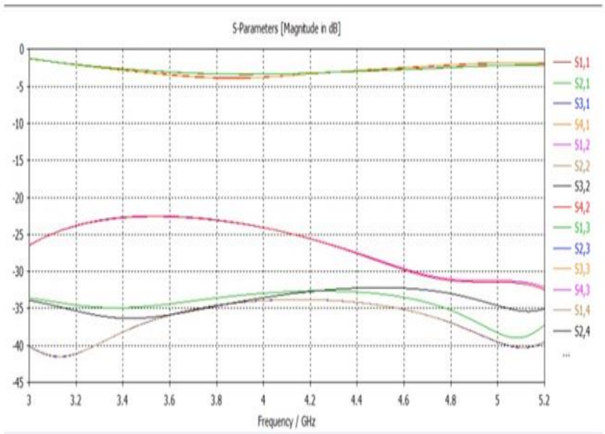

Fig 7. CST Result.

1. Total Gain:
In a receiving antenna, the gain describes how well the antenna converts radio waves arriving from a specified direction into electrical power. When no direction is specified, gain is understood to refer to the peak value of the gain, the gain in the direction of the antenna's main lobe. In case of MIMO antenna the antenna gain after transmission would we equal to the shown in fig. Antenna Gain describes how much power is transmitted in the direction of peak radiation to that of an isotropic source.[8]

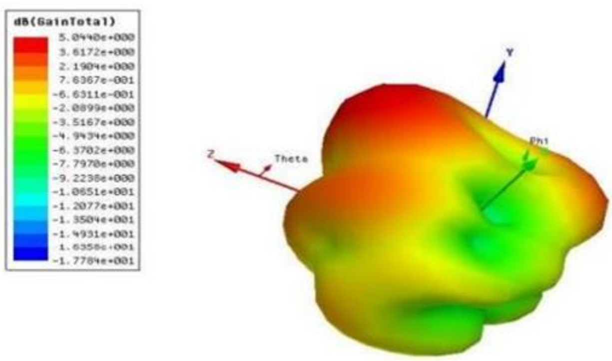

Fig 8. Total gain

2. Radiation Pattern:

In the field of antenna design the term radiation pattern (or antenna pattern or far-field pattern) refers to the directional (angular) dependence of the strength of the radio waves from the antenna or other source. Radiation pattern is the variation of the power radiated by an antenna as a function of the direction/angle away from the antenna. This power variation as a function of the arrival angle is observed in the antenna's far field. [9]

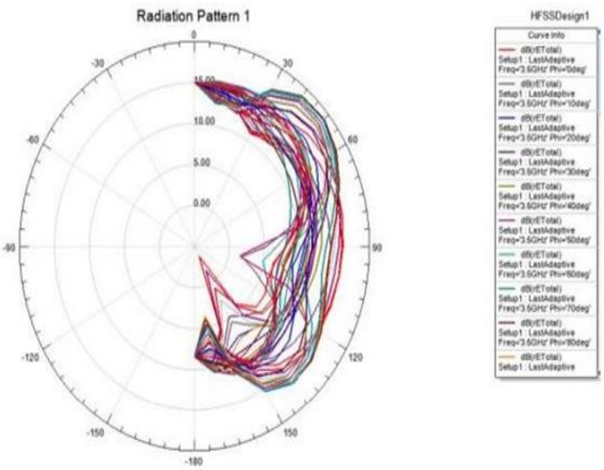

Fig 9. Radiation pattern

VII. VOLTAGE STANDING WAVE RATIO (VSWR)

To measure of how efficiently radio-frequency power is transmitted from a power source, through a transmission line, into a load (for example, from a power amplifier through a transmission line, to an antenna). In an ideal system, 100% of the energy is transmitted. VSWR is a function of the reflection coefficient which is described by the ratio of voltage reflected from the antenna to the voltage delivered to the antenna.[7]

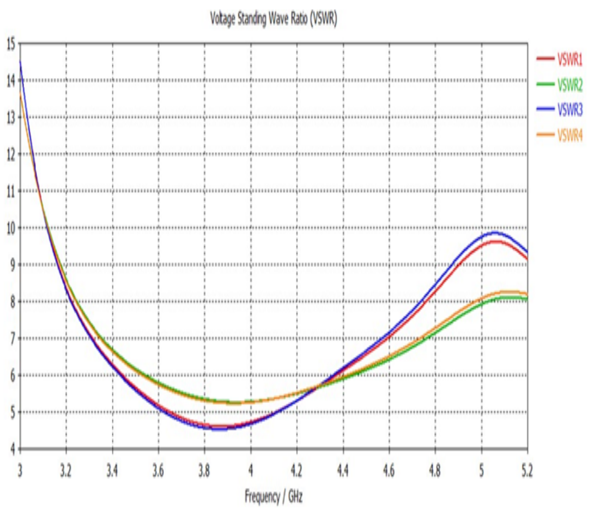

Fig 10. Voltage standing wave ratio graph

VIII. USER HAND EFFECT

In motion-sensing interaction with large displays through bare hands, we can observe that users alternate their hands and move their bodies frequently. What cause such actions and how these actions affect free hand interaction results are less systematically investigated.

To address this gap in knowledge, we conducted studies on Pointer-Acceleration (PA)-based free hand interactions of target selection and found that (1) users made more frequent hand alternations when selecting small targets with large movement amplitudes, as in such cases users were not only affected by observable arm fatigue, but were alsoalternation led to the hand orientation effects: target selection on display areas at the operating hand's side was more efficient and accurate than that at the opposite side.

Antenna's performances will be reduce by 18% if the human hands are in close proximity. 4 antennas not practically efficient as smart phones remain mostly in the user's hand. Same issue comes with 6x6 MIMO design. 4x4 MIMO design has the least User Hand Effect.[13]

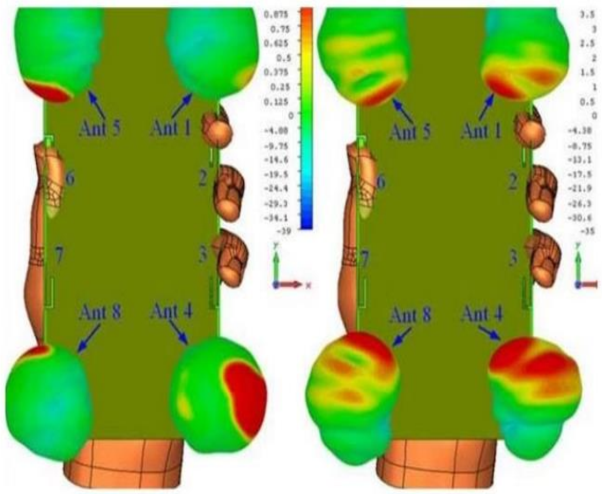

Fig 11. User hand effects in smartphones

IX. ENVELOPE CORRELATION COEFFICIENT (ECC)

Envelope Correlation Coefficient tells us how independent two antennas' radiation patterns are. So if one antenna was completely horizontally polarized, and the other was completely vertically polarized, the two antennas would have a correlation of zero. Similarly, if one antenna only radiated energy towards the sky, and the other only radiated energy towards the ground, these antennas would also have an ECC of 0. Hence, Envelope Correlation Coefficient takes into account the antennas' radiation pattern shape, polarization, and even the relative phase of the fields between the two antennas.

To get the mathematical formula for ECC, let's define the radiation pattern mathematically as a vector function in spherical coordinates. We'll call the radiation pattern $\overline{F_1(\theta,\phi)}$ (the line on the top means it is a vector function), and we can write the radiation pattern as:

$$\overline{F_1(\theta,\phi)} = F_{1\theta}(\theta,\phi)\cdot\overline{a_\theta} + F_{1\phi}(\theta,\phi)\cdot\overline{a_\phi} \quad \text{……….(1)}$$

In (1), (θ,ϕ) represents the spherical angles (elevation, azimuth),represents a unit vector in the theta direction, and $\overline{a_\phi}$ represents a unit vector in the phi direction. Equation (1) is a mathematical representation for a vector-valued function defined over the sphere. The vector notation represents the polarization of the Electric Field.

Note also that $F_{1\theta}(\theta,\phi)$ and $F_{1\phi}(\theta,\phi)$ are complex functions; the angle of the complex value represents the relative phase of the radiation pattern at each point.

The envelope correlation coefficient is written mathematically in Equation (2):

$$\rho_e = \frac{|\int\int \overline{F_1}\cdot\overline{F_2^{\star}}\,d\Omega|^2}{\int\int|\overline{F_1}|^2 d\Omega\cdot\int\int|\overline{F_2}|^2 d\Omega} \quad \text{……………(2)}$$

That's a lot of math. Rewritten in English, Equation (1) simply says the antenna's radiation pattern varies over a sphere (that is, it will vary in different directions from the antenna) and have an associated polarization (this is the vector part - the direction of the E-field). Equation (2) is a measure of how correlated two different antennas' radiation patterns are. If they are the exact same (so that F1=F2), the correlation coefficient would be 1.0. If they are completely independent, the correlation would be 0.

X. COMPARISON OF ECC

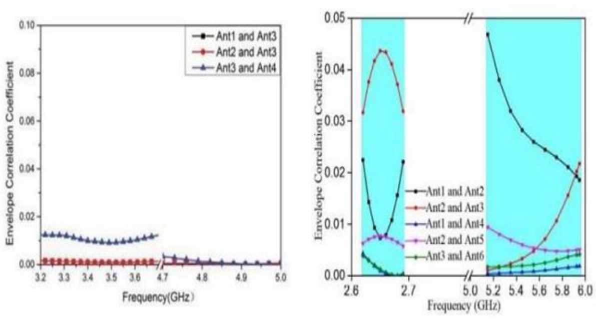

Fig 12. Envelop Correlation coefficient of (a)4X4 MIMO (b)6X6 MIMO

For both Low Band and High Band, ECC of 4x4 MIMO antenna is least compared to 6x6 MIMO antennas. Which is desired in practical field and 4x4 antennas is commercially efficient as well.

	4x4 MIMO	6x6 MIMO
Low Band	0.01	0.03
High Band	0.001	0.01

XI. ANTENNA EFFICIENCY

Antenna Efficiency is the ratio of power radiated (Prad) by the antenna to the power supplied (Ps) to the antenna. The efficiency of an antenna is usually measured in an anechoic chamber where an antenna is fed with some power and the strength of the radiated electromagnetic field in the surrounding space is measured.

$$Antenna\ Efficiency = \frac{P_{RAD}}{P_T}\ \%$$

An ideal antenna has 100% antenna efficiency i.e., it transmits all the power fed to it. But in the real world, a good antenna radiates only 50 to 60% of power supplied to it.

	4x4 MIMO	6x6 MIMO
Low Band	85%	65%
High Band	53%	78%

1. Low Band:
For 4x4 MIMO the average efficiency in Low Band is around 85% and for 6x6 MIMO is 65% approximately.

2. High Band:
While in high band it is 53%, and 78% respectively.

XII. CONCLUSION

A dual-band (4 antennas) MIMO array for 5G smart phone applications is proposed.The proposed antenna is located on the side frame, to create a full screen smart phone antenna design.Its ECC offers the best results.

It is the most efficient for Lower Bands, but the Higher Band efficiency can be improved by simple design changes following the 6x6 antenna design.To achieve a relatively high isolation, the antenna size is relatively small, ideal for today's ultra-thin smart phone communications.

XIII. FUTURE WORK AND PERSPECTIVE

As we see that A.E in high band is low so our intention to increase it in higher band. From analysis of three papers we propose that antenna is design on the top surface of circuit board.

In future, need to reduce antenna losses (reducing conduction losses, dielectric losses) by using good substrate material like low temperature Co-fired Ceramic substrate has the advantage of low dielectric and conduction losses to increase efficiency.

By 2021, global mobile data traffic will be seven times higher than it was in 2016. Video will account for more than 78 percent of all mobile data and smart terminals will consume an average of 15 GB of data per month. With wireless networks relying on spectrum for expanding network capacity and sharing air interface bandwidth, unprecedented challenges are creeping over the horizon.

In airports, stadiums, squares, subways, and other public spaces, network speeds can become unbearably slow when there are lots of people, regardless of the type of mobile phone used, even for short video clips. Current networks fall short when it comes to the data requirements of new applications as a result of current wireless network tech, limited radio spectrum, and shared bandwidth between all terminals in a cell.

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