Dual-beam Orthogonal Circular Polarized Antenna

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***Abstract*—A novel mm-wave-antenna structure has been proposed and investigated. It operates at 32 GHz with 3.2 GHz (-10 dB) bandwidth. It has the potential to be easily scaled for 5G US band. The structure is composed of a monopole antenna above a ground plane and an SIW wall. The antenna structure was studied numerically, revealing a directivity of 6.5 dBi within a bandwidth of 3.2GHz. In addition, the effects of different structural parameters have been investigated. The radiation pattern of the antenna reveals two orthogonal beams, circularly polarized, separately in the left and right direction.**

***Index Terms*— Antenna, mm-wave, circular polarization, dual beam antenna, 5G.**

I. Introduction

With the advancement of communication technology and emerging high data rate applications, the necessity for wireless networks with very high data transmission rates and spectral efficiency is obvious. It is expected that future communication systems will have data rates of Gbps and latencies in the order of milliseconds. To meet these requirements the 5G system has been proposed and a large amount of research is being done in this field. Some emerging and related technologies in 5G are mm-wave communication, full duplex and massive Multiple Input Multiple Output (MIMO) [1].

Full duplex systems have the advantage of transmitting and receiving at the same time and in the same frequency band. Therefore, they are capable of doubling the spectral efficiency of wireless communications. A serious challenge in implementing the full duplex systems is the Self Interference, which is the power transmitted from the transmitter to its own receiver, which should be suppressed effectively [2],[3].

Mm-wave communications have attracted huge research interest for 5G systems, since it can provide large bandwidth, which would results in an increased system capacity. However, there are a number of challenges in deployment of mm-wave communication systems such as path loss, penetration loss and high power consumption [4]. On the other hand, because of short wavelengths the dimensions of the mm-wave antennas are very small, enabling packing a large number of antennas in a small device. In order to compensate for the high losses in mm-waves, the antennas should be implemented in MIMO configuration [5]. The main issue in MIMO system is the mutual coupling between the antenna elements, so some techniques have been considered to mitigate the mutual coupling.

Substrate Integrated Waveguide (SIW) is a promising structure for isolating mm-wave antennas. It has been used to develop various mm-wave communication devices such as antennas, cavities etc [6]-[7]. In this paper, a mm-wave monopole antenna over a ground plane, employing an SIW wall is proposed and studied.

II. Proposed Antenna Structure

The proposed structure, as shown in Fig. 1 in 3D view, is a combination of a simple monopole antenna on a ground plane and a SIW wall. Brief descriptions of parameters involved and their dimensions are presented in TABLE I.

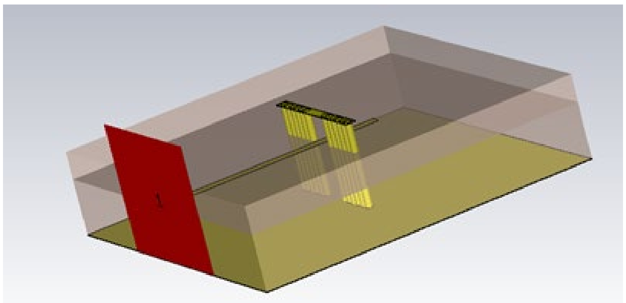

Fig. 1. Proposed antenna structure consisting of a monopole over a ground plane and a SIW wall extending from top substarte to ground plane

As can be seen in the Fig. 1. the structure is made up of two layers of substrate with different thicknesses and of the same material (Rogers RT5880) with εr=2.2. The feed line extending into the monopole is placed on the first layer and the SIW wall penetrates the two layers.

TABLE I. Structural parameters for the proposed antenna

Parameter	Description	Value(in mm)
d	Length of the top metal	3.8
W_2	Width of the top metal	0.3
l	Length of the monopole	6.65
W_1	Width of the monopole	0.3
h_{ls}	Height of lower substrate	0.787
h_{ts}	Height of top substrate	1.575
sa	Width of the hole in SIW wall	1
r	Radius of VIAs	0.11
S	The separation between vias	0.245

III. Results and Discussion

The proposed structure has been simulated using CST software and the effects of different structural parameters have been investigated. As expected the length of the monopole measured from the SIW wall plays a critical role in the radiation behavior of the structure. In Fig. 2, the S-parameter of the structure is shown for various monopole lengths.

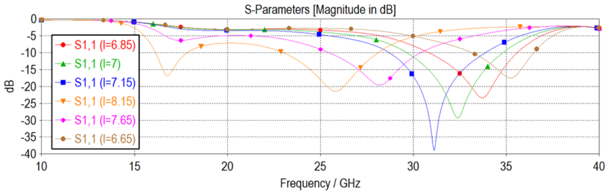

Fig. 2. S-parameters of the antenna for various monopole lengths

At first glance, the length l=7.15 mm seems to be the best choice for the monopole antenna. However, further investigation, considering the far-field results and making a compromise between reflection and radiation, revealed that the optimum length is about l=6.65 mm. In this case, within the antenna impedance bandwidth (33.2 GHz - 36.4 GHz), the radiation pattern maintains its shape to within allowable limits. The absolute radiation pattern at 35 GHz is shown in Fig. 3, presenting two beams. In this antenna the radiation and total efficiency are found to be 78% and 77%.

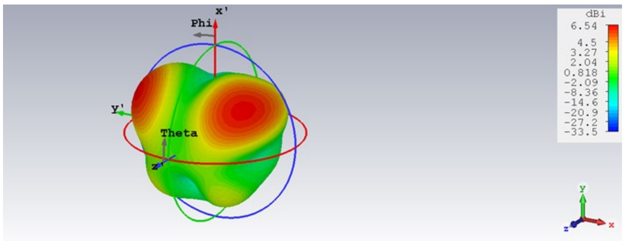

Fig. 3. Absolute radiation pattern for the antenna at 35 GHz

An analysis of the polarization of the beams led to the fact that each of the two beams benefits from one type (the left or right hand) of circular polarization, Fig. 4 and Fig. 5. Also it is interesting to note that the two resulting beams are almost spatially orthogonal to each other.

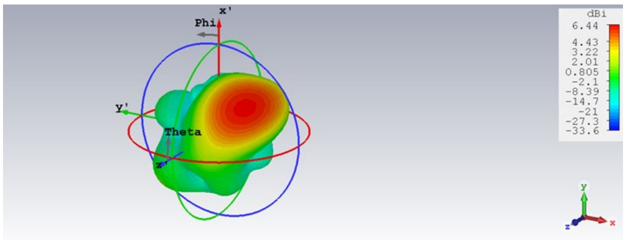

Fig. 4. Left polarized radiation pattern for the antenna at 35 GHz

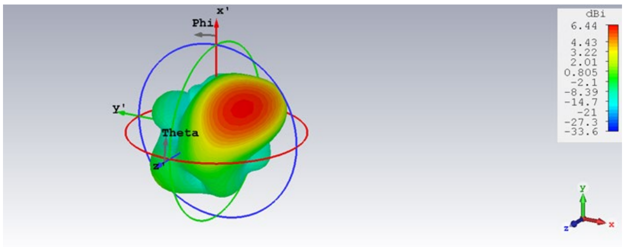

Fig. 5. Right polarized radiation pattern for the antenna at 35GHz

As can be seen in the far field pattern, Fig. 3, the beams are tilted. In order to find the exact locations of the beams, the 2D map of the far field is plotted in the theta phi plane and shown in Fig. 6. From this figure, the two beams are 98 degree separated, almost orthogonal, which separation can be adjusted to 90 degree by revising the design.

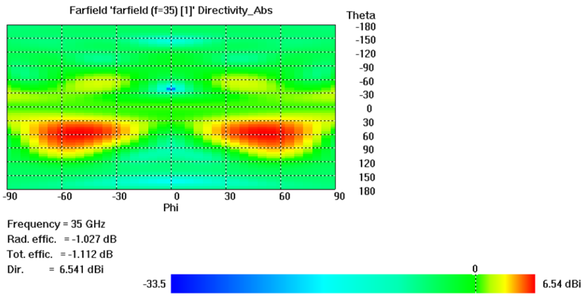

Fig. 6. The locations of the beams in Theta Phi plane for the proposed antenna at 35GHz

Fig. 7 shows the left and right polarized beams in the polar plane. The main lobe magnitude for both beams are 4.41 times over the isotropic reference (6.4 dBi) , the 3 dB beam width for the beams is 53.2 degree and the side lobe level is -5.4 dB.

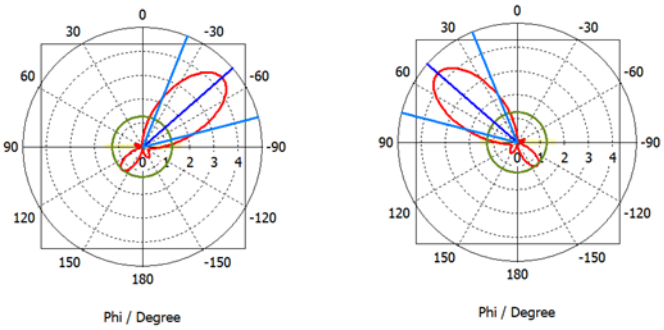

Fig. 7. Polar plane patterns at 35GHz: Left: left polarization, main lobe direction at -49 deg. Right: right polarization, main lobe direction +49 deg.

Circularly Polarized (CP) antennas are important and attractive for various modern wireless communication systems such as satellite communication systems and radio frequency identification (RFID) systems. For the proposed antenna, the simulated Axial Ratio (AR) shown in Fig. 8, indicates an AR of nearly 1 at theta 55 degree. It can be seen that the beam width for the circular polarization (AR<3dB) is quite wide and more than 80 degrees.

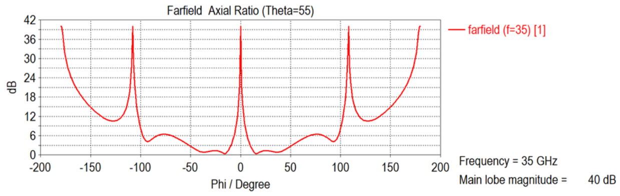

Fig. 8. Simulated AR at theta 55 degrees for the antenna at 35 GHz

IV. CONCLUSION

A mm-wave antenna consisting of a dipole antenna above a ground plane and an SIW wall was proposed and analyzed. The simulation results show that it has two similar beams which are almost orthogonal to each other and each has a different circular polarization. These properties can be beneficial in various applications such as full-duplex and satellite communication systems to improve capacity. The SIW wall can increase the isolation between two adjacent antennas and this is planned for further investigation.

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