SIW fed MIMO DRA for future 5G applications

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***Abstract*—In this paper, a four element multiple-input multiple-output (MIMO) cylindrical dielectric resonator antenna (DRA) is presented. Each element of MIMO antenna system consists of substrate integrated waveguide (SIW) fed cylindrical DRA which are arranged such that MIMO configuration provides both spatial and polarization diversity to combat multipath fading. The proposed antenna is operating at 27.7 GHz with the simulated impedance bandwidth ($|S_{11}| < -10$ dB) of 6.92% (26.64-28.55 GHz). The input port isolation is better than 27 dB throughout the operating bandwidth. For all the four excitation ports, the antenna radiates in broadside direction with peak gain ranging from 5.07-5.70 dBi over the operating band. The envelope correlation coefficient (ECC) is well below 0.0005 and channel capacity loss (CCL) is under 0.6 bits/sec/Hz in the desired band. The proposed antenna could be suitable for next generation 5G communication systems.**

I. Introduction

The demand of higher data rate and larger bandwidth has drawn attention to millimeter-wave (mm-W) frequency spectrum which has been proposed to be an important part of future 5G communication systems. Most of the current research is focused on the 28 GHz band, the 38 GHz band, the 60 GHz band, and the E-band (71-76 GHz and 81-86 GHz) [1]. At present, a considerable amount of research has been devoted for the development of mm-W components including antennas. Moreover, to cater to the demands of modern communication, the requirement of MIMO systems became indispensable. The MIMO technology utilizes multiple radiators at transmitting and receiving end that greatly enhances channel capacity, data rate, link reliability in multipath channels [2].
Over the past few years, a considerable amount of work has been dedicated to design MIMO antennas for numerous wireless communication systems [2]. The major drawback with the printed/metallic antennas are their low efficiency due to higher conductor losses at mm-W frequency. On the other hand, dielectric resonator antenna has many advantages such as high efficiency, especially at mm-W frequency range, no surface wave generation etc [3]. However, a few DRA based MIMO antennas are available in the open literature [4]–[6]. The designs referred in [4]–[6] make use of either aperture coupling or microstrip line based feeding mechanism. However, the feeding losses of these excitation mechanism are considerably high at mm-W frequency range. On the other hand, SIW based feeding mechanism can minimize radiation losses and parasitic radiation at mm-W frequency. In [7], SIW fed rectangular DRA has been reported with efficiency greater than 90% in mm-W frequency band [7].

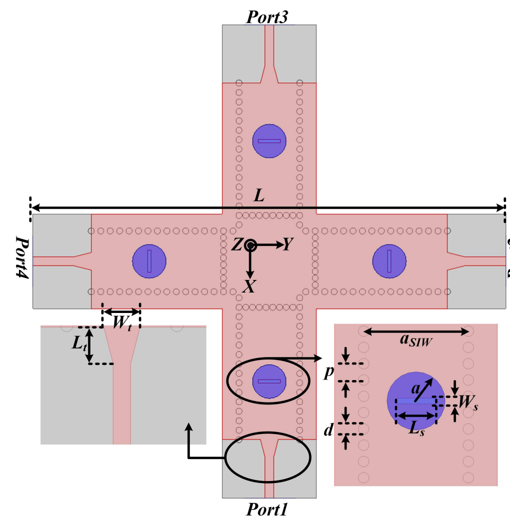

Fig. 1. Schematic of proposed SIW fed MIMO DRA. $L = 35.04$, $L_t = 1.32$, $W_t = 1.32$, $p = 0.7$, $d = 0.455$, $a_{SIW} = 4.5$, $a = 1.25$, $L_s = 1.65$, $W_s = 0.25$ (all dimensions are in mm)

In this paper, a four element SIW fed MIMO DRA is proposed for next generation 5G communication systems. The proposed antenna offers both the polarization and spatial diversity with good isolation performance and low envelope correlation. All the simulations are done in Ansoft HFSS.

II. Antenna Design

Fig. 1 shows the schematic of proposed SIW fed MIMO DRA. The cylindrical DR is excited in $HE_{11\delta}$ mode by placing it symmetrically over a narrow slot situated on the top wall of SIW. The material used to design SIW is RT/Duroid 6002 of relative permittivity 2.94 and thickness of 0.254 mm. The SIW is designed in Ka-band for single TE_{10} mode operation [8]. The DR under investigation is made of RT/Duroid 6010 of relative permittivity 10.2 and has dimensions: radius a = 1.25 mm and height h = 1.524 mm.

III. Results and Discussions

The simulated response of the proposed antenna is shown in Fig. 2. The antenna is operating around 27.7 GHz and exhibits an impedance bandwidth of 6.92% (26.64-28.55 GHz) for all the four ports. The simulated input port isolation is below 27

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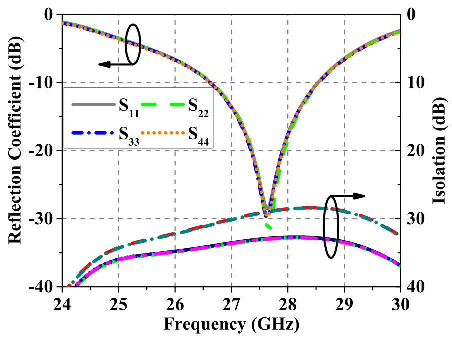

Fig. 2. Simulated response of the MIMO DRA

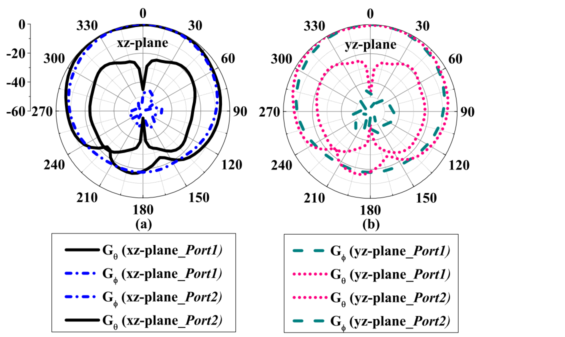

Fig. 3. Simulated normalized radiation pattern of the proposed MIMO DRA (a) xz-plane (b) yz-plane

dB over the operating bandwidth.

Fig. 3 depicts the simulated normalized radiation pattern at 27.7 GHz. The antenna radiates in broadside direction with the cross polarized level below -40 dB in xz-plane and -20 dB in yz-plane for *Port1*. A similar type of radiation pattern is obtained when excited at *Port2* and the cross polar level here is below -20 dB in xz-plnae and -40 dB in yz-plane. The radiation pattern for remaining ports are not shown for brevity. Envelope correlation coefficient is one of the prime figure of merit for multi-antenna systems and it quantifies the level of coupling between the antenna elements. Under certain assumptions, ECC between i^{th} and j^{th} elements can be calculated for N-port antennas system as [9]

$$\rho_{eij} = \frac{\left|\sum_{n=1}^{N} S_{in}^{*} S_{nj}\right|^2}{\prod_{k=i,j}\left[1 - \sum_{n=1}^{N} S_{kn}^{*} S_{nk}\right]} \quad (1)$$

where, S_{ij} is the S-parameters of MIMO system and $\{\cdot\}^*$ denotes the complex conjugate. Fig. 4(a) depicts the variation of ECC with frequency. It is observed that over the operating band, the ECC does not exceed 0.0005, satisfying the low ECC criteria (ECC<0.3 [2]) for practical MIMO system. The correlated environment will induce a loss in the channel capacity. Assuming only the receiving antennas are correlated and for high signal to noise ratio (SNR), the loss induced in the capacity is calculated using the equation given in [10].

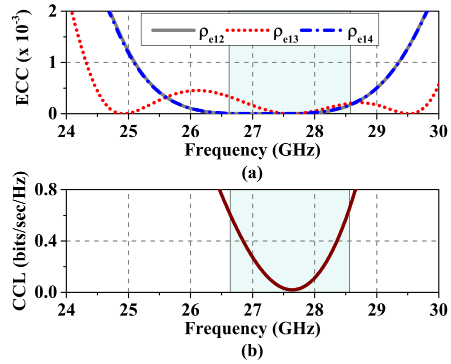

Fig. 4. Simulated variation of (a) ECC (b) channel capacity loss with frequency

From Fig. 4(b), it is observed that the capacity loss is below 0.6 bits/sec/Hz over the band of interest.

IV. Conclusion

A four element SIW fed MIMO DRA has been proposed for next generation 5G communication systems. The proposed antenna provides both polarization and spatial diversity. The antenna exhibits an impedance bandwidth of 6.92% for all the four ports and the input port isolation is better than 27 dB over the operating band. The antenna radiates in broadside direction with the peak gain variation of 5.07-5.70 dBi over the band. The proposed antenna shows a good MIMO performance with ECC less than 0.0005 and channel capacity loss under 0.6 bits/sec/Hz over the band of interest.

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