MIMO Based Rectangular Micro Strip Antenna for 5th Generation Communication System

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Abstract: Now a day's antennas plays a major role in communications where its demand is getting increased to feed the needs in this paper the basic Multiple Input Multiple Output (MIMO) antenna is designed which is of 8 matrix sizes for 5G devices which are high in range and having higher bandwidth. These antennas are of size occupies 3×4 mm^2 each which is implanted on top most layer of substrate plate in H-shaped rotated Patch form. Where the total size of substrate we take is of $31.2 \times 31.2 \times 1.57$ mm^3, size with dielectric constant of size 2.2. We place total 8 MIMO antennas in substrates top layer and the substrates bottom is a ground plane where this ground plane is of Electromagnetic Band Gap (EBG) design only for obtaining efficiency and gain enhanced. For avoiding spurious radiation if any we feed out substrate from the bottom layer through vias. These kinds of antennas have resonation at 27 GHZ with bandwidth of 6DB. In the whole band width of antennas attained gain is of more than 7 dB that has a high range 8dB. Similarly the efficiency we obtained in these antennas is about 65% than the highest of 93%. CST microwave design tools are used for these antennas design and the simulation results have given the better performance of the MIMO antennas which makes them suitable of 5G technology.

Index Terms 5G, EBG, High Gain, MIMO, Efficiency, Patches.

Introduction: With an increase in the number of users the frequency allocation is getting deficient due to limited channel bandwidth. Within in the same frequency bandwidth the number of users cannot exceed a specified limit. Also, the co-channel interference increases with an increase in number of users. After the evolution of high definition (HD) and quadruple high definition (QHD) video resolutions, it becomes quite difficult for the handheld devices to send or receive large volume videos on the 3G and 4G frequency channels. It thus becomes a necessity to have a wider bandwidth and a faster data rate for rapid transmission and reception of high quality multimedia wirelessly from one terminal to the other. To cater for this problem, 5G frequencies are under research due to their wider bandwidth. 5G offers greater bandwidth with more number of frequency channels as compared to 3G and 4G thus making it suitable for increased number of users who demand fast data rate on the go. Besides its impressive features, 5G frequencies face a potential problem related to the low penetration power due to which the signal fades and gets weaker while reaching from transmitter to receiver using one antenna at each end. In order to enhance the range of the transmitted signal, Multiple Input Multiple Output (MIMO) and/or array antennas can be a better solution especially when dealing with compact battery powered devices. Few designs of compact 5G antennas have been presented in. It has been observed from the review that the antennas presented are mostly single antennas and few array antennas as it is very difficult to achieve high gain using a single antenna. The array antennas, however, being fed through single port has the same capacity performance as that of single antennas. Due to this reason, the frequency channel is busy most of the time thus reducing data transfer rate. Also, the proposed antennas possess poor bandwidth thus limiting the number of frequency channels. Another issue associated with the 5G designs, presented in the literature, is that the antennas are mostly not in MIMO configuration which makes them un-suitable for devices demanding a high data rate and throughput performance. An H-shaped antenna is presented by Wong et.al in for WLAN frequencies. The design covers dual band. However, it is not MIMO antenna, thus not suitable for high date rate smart devices. It is therefore a strong need to develop the MIMO antennas for 5G devices so that a higher data rate and a wider bandwidth can be made possible.

In this paper we present a printed MIMO antenna system for future smart 5G devices such as smart watches and dongles etc. The design presents eight similar antennas etched on the front of a Rogers RT-5880 substrate board. Each antenna of the MIMO system is a rotated H-shaped patch and covers a wide bandwidth for future 5G communication. The geometry of the proposed 5G MIMO antennas and their simulation and measurement results will be discussed in the upcoming sections.

Basic Antenna: The MIMO antennas are modeled and simulated in CST Microwave Studio®, as presented in figure 1, whereas, the fabricated prototype is presented in figure 2.
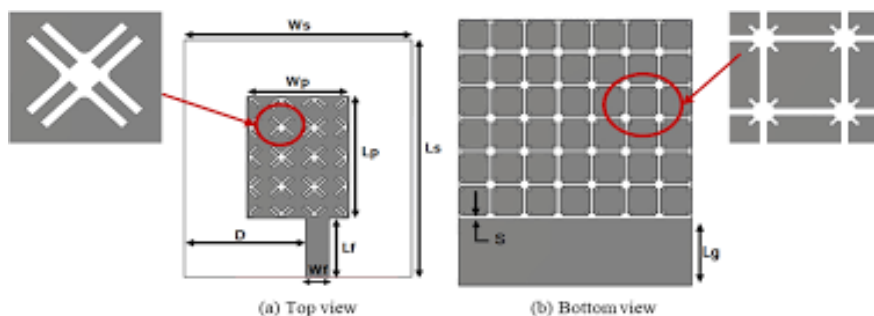
Figure 1: Basic antenna from both views

It can be anticipated that few discrepancies may incur between the simulation and measurement results mainly due to soldering of RF connectors which extend outside ground boundary.
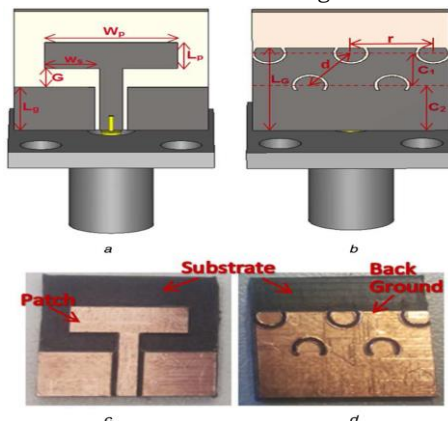

Figure 2. Antenna Fabrication

The detailed dimensions of the antennas and the ground plane are shown in figure 3. It can be seen that the size of the substrate used for the design is 31.2 x 31.2 x 1.57 mm^3 which fits well within the housing of smart device as smart watch or internet dongle. The geometry of each antenna resembles a rotated H-shaped patch, which along with its feed line occupies a space of 3 x 4 mm^2 which makes it suitable small handheld future 5G devices. The via-holes drilled for the purpose of feeding have a diameter of 0.5 mm. The horizontal edge-to-edge spacing between the antennas is 11.1mm which is approximately 0.93λ at 25 GHz. Likewise; the vertical edge-to-edge spacing is 10.1 mm which is approximately 0.84λ at 25 GHz. The dimensions of the antennas and the ground plane are optimized to achieve better s-parameter and radiation performances. The simulations have shown that the H-shaped patch gives a wider 6 dB bandwidth as compared to a rectangular patch.
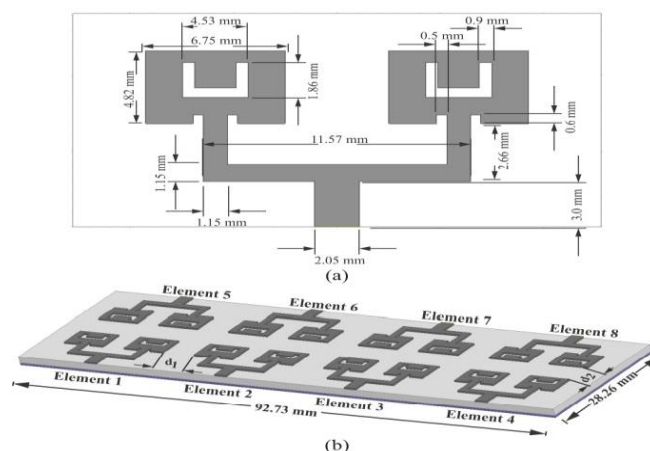

Figure 3. Simulation model of antenna

It can be seen from figure 1 that the design is comprised of eight H-shaped MIMO antennas printed on the top layer of Rogers RT-5880 board whereas, the bottom layer is composed of an EBG based ground plane which consists of slots each having a width of 0.2 mm. Each antenna has a microstrip feed line that is fed from the back through via hole to minimize spurious radiations. The RF coaxial connectors used in the fabricated prototype are 2.92 mm type female connectors. The simulations have been carried out at the

Research Institute for Microwave and Millimeter-Wave Studies (RIMMS), National University of Science and Technology (NUST), Pakistan, whereas, the testing of the antennas is performed in the antenna laboratory at Beijing University of Posts and Telecommunications (BUPT), China. The proposed design is composed of four antennas at the corner and four at the center. The results of one of the corner antennas and one of the center antennas are presented for the ease of analysis.
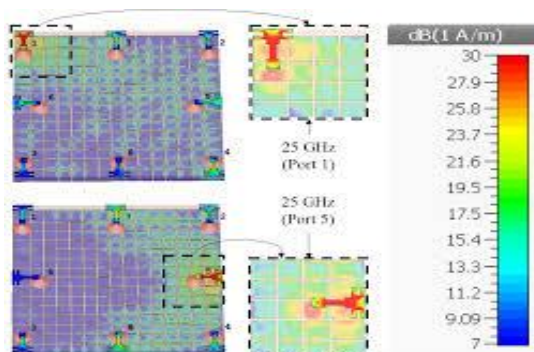

Figure 4. MIMO Antenna Dimensions

The dimensions the proposed H-shaped patch antenna are smaller than most of the designs from the literature. Also, the dimensions of the proposed MIMO configuration are smaller than other 8-element MIMO antennas. The MIMO antennas presented in this work are confined to a small area, whereas, most of the 5G MIMO designs are not confined to a small area thus making them not suitable to be implemented in current devices. The proposed design, with few modifications, can thus be etched within 3G/4G devices where we have relatively large spacing between MIMO antennas.

Results: This section will present and compare the simulation and measurement results of the 5G MIMO antennas. The S-parameters of the 5G MIMO antennas are presented in figure 4, wherein, the parameter SXX represents the reflection loss of the antennas. The SXX curves are shown for only antenna 1 and antenna 5, as all the other antennas are identical to these and are symmetrically placed. It can be seen that the antenna 1 and antenna 5 possess almost identical reflection coefficients in simulations due to which measurement result for only antenna 1 is shown. For practical antennas with a compact profile, the bandwidth is usually defined with reference to SXX value of – 6 dB whereas, for normal antennas it is usually defined with respect to – 10 dB. The antennas presented in this paper are compact and cover a very small geometry due to which the bandwidths are defined at – 6 dB mark. It can be seen that the antennas are resonating at approximately 25.2 GHz with a simulated bandwidth of 4.1 GHz (23.1 – 27.2 GHz) whereas, in the measurements, the antennas are resonating at 25.4 GHz with a bandwidth of 5.68 GHz. The antennas are thus covering 5G frequency band which ranges from 24.25 – 27.5 GHz. A minor discrepancy has been observed between the simulation and measurement results which occurred mainly due to the substrate tolerances and fabrication imperfections.
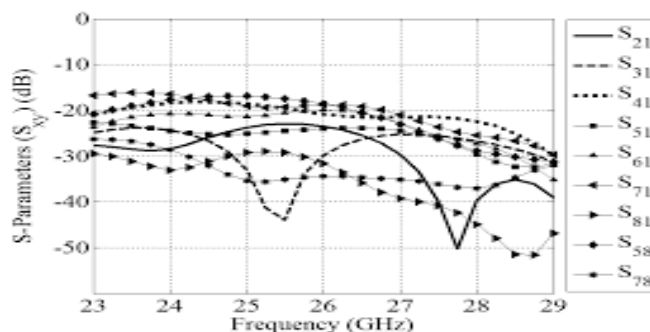

Figure 5. Measurement of Simulation

The SXY curves of the MIMO antennas are shown in figure 5. The SXY parameter represents the isolation between individual elements. It was observed while simulations and measurements that the antennas possess an isolation performance better than 15 dB over the entire frequency bandwidth. The simulated minimum value of SXY is 16.21 dB, whereas, the measured minimum is 16.19 Db. The simulated current distributions of the MIMO antennas are shown in figure 5. The current distribution element 5 is different from that of element 1 due to their different positions on the substrate board. The antenna # 1 lies on the corner whereas; antenna # 5 lies between the other two antennas thus resulting in both elements having

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different radiation patterns. The simulated and measured radiation patterns of the 5G MIMO antennas at 25 GHz are shown in figure 6. The radiation patterns of only Antenna # 1 and Antenna # 5 are shown as other antennas are identical to these and are symmetrically placed. It can be seen that the antennas demonstrate an approximately directional radiation pattern. A discrepancy has been observed between simulation and measurement patterns which may have incurred due to soldering of SMA connectors as the housing of the connectors extends outside ground boundary. This might have been avoided if pig-tail connectors were used.
Efficiency and Gain: The gains and efficiencies of the MIMO antennas at different frequencies are shown in figure. Gain is computed by the 'Gain comparison method' using standard gain Horn antenna, whereas, for the measurement of efficiency 'Wheeler Cap method' is used. Some discrepancies have been observed between the simulated and the measured values which are mainly due to the imperfections in the fabrication of the antenna especially the flange connectors which extend outside ground boundary. The average difference between the simulated and measured gain of Antenna # 1 is 1.41 dB whereas, that for efficiency is 14.2 %. Similarly, the average difference between the simulated and measured gain of Antenna # 5 is 1.05 dB whereas, that for efficiency is 12.9 %.
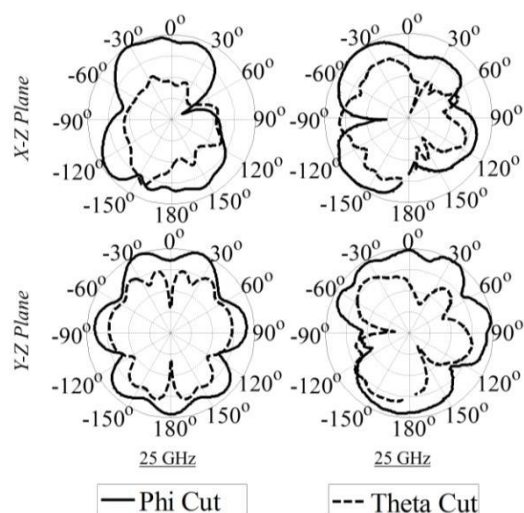

Figure 6. Antennas ——Phi Cut --- Theta Cut Pattern of Radiation

Comparison*:* The gain and efficiency performance of the MIMO antennas is better than most of the 8-Element MIMO antennas in the literature. Also, the design covers a smaller area than most of the designs which makes it distinctive and more suitable for small wearable and portable devices. Moreover, the MIMO configuration with eight rotated H-shaped patch antennas is rare and will give a better capacity and throughput performance than the other 2-element and 4-element MIMO antennas in the literature. A comparison with other 5G designs from the literature.

Antenna Analysis: The key parameters that have been studied for analyzing the MIMO performance of the proposed antennas include envelope correlation coefficient (ECC), mean effective gain (MEG) and effective diversity gain (EDG). Each parameter will be discussed in this section. The ECC curves between different MIMO pairs are shown in figure 8. The ECC values have been approximated using the S-parameters method. It can be seen from the curves that in the bandwidth of 23 – 27 GHz, the relatively larger values of correlation coefficients exist between antenna 1 & antenna 5, antenna 1 & antenna 7 and antenna 6 & antenna 7. The peak value of correlation coefficient is 0.03 which is much smaller than the practically acceptable value. From figure 5, it is obvious that the measured SXY is better than simulated SXY which means that the measured correlation coefficients will be better than the simulation ones.
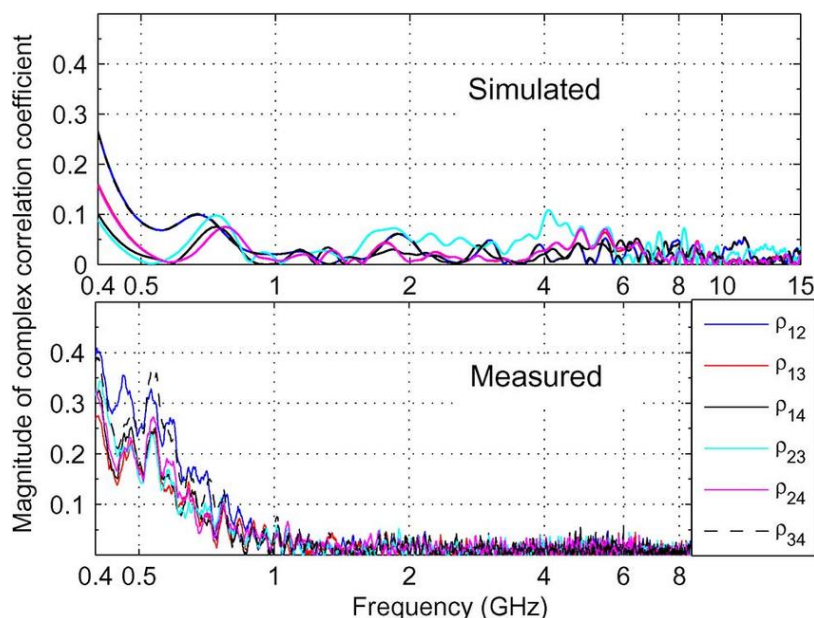
Figure 7. Coefficient of Correlation

Gain Effect: The simulated and measured values of mean effective gain of the proposed 5G MIMO antennas are calculated using the efficiency method, and are shown in Table III-IV. It can be seen that the antennas possess good values of MEG which happened primarily due to a better isolation between MIMO antennas. Also, the ratios of MEG of different elements are approximately equal to 1 which validate a good diversity performance of the MIMO antennas. The measured mean effective gains are slightly smaller than the simulated ones. This is primarily due to substrate tolerances, fabrication and testing imperfections.

Analysis of Every Parameter: A detailed parametric analysis was performed on different parameters of the MIMO design. The analysis was performed on antenna element 1 for the ease of understanding. The effect of variation of each parameter will be discussed in this section.

Approach: The design of the MIMO antennas proposed in this paper is composed of eight similar H-shaped patch antennas printed on the top layer of the substrate that comprises of an EBG based ground plane. This type of ground plane in the design improves its gain and reflection coefficient. The design can thus be divided into different configurations to understand the step-wise approach. Configuration 1 shows a single antenna (at the corner) with simple ground plane, configuration 2 shows single antenna (at the center) with simple ground plane, configuration 3 shows 8 antennas with simple ground plane, whereas, configuration 4 shows 8 antennas with EBG ground plane. The S-parameters of each configuration are shown in figure 8 whereas; the gain performance is shown in figure 9.
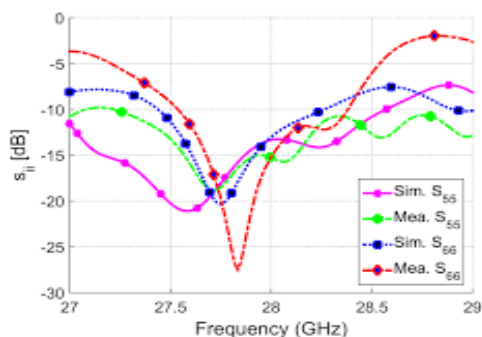

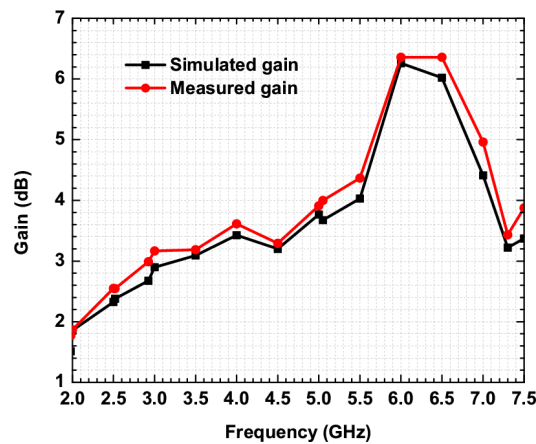**Figure 8. Proposed Antenna S Parameter**

Figure 9. Proposed Antenna Gain

It can be seen that the EBG ground plane provides much better reflection performance as compared to a simple ground plane. Also, the gain performance of the configuration 4 is much better than the other configurations.

Conclusions: A design of 8 x 8 MIMO antennas was presented for 5G communication. The antennas demonstrated a compact geometry and a wide bandwidth of 4 GHz ranging from 23.1– 27.2 GHz. There has been observed a good agreement between the simulation and the measurement results. The design presented in this paper displayed good return loss and radiation performances thus making it suitable for future 5G devices such as smart watches and dongles etc. Reduction in the size of the substrate, improvements in the fabrication of the antennas and measurements with new dimensions, will be a part of immediate future work.

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