Compact 8-Port MIMO Antenna for 5G (n257/n259) Millimeter-wave Applications

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Abstract:

This paper describes a planar 8-port microstrip line-fed MIMO antenna that operates in the 5G millimetre-wave band. As the main radiator, a rectangular-shaped patch antenna is designed on the Rogers RT5850 substrate to achieve a resonance frequency of 27.85 GHz. By etching a circular ring-shaped slot into an artificially occurring material unit cell from the basic patch radiator, a supplemental resonance band at 42 GHz is obtained. The size of the proposed MIMO antenna is 434 mm^2. The evaluated findings demonstrate that the antenna accomplishes bandwidths of 26.92–28.67 GHz for L-band (n257) and 40.65–44.07 GHz for V-band (n259). Therefore, it offers more than 25 dB of port isolation among antenna elements without using any decoupling structure. The examined diversity performance parameters showed an envelope correlation coefficient (ECC) less than 0.005, a diversity gain of nearly 10 dB, and a channel capacity loss (CCL) less than 0.35 bits/s/Hz. According to traditional limits, the ratio of the mean effective gain of the MIMO antenna is nearly 0 dB. The results demonstrate the design's effectiveness for mm-wave 5G applications.

KEYWORDS: MIMO antenna, millimetre-wave and 5G, mm-wave applications

I.INTRODUCTION

One of several essential criteria for another evolution of mobile communication systems is the ability of cellular mobiles to transmit information at a significantly faster rate of speed. Cell phone antennas are therefore simple to observe and also have a low profile [1]. To fulfill the standards of long-term evolution (LTE) as well as 5th generation (5G) telecommunications technologies, portable equipment's antenna should indeed enable broadband function, an increased bit rate, and low power usage [2]. This implies that a cell phone antenna ought to be allowed to navigate in the mm-wave portion of the visible (electromagnetic) EM spectrum in addition to handling the required bit rate for potential developments.

Because of the dimension constraints, a cellphone antenna needs to be capable of functioning well across many frequencies in the mm-wave spectrum intended to enable the implementation of the evolution of wireless generations [3]. The antenna system might well be complicated, with levels of strong EM absorption to generate radiation characteristics of the required form in a range of aspects, or it could have a 3D shape to function properly in one band of frequencies as well as satisfy a defined objective in special implementations [4]. PIF antennas with simple systems, Agile Multiband, and radiation patterns that have similar symmetry are chosen for cellphones due to size and mass constraints [5].

There are still multiple challenges in developing a MIMO antenna system that can be utilised in cellphones for future generations of cellphone communication systems. Because of a shortage of area, the dimensions of a receiver's MIMO antenna must initially be limited. Given the slight surface region for an antenna on a cellphone, the concern is providing high separation among antenna components. Another concern is the MIMO antennas' capability of operating at various wavelengths while still getting sufficient bandwidth at every Agile Multiband. The fourth concern is to generate the required shape of a coverage diagram across the operative frequency bands [6].

A MIMO antenna might be needed to provide a variety of diversifications, such as spatial, polarization, and pattern variability. One of the biggest critical challenges in designing MIMO antennas for cell phones is the stipulation of a reduced envelop correlation coefficient (ECC) as well as an increased diversity gain (DG).

In [7], a double-banded printed millimeter-wave antenna was presented. [9] introduces a dual-band 28/38 GHz MIMO antenna having two components, higher than 22 dB isolation, as well as a directivity of roughly 5.2 dBi. A double band 27/39 GHz MIMO antenna having 2 segments, isolation higher than 30 dB, and directivity near 5 dBi is described in [7].

A double-banded 28/38 GHz bay MIMO antenna containing 2 components and a separation of more than 27 dB is shown in [8]. It examines a 2-port MIMO antenna that operates at 28/38 GHz. [9] describes a double-band, four-port antenna that performs at both 28 and 38 GHz, has a directivity of more than 7.58 dBi, and also has an isolation of roughly 20 dB. A 4-port of double-banded 28/38 GHz antennae having a directivity of more than 7.9 dBi is described in [10].

The study of a dual-band (27.85 GHz and 42 GHz), 8-port MIMO antenna designed for 5G mm-wave applications. The layout includes 4-two port MIMO planar antennas are placed orthogonally each other on Rogers's substrate with a relative permittivity of 2.2 and size of antenna is 434 mm^2. To obtain the dual-band in single antenna a circular slot is itched in the center of the rectangular patch. A 2-port antenna is designed by placing single element antennas orthogonally to each other. Two antennas resonate at the same frequency bands without using any decoupling network, and the isolation between the two radiators is satisfactory for both operating bands. The final 8-port proposed antenna is evolved by placing four 2-port antennas orthogonally to each other. All antennas resonate at the same frequency bands without using any decoupling network, and the isolation (>25 dB) between all radiators is satisfactory for both operating bands. Utilizing the HFSS simulation, which is the industry norm, the antenna was created.

This paper is divided into the following sections: The design of a single-element antenna with an evolution process to achieve the desired 27.85/42 GHz frequency bands is covered first. Second, the processes for designing 2-port MIMO antennas are discussed, followed by 8-port MIMO antennas. The results of the MIMO tests (S-parameters and radiation characteristics) are extracted, as are its diversity parameters, such as the envelop correlation coefficient (ECC), diversity gain (DG), and channel capacity loss (CCL).

II. DESIGNING AND SIMUATION RESULTS

SINGLE ELEMENT ANTENNA

The evolution process of basic rectangular patch antenna is shown in the Fig 1.The antennas were built on a Rogers RT5850 substrate, with a relative permittivity of 2.2 and a thickness of 0.8 mm.

The patch arrangement is placed in the middle of the substrate, where a circular, ring-shaped slot and a circle slot are itched on the patch.

The stimulated response of the reflection coefficient and gain of the single antenna by stages 1, 2, and the proposed antenna, are shown in Fig. 2(a, b). The stage1 antenna resonates at 28 GHz, and the stage2 antenna creates resonance at 27.1 GHz and additional resonance at 41 GHz. The proposed antenna resonates at 27.1 GHz and 41.5 GHz, as shown in Fig. 2(a). The gain response of the single port antenna is shown in Fig 2(b). The peak gains of the antenna in the lower and upper bands are 7.7 dB and 3.3 dB, respectively.

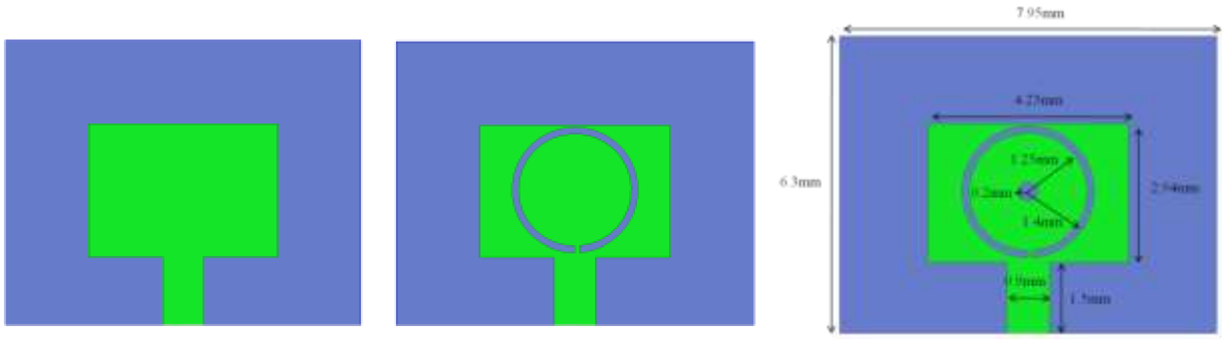

Fig. 1: Geometrical layout stages of the basic proposed patch antenna

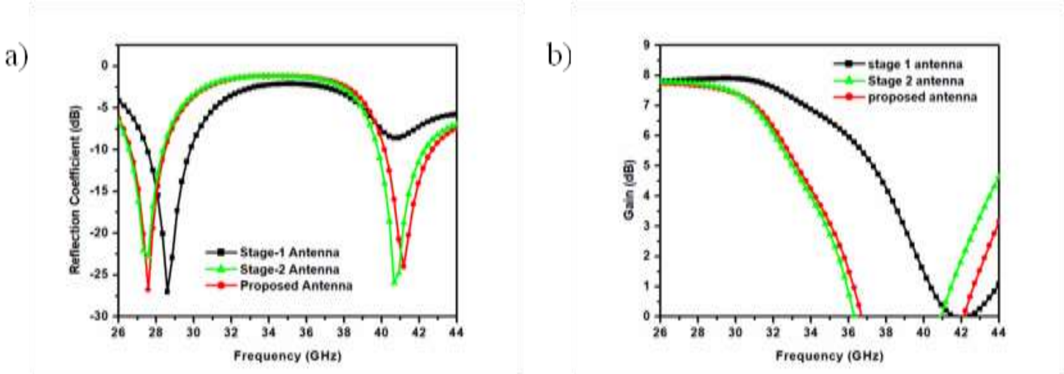

Fig. 2: Simulated response of (a) reflection coefficient and (b) gain of the proposed antenna

2-PORT MIMO ANTENNA

The basic orthogonal structure of 2-port MIMO antenna as shown in Fig 3. In the simulated s-parameter of a 2-port MIMO antenna, as shown in Fig. 4(a), two antennas resonate at the of 26.92 GHz–28.67 GHz and 40.65 GHz–44.07 GHz frequency bands, without using any decoupling network the isolation between the two radiators is more than 25 dB for both operating bands, as shown in Fig. 4(a). The gain response of a two port antenna is shown in Fig. 4(b). The peak gains of the antenna at the lower band and upper band are 7.6 dB and 5.8 dB, respectively.

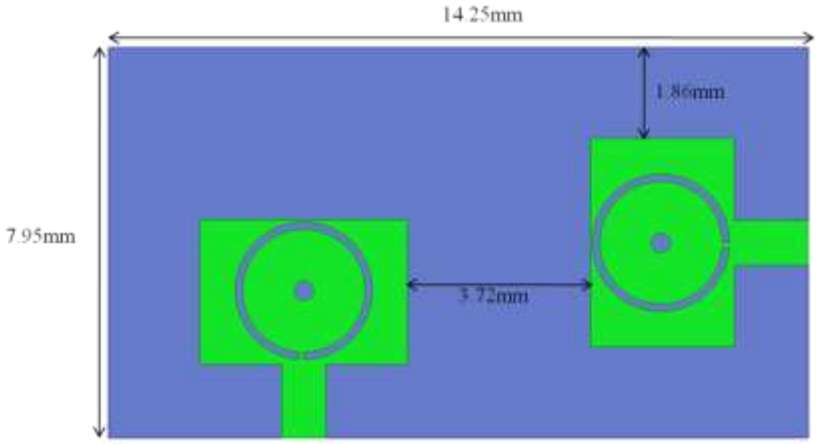

Fig. 3: Geometrical layout for a 2-port MIMO antenna

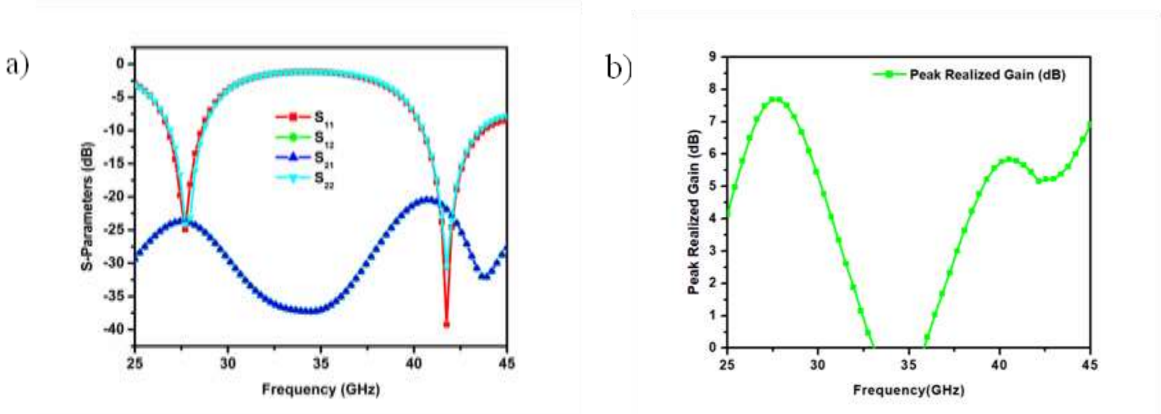

Fig. 4: Stimulated responses of (a) S-parameters and (b) peak realized gain for a 2-port antenna

2-Port MIMO Antenna Diversity Performance

The MIMO antenna performance is analysed by diversity parameters like the envelope correlation coefficient (ECC), diversity gain (DG), mean effective gain (MEG), and channel capacity loss (CCL).

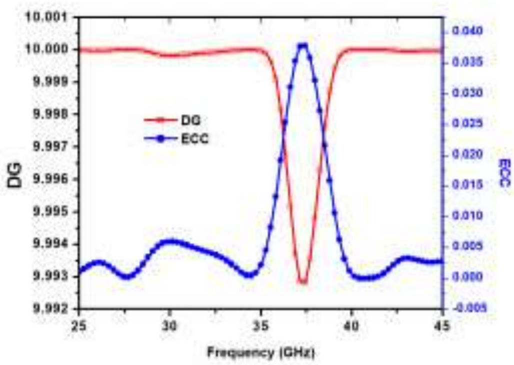

Fig. 5: Simulated 2-port antenna for ECC and DG.

The ECC is an important primary constraint that explores how much the communication channels are isolated or correlated with each other when transmitted simultaneously. It can be calculated efficiently by using the radiation method approach; the formula is depicted in equation (1). In practical applications, the upper value of ECC is 0.5. Another important parameter for MIMO antennas is diversity gain. Diversity is achieved by the receiver when it receives multiple versions of the transmitted stream through different channels, and the value of DG is always close to 10; DG can be obtained by using equation (2). The simulated correlation coefficient of an orthogonal structure is very low (0.005) throughout the impedance bandwidth, and the DG value is closer to 10 as shown in Fig. 5.

$$\rho_e = \frac{\left| \iint_0^{4\pi} [E_1(\theta,\emptyset) * E_2(\theta,\emptyset) d\Omega] \right|^2}{\iint_0^{4\pi} |E_1(\theta,\emptyset)|^2 d\Omega \iint_0^{4\pi} |E_2(\theta,\emptyset)|^2 d\Omega} \quad (1)$$

$$DG = 10\sqrt{\sqrt{1-(\rho_e)^2}} \quad (2)$$

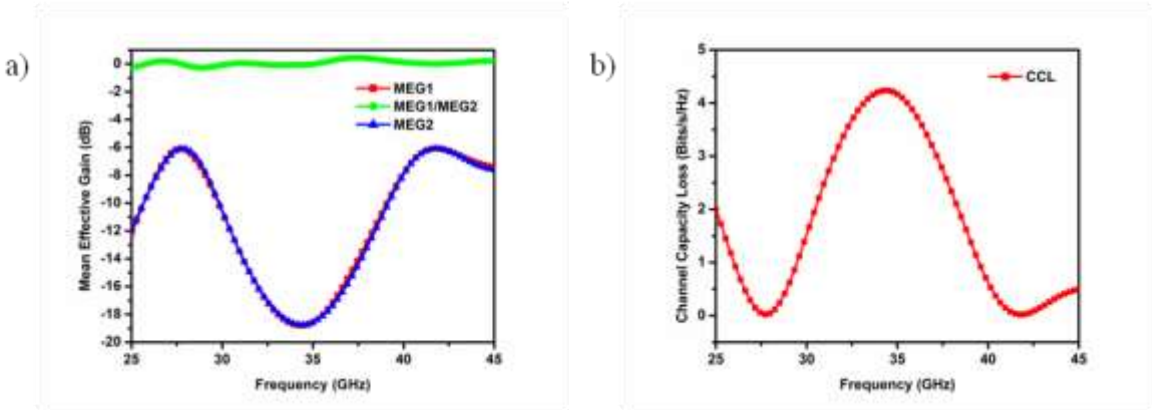

Fig. 6: (a) MEG and (b) CCL simulations for a 2-port MIMO antenna.

One more characterized parameter of a MIMO antenna is MEG (mean effective gain). MEG measures antenna performance where the effect of the environment is taken into account in the gain performance of the antenna. For two port MIMO antenna MEG calculated by using equations (3 and 4), for equal power levels, the ratio between MEGs should be less than ±0.3dB.

$$MEG_1 = 0.5[1-|S_{11}|^2 - |S_{12}|^2] \quad (3)$$

$$MEG_2 = 0.5\ [1-|S_{22}|^2 - |S_{21}|^2] \quad (4)$$

Furthermore, another parameter is CCL (channel capacity loss), which gives an insight into the upper limit of the message rate up to which signals can be constantly transmitted over a communication channel. For good MIMO performance, CCL should be less than 0.5 bits/s/Hz. The following equation (5) can be used to calculate 2-port MIMO: As shown in Fig. 6(a, b), the simulated CCL and MEGs of the two structures are the desired values throughout the operating frequency band.

$$C_{loss} = -log_2 \det(\beta^R) \quad (5)$$

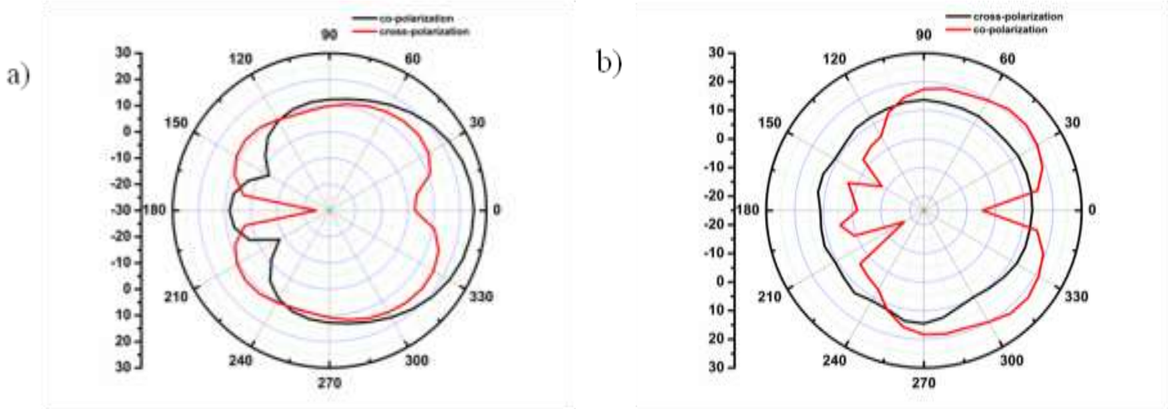

Fig. 7: Simulated E-field Radiation Patterns at (a) 27.85 GHz and (b) 42 GHz

Figures 7(a, b) depict the radiation performance of the MIMO antenna by displaying simulated 2D far-field radiation patterns. The far-field radiation patterns in the E-plane (xz-plane) and Y-plane (yz-plane) are shown at 27 GHz and 42 GHz, respectively. All the radiation patterns are unidirectional. As shown in Figs. 7(a, b), the amount of co-polarization is greater than the amount of cross-polarization.

8-PORT MIMO ANTENNA

The structure of an 8-port MIMO antenna is shown in Fig. . The simulated s-parameters for an 8-port MIMO antenna are shown in Fig. 9(a). For 5G mm-wave applications, all antennas resonate in the same frequency bands (26.92 GHz–28.63 GHz and 40 GHz–44.07 GHz), and applications for frequency bands n257 and n259 All the antennas are mutually orthogonal to each other; therefore, isolation between the antenna elements is greater than the 25 dB shown in Fig. 9(a).

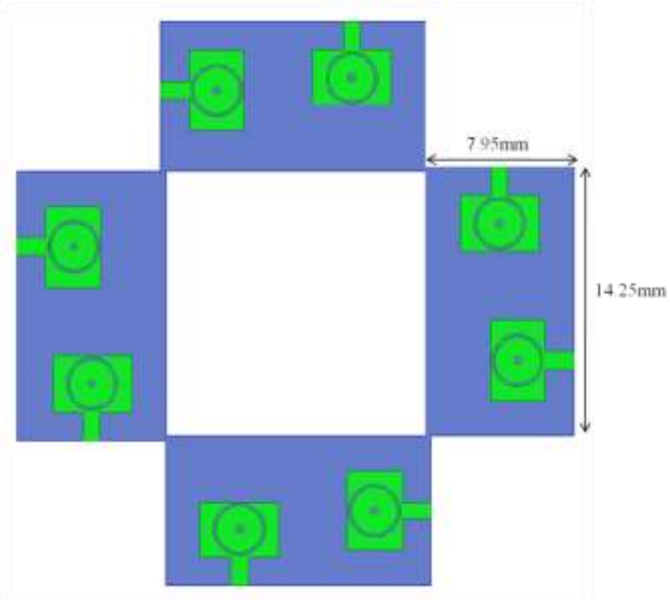

Fig. 8: Geometrical layout for an 8-port MIMO antenna

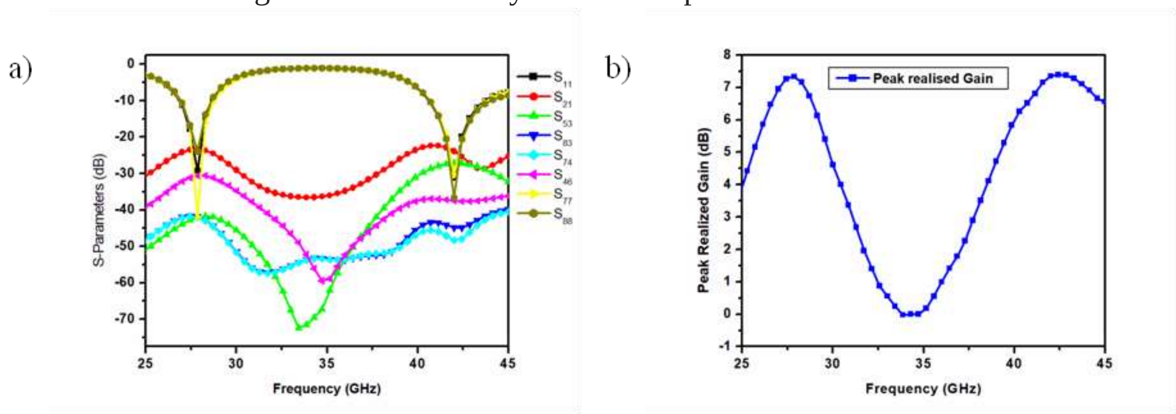

Fig. 9: Simulated response of (a) the S-parameter and (b) the peak realized gain for an 8-port antenna.

The gain response is shown in Fig. 9(b). Peak realized gains for the antenna are 7.33 dB for the lower band and 7.39 dB for the upper band, respectively.8-Port MIMO Antenna Diversity Performance.

The MIMO antenna performance is analyzed by diversity parameters like the envelope correlation coefficient (ECC), diversity gain (DG), mean effective gain (MEG), and channel capacity loss (CCL).

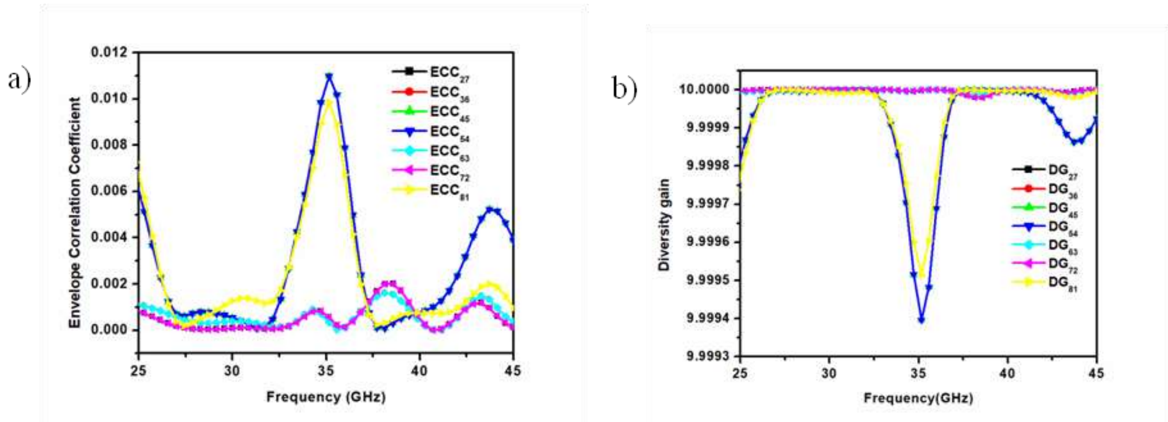

Fig. 10: Simulated 8-port antenna for (a) ECC and (b) DG

The simulated envelope correlation coefficient (ECC) and diversity gain (DG) of an 8-port network are shown in Fig. 10(a) and (b). From the graph, the ECC and DG values during the operating band are less than 0.003 and nearly 10 dB, respectively. The proposed antenna is enhancing the isolation therefore MEG and CCL are lies within the practical range as shown in the Fig. 11(a) and (b).

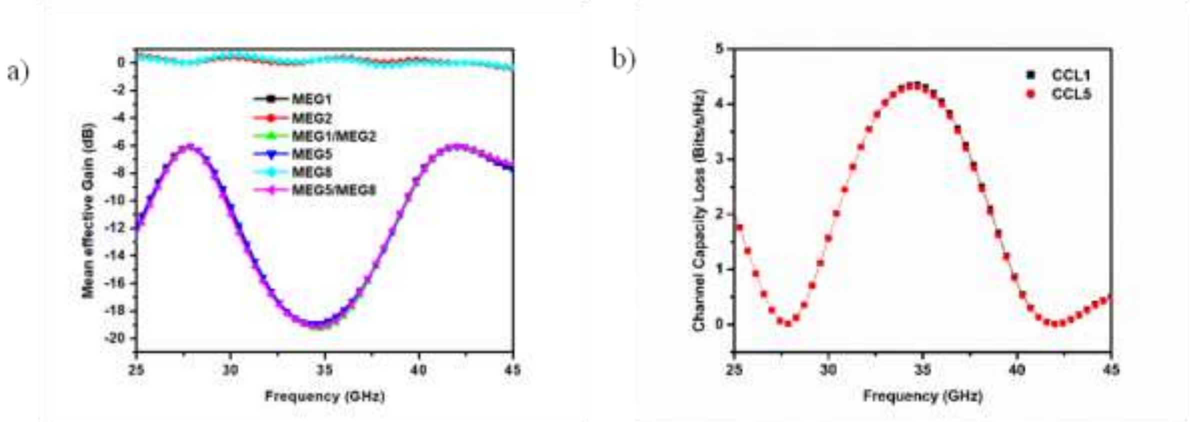

Fig. 11: Simulated (a) MEG, (b) CCL for a 2-port MIMO antenna

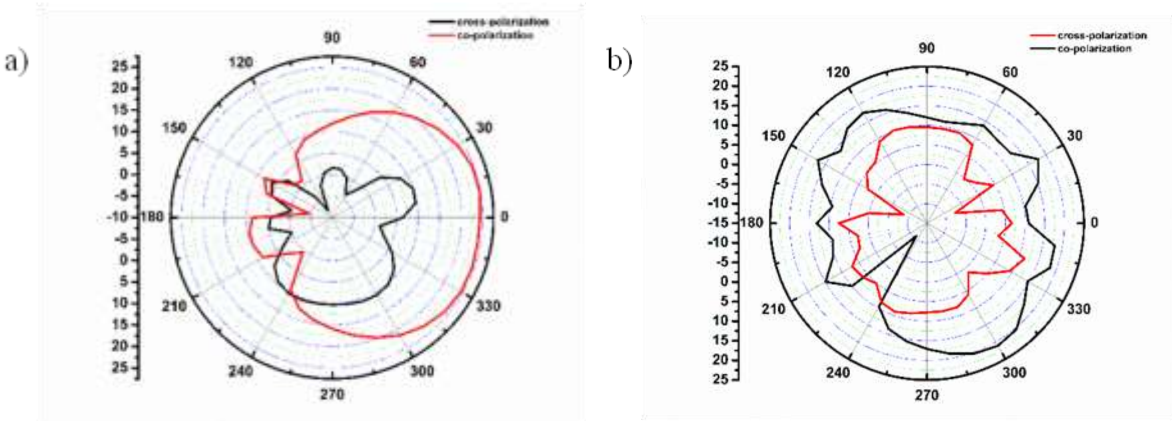

Fig. 12: Simulated E-field Radiation Patterns at (a) 27.85 GHz and (b) 42 GHz

Fig. 12(a) and (b) show how well the MIMO antenna radiates by simulating 2D far-field radiation patterns. The far-field radiation patterns in the E-plane (xz-plane) and Y-plane (yz-plane) are shown at 27.85 GHz and 42 GHz, respectively. All the radiation patterns are omni-directional. Co-polarization is greater than cross-polarization, as shown in Figs. 12(a, b).

III. CONCLUSION

An 8-port MIMO antenna for millimeter-wave applications with the size of 434mm^2 which resonates at dual band for 26.92GHz-28.63GHz (n257) and 40.65GHz-44.07GHz (n259) at the resonance frequencies of 27.85GHz and 42 GHz. Without using any decoupling network, the isolation between the eight radiators is achieved more than 25dB, peak realized gain of the both lower and upper frequency bands are7.33dB and 7.39dB respectively, the diversity performance of the 8-port MIMO antenna are ECC < 0.005, DG is nearly 10dB, MEG < -6dB and CCL< 0.01 bits/sec /Hz, endorse enrich performance over the operating bands.

IV. REFERENCES

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