Differentially-Driven Dielectric Resonator Antenna using TE_{20} Mode Substrate Integrated Waveguide

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***Abstract*—This paper presents a differentially fed rectangular dielectric resonator antenna (DRA) for millimeter-wave applications. The intrinsic field distribution of TE_{20} mode of substrate integrated waveguide (SIW) allows the differential excitation of DRA by utilizing dual-slot located on the top wall of SIW. The proposed antenna is designed at 28 GHz and possess the impedance bandwidth of 4.3%, covering the frequency range of 27.4-28.6 GHz. The proposed antenna radiates in the broadside direction and the difference between the co-polarized and the cross polarized level is greater than 20 dB in XZ-plane and 30 dB in YZ-plane. The simulated peak gain of the proposed antenna is 4.54 dBi at 28 GHz. The proposed antenna can be utilized to design multiple-input multiple-output antennas and antenna arrays for next generation 5G communication system.**

I. INTRODUCTION

The inherent advantages such as small size, low loss, relatively wider bandwidth, high efficiency (due to negligible conductor loss and no surface wave generation), ease of excitation makes the dielectric resonator antenna more preferable over the conventional microstrip antennas at millimeter-wave frequency band [1]. The most common method of DRA excitation involves the aperture coupling, microstip feed, co-planar waveguide feed etc. At the millimeter wave frequency, the losses from the feed line are prominent and can be minimized using alternative excitation mechanism such as rectangular waveguide, dielectric image guide etc. However, the non-planar nature of the rectangular waveguide limits its use with monolithic microwave integrated circuit (MMIC) technology and low profile applications. To alleviate this limitation, the substrate integrated waveguide (SIW) [2] technology has emerged as a promising candidate for the future design at millimeter-wave frequency band.

With the rapid evolution in wireless communication systems, the requirement of signal integrity is higher than ever. The advancement in the field of integrated technology now allows to integrate the whole circuitry in a single MMIC. The differentially-driven antennas can be integrated with MMICs circuits and thus reduces the loss caused by the use of additional baluns. Furthermore, they also provide relatively low cross polarized fields. Therefore, differential-fed antennas can be a good candidate for millimeter-wave applications [3]. Very few differentially-driven DRAs have been available in the open literature and most of the proposed designs are in the lower frequency band (2.4 GHz) [4], [5].

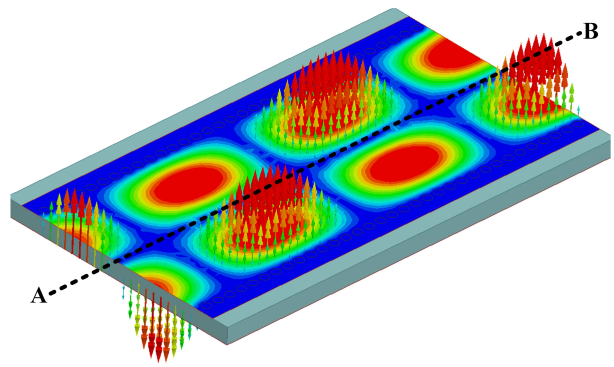

Fig. 1. TE_{20} mode electric fieled distribution in substrate integrated waveguide

In this paper, a differentially-fed rectangular dielectric resonator antenna is proposed at 28 GHz for next generation 5G communication system. Here, the differential feeding network is developed using the higher order TE_{20} mode SIW in which the rectangular DR is excited using the dual-slot situated on the top wall of SIW. Due to the simple and compact nature of the feed, the single element design can be extended to design antenna arrays and MIMO antennas for millimeter-wave applications.

II. ANTENNA DESIGN

Fig. 1 shows the electric field distribution of TE_{20} mode in the SIW structure. From the figure it is observed that with respect to the center line AB, the electric field shows the odd symmetry *i.e.* the electric field has the same amplitude but reversed phase along the line of symmetry [6]. Therefore, this characteristics of TE_{20} mode allows the differential excitation of rectangular DRA using dual-slot located at the top wall of SIW.

Fig. 2 shows the proposed differentially-driven DRA. The SIW is designed on Rogers RT/Duroid 5880 of relative permittivity 2.2 and thickness 0.787 mm. The SIW is designed to operate in TE_{20} mode and the energy to the DRA is coupled through the two narrow apertures situated on the top wall of SIW. The material used to design the DRA is Rogers RT/Duroid 6010 of relative permittivity 10.2 and height 1.5 mm. The electric field distribution in DRA depicted in Fig.

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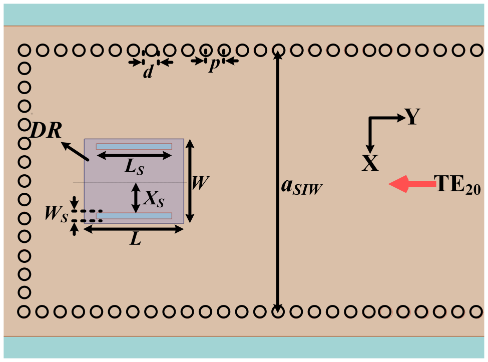

Fig. 2. Schematic of proposed SIW fed MIMO DRA. $p = 0.6$, $d = 0.4$, $a_{SIW} = 8.7$, $L = 3.3$, $W = 2.8$, $L_S = 2.5$, $W_S = 0.2$, $X_S = 1.05$ (all dimensions are in mm)

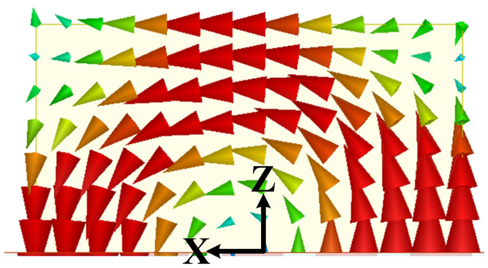

Fig. 3. Electric field distribution in DRA at 28 GHz

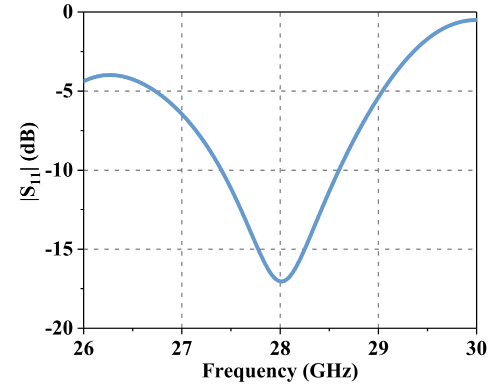

Fig. 4. Simulated response of the proposed differentially-driven DRA

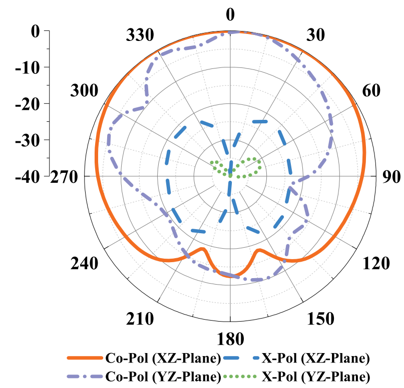

Fig. 5. Simulated normalized radiation pattern of the proposed antenna

3 confirms the excitation of $TE^y_{1\delta1}$ mode in the rectangular DRA.

III. Results and Discussion

The simulated response of the proposed differentially-driven DRA is shown in Fig. 4. The theoretical resonant frequency for the said dimensions is 25.2 GHz whereas the corresponding simulated value is 28 GHz. This discrepancy is due to the fact that the infinite ground plane is considered in the theoretical analysis of rectangular DRA and also the effect of slot is not taken into account. Similar kind of discrepancy has also been observed in [7]. The simulated impedance bandwidth of the proposed antenna is 4.3%, covering the frequency range of 27.4-28.6 GHz.

The simulated normalized radiation pattern of the proposed antenna at 28 GHz is shown in Fig. 5. The difference between the co-polarized and the cross-polarized field is >20 dB in XZ-plane and >30 dB in YZ-plane. The simulated peak gain and radiation efficiency of the proposed antenna is 4.54 dBi and 87%, respectively at 28 GHz.

IV. Conclusion

In this paper, a differentially-driven rectangular dielectric resonator antenna (DRA) has been proposed for millimeter-wave applications. The differential feeding network has been developed using TE_{20} mode of substrate integrated waveguide and the energy to the DR is coupled through the two narrow apertures situated on the top of SIW. The proposed antenna exhibits the impedance bandwidth of 4.3% (27.4-28.6 GHz). The cross polarization level better than -20 dB in XZ-plane and -30 dB in YZ-plane has been obtained. The peak gain of 4.54 dBi has been achieved at 28 GHz. The proposed antenna could be suitable for next generation 5G communication system.

References

[1] A. Petosa, *Dielectric Resonator Antenna Handbook*, 1st ed. Artech House, Boston, 2007.

[2] M. Bozzi, A. Georgiadis, and K. Wu, "Review of substrate-integrated waveguide circuits and antennas," *IET Microwaves, Antennas Propagation*, vol. 5, no. 8, pp. 909–920, 2011.

[3] H. Jin, W. Che, K. S. Chin, W. Yang, and Q. Xue, "Millimeter-wave te20-mode siw dual-slot-fed patch antenna array with a compact differential feeding network," *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 1, pp. 456–461, 2018.

[4] B. Li and K. W. Leung, "On the differentially fed rectangular dielectric resonator antenna," *IEEE Transactions on Antennas and Propagation*, vol. 56, no. 2, pp. 353–359, 2008.

[5] X. S. Fang, K. W. Leung, E. H. Lim, and R. S. Chen, "Compact differential rectangular dielectric resonator antenna," *IEEE Antennas and Wireless Propagation Letters*, vol. 9, pp. 662–665, 2010.

[6] P. Wu, J. Liu, and Q. Xue, "Wideband excitation technology of te_{20} mode substrate integrated waveguide (siw) and its applications," *IEEE Transactions on Microwave Theory and Techniques*, vol. 63, no. 6, pp. 1863–1874, 2015.

[7] W. M. A. Wahab, D. Busuioc, and S. Safavi-Naeini, "Low cost planar waveguide technology-based dielectric resonator antenna (dra) for millimeter-wave applications: Analysis, design, and fabrication," *IEEE Transactions on Antennas and Propagation*, vol. 58, no. 8, pp. 2499–2507, 2010.

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