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MIMO Antenna with Rectangular Complementary Split Ring Resonators for 28 GHz

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Abstract— **A Multiple Input Multiple Output (MIMO) antenna for 5G systems using 28 GHz band is presented in this paper. This MIMO antenna is designed on Rogers RT 5880 substrate having ε_r=2.2 and tanδ=0.0009. The substrate is 0.787 mm thick and it has an area of 23.65 x 23.12 mm^2. Complementary Split Ring Resonators (CSRR) are used to improve bandwidth of this four element MIMO antenna by 1.5%. The MIMO antenna is operating in the range of 27.19 GHz to 30.21 GHz and has an impedance bandwidth of 10.78%, with maximum gain of 8.43 dBi at resonating frequency. Simulations of MIMO antenna show good results so it can be utilized for 5G communication systems.**

Keywords*— Fourth Generation (4G), Fifth Generation (5G), Multiple Input Multiple Output (MIMO), Complementary Split Ring Resonators (CSRR), Envelop Correlation Coefficient (ECC)

I. INTRODUCTION

At the moment, with 4G at our disposal, we are facing issue of bandwidth scarcity and for this purpose scientific community is now focusing on more efficient future of wireless networking, that is, 5G (Fifth Generation). Every generation of wireless networking is significantly faster and more capable than the previous ones and so will 5G be. This networking technology is shifted on higher frequencies therefore it provides wide bandwidth. For any wireless system, antennas are considered as elementary parts and all the responsibility comes on the design of antenna.

Various designs for this technology have been proposed in past including microstrip patch antennas and array antennas. A slotted microstrip patch antenna with circular slots is proposed in [1], its resonating frequency is 28 GHz, possesses bandwidth of 2.48 GHz and has a gain of 6.37 dBi. A 2x2 microstrip patch array antenna is proposed in [2] for 5G wireless communications to enhance gain and directivity. This design operates in 3.4 to 3.6 GHz band and has gain of 5.37 dBi. Antennas discussed in [1,2] are microstrip patch and array antennas and since they are fed through one port only, it causes frequency channel to be busy most of the time and therefore results in signal weakening [3]. These antennas have limited gain and bandwidth, to cater this issue, MIMO antennas can be a better option.

A 2x1 compact MIMO antenna is presented in [4] for LTE handsets operating in 800 MHz band. This antenna has a gain of 2.2 dBi. Similarly, an S-shaped 2x1 MIMO antenna for WLAN applications is presented in [5]. This antenna is operating in three bands and it has gain of 3.26 dBi at 2.4 GHz, 3.6 dBi at 3.33 GHz and 5.4 dBi at 5.8 GHz. It has bandwidth of 720 MHz at 2.4 GHz, 547 MHz at 3.33 GHz and 821 MHz at 5.8 GHz. Although the antennas presented in [4-5] are MIMO antennas but they offer limited gain which can be increased. So, the objective is to design a MIMO antenna for 5G systems which resonates on 28 GHz, offer reasonable gain and bandwidth.

A 4x4 MIMO antenna is proposed with better gain as of [1-5] and then rectangular shaped split ring resonators are introduced in design to increase the bandwidth. The proposed design is resonating at 28 GHz. This paper is organized in a manner that II covers design of antenna and III covers detailed parametric analysis. Likewise IV addresses about simulated results and conclusions in V.

II. ANTENNA DESIGN

The prototype is converted into MIMO antenna in which four microstrip patch antennas are designed in a symmetrical manner on substrate. Bottom layer is comprised of split ring resonators to increase bandwidth. These split rings are meta-material structures made up of copper and they show negative refractive index [6]. Their size is even smaller than operating wavelength and therefore used in antennas to increase bandwidth, lessen the antenna size and gain enhancement etc. For MIMO, the size of substrate is 23.12 x 23.65 mm^2. The vertical centre to centre spacing between the antennas is 0.39λ and horizontal spacing is 1.42λ.

Figure 1(a) shows top view while figure 1(b) shows bottom view of the MIMO design respectively. From figure 1(a) 'A1' shows length of feed line and 'A2' shows width of feed line. Similarly 'B1' and 'B2' shows length and width of patch respectively. Likewise 'C1' shows length of quarter wave transformer. Bottom layer of MIMO antenna uses split ring resonators, having 0.2 mm thickness and separated from each other at a distance of 0.2 mm. Both split rings are kept open by a spacing of 0.3 mm. 'P1' and 'P2' shows length, width of outer split ring whereas 'Q1' and 'Q2' shows length and width of inner split rings respectively.

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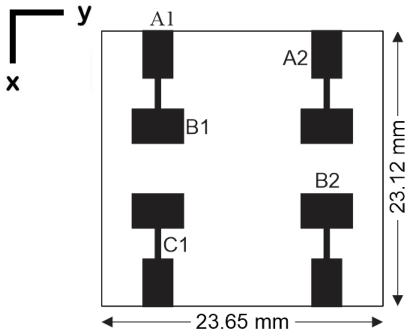

Fig. 1a. MIMO Antenna (Top Layer)

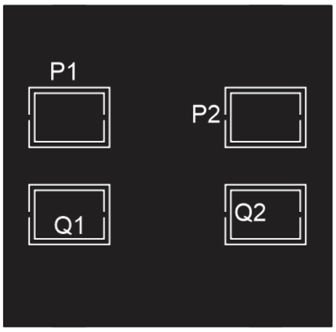

Fig. 1b. MIMO Antenna (Bottom Layer)

Dimensions for transmission line and quarter wave transformer are same however patch is optimized to obtain better results and make antenna operational at desired frequency. Dimensions of MIMO design are given in table 1.

Table I: Values for parameters of MIMO design

Parameters	Value (mm)
A1, transmission line length	3.91
A2, transmission line width	2.42
B1, length of patch	3.00
B2, width of patch	4.23
C1, length of transformer	2.67
P1, outer ring length	4.50
P2, outer ring width	6.00
Q1, inner ring length	3.70
Q2, inner ring width	5.20

III. PARAMETRIC ANALYSIS

A detailed parametric analysis is also carried out on MIMO design by changing length and width of patch to have better understanding. By changing these parameters the resonating frequency of antenna and impedance matching of design also changes. Length of patch in the design accounts for resonant frequency at which antenna is operating and width is responsible for impedance matching. From figure 2, increase in the value of length causes the operating frequency to shift toward lower value and vice versa. Similarly, the width of the transformer affects impedance matching of the design which is shown in figure 3. By increasing width of transformer better impedance matching is obtained and vice versa.

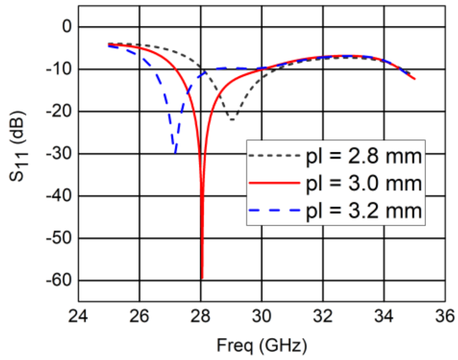

Fig. 2. Effect of optimization on length of patch of MIMO antenna

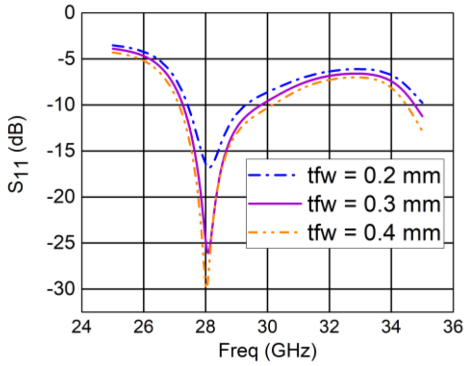

Fig. 3. Effect of optimization on width of transformer of MIMO antenna

IV. RESULTS

Contrast of single element patch antenna and MIMO antenna is depicted in figure 4.

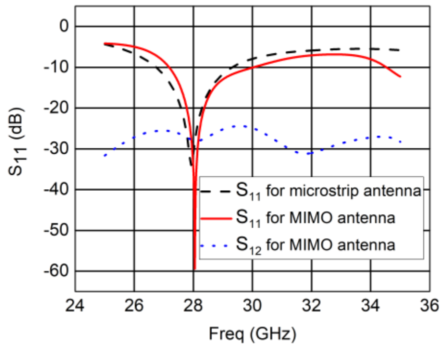

Fig. 4. S11 comparison of microstrip patch and MIMO antenna

Resonating frequency of both antennas is 28 GHz and thus covering 5G frequencies band which is the requirement. Microstrip patch antenna has an impedance bandwidth of 9.32% while MIMO antenna has impedance bandwidth of 10.78%. Moreover the antenna also possesses a reasonable gain of 8.43 dBi as shown in figure 5.

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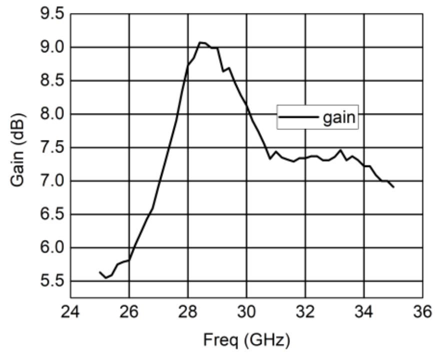

Fig. 5. Graph for gain of proposed MIMO antenna

Figure 6 shows the coupling between all radiating elements with the help of S_{12}, S_{13}, S_{14}. From this figure we can see that there is very less coupling between the radiating elements as response of all elements is below -15 dB for our required bandwidth.

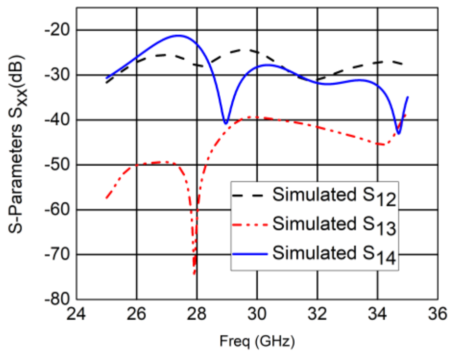

Fig. 6. Simulated Sxx of proposed MIMO antennas

Figure 7 shows the radiation pattern of MIMO design at 28 GHz. By seeing at radiation pattern it can be inferred that proposed design is directional in XZ plane.

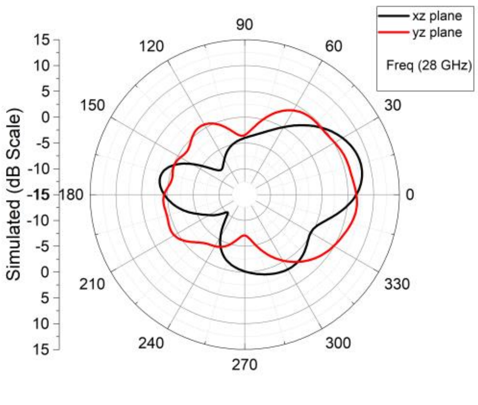

Fig. 7. Radiation pattern of proposed MIMO design

Envelope correlation coefficient shown in figure 8 is calculated by method presented in [7], it tells about the impact of dissimilar propagation paths of signals that reach antenna. All the ECC's have value below 0.1 which means that there is low correlation between the input pair ports. It indicates good performance of the MIMO antenna.

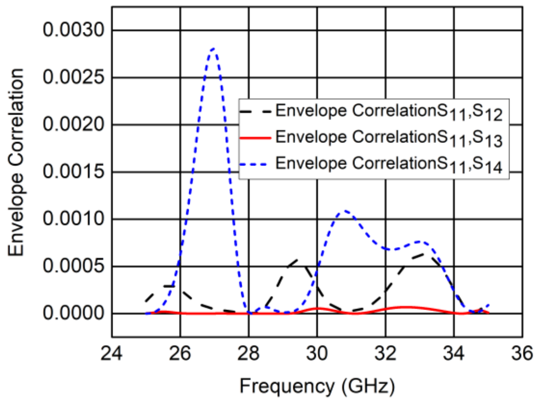

Fig. 8. Envelope correlation coefficients of proposed MIMO antenna

V. CONCLUSION

A 4x4 MIMO antenna is proposed which operates on 27.19 – 30.21 GHz. Results gathered after simulations showed that antenna has return loss below -10 dB, it also shows good radiation pattern and a gain of 8.43 dBi. There exists low correlation between input ports as all ECC's are below 0.1. All these characteristics show that this compact antenna is appropriate for 5G communications

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