Omni-directional Antenna Array with Improved Gain for 5G Communication Systems

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***Abstract*—An omni-directional antenna array with enhanced gain is presented in this paper. Designed in the 5G operating band of 25.92-29.12GHz, the antenna exhibits a simulated average peak gain of 7dBi. It consists of 4 dipoles and a substrate integrated waveguide cavity. The -10dB frequency band of the 1×4 linear array is 25.87-29.24GHz and the peak gain is higher than 12dBi in the operating frequency band.**

Keywords*—*Omni-directional, antenna array, improved gain

I. Introduction

Fifth-generation (5G) communication systems are expected to utilize millimeter-wave (mm-Wave) bands due to the global bandwidth shortage at the existing lower frequency bands [1]. In the 3rd Generation Partnership Project (3GPP) 5G specification (Release 15), four frequency bands in the frequency range 2 have been proposed for the 5G new network [2]. At these high frequencies, one of the major challenges is high free space path loss [3]. To overcome these losses and achieve the desired gigabit per second data rate as required by the 5G communication system, high gain antenna systems such as antenna arrays have to be deployed at both user equipment and base station. Furthermore, in places such as stadiums and shopping malls where users are evenly distributed in spacious areas, omni-directional antenna systems are preferred [4].

In recent years, some antennas and antenna arrays for 5G applications have been proposed [5]-[9]. However, they either have low gain or narrow bandwidth. For example in [5], an omni-directional antenna operating at 28GHz is presented, although it has a small gain of 2.08dBic and a narrow -10dB bandwidth (27-28.5GHz). Another example is the omni-directional T-slot linear antenna array with 8 elements proposed in [6], which has a low gain of 10dBi and -10dB bandwidth of only 2GHz at 28GHz. In [7], a high gain patch antenna array (30 elements and size of 102mm×96.5mm) with a peak gain of around 22dBi is presented, but the -10dB bandwidth is also narrow (26.9-29.2GHz).

In this paper, an antenna operating at 28GHz was simulated using the ANSOFT-HFSS 3D electromagnetic simulation software. It has a -10dB frequency band of 25.9-29.1GHz with a peak gain higher than 7dBi and an omni-directional radiation pattern. In addition, its compact array (23.2mm×68mm) was designed using a corporate feed network and with only 4 elements, it can achieve a peak gain of more than 12dBi in the operating frequency band.

II. Element Design

The gain of an array is mainly determined by the gain of each element. The configuration of the proposed antenna element is shown in Fig. 1, where the yellow part is the patch printed on Rogers RO4003 substrate with relative permittivity of 3.55, dielectric loss tangent of 0.0027 and thickness of 0.203mm; the blue part is ground.

This element consists of 4 dipoles and a Substrate Integrated Waveguide (SIW) cavity, which serves as a power splitter to feed the dipoles, a 50Ω microstrip line being used to feed the element.

The simulated S_{11} and radiation patterns of this element are shown in Fig. 2 and Fig. 3, respectively. As shown in Fig. 4, The element has a fractional bandwidth (FBW) of 11.6% (25.9-29.1GHz), an average peak gain of 7dBi and an average radiation efficiency of 95% in the operating frequency band.

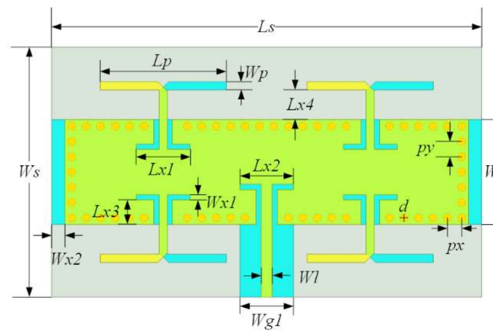


Fig. 1. Configuration of the proposed antenna element. (Ls = 16mm, Ws = 9.3mm, Lp = 4.7mm, Wp = 0.3mm, $Lx1$ = 2mm, $Lx2$ = 2mm, $Lx3$ = 0.9mm, $Lx4$ = 1mm, $Wx1$ = 0.2mm, $Wx2$ = 0.5mm, Wl=0.4mm, $Wg1$ = 2mm, $Wg2$ = 3.9mm, px = 0.54mm, py = 0.57mm, d = 0.3mm)

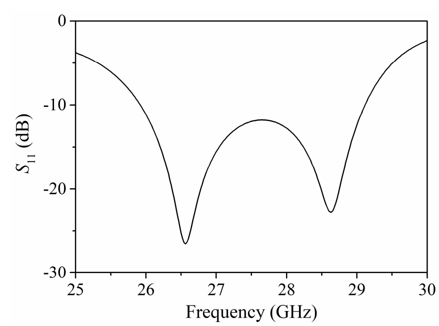


Fig. 2. Simulated S_{11} of the antenna element.

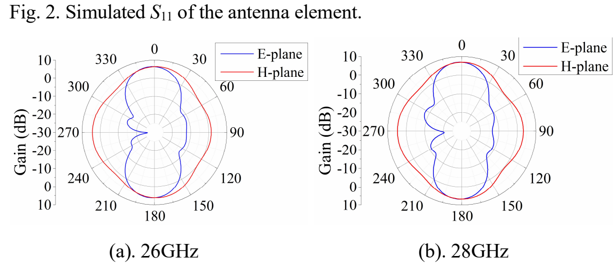


Fig. 3. Simulated radiation pattern of the antenna element at two different frequencies (a) 26GHz, (b) 28 GHz.

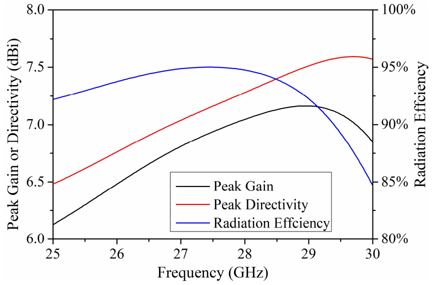


Fig. 4. Simulated peak gain, directivity and radiation efficiency of the antenna element.

III. Array Design and Discussion

As shown in Fig. 5, a 1×4 antenna array was designed using the element in Fig. 1 and a corporate feed network. The proportion of power fed to the four elements is 1:3:3:1 with 0 phase propagation. The simulated results are shown in Figs. 6-8. This compact array (23.2mm×68mm) has -10dB bandwidth of 25.8-29.3GHz, a peak gain higher than 12dBi, a half power beam-width (HPBW) of 16.2°, and the side lobe level of less than -10dB.

Table I compares successfully this work with some other published antenna arrays working at 28GHz. In fact, the proposed array has a broader bandwidth with a high gain element.

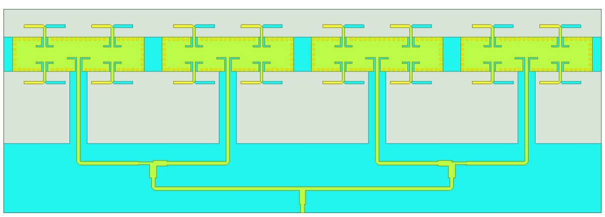


Fig. 5. Configuration of the proposed antenna array.

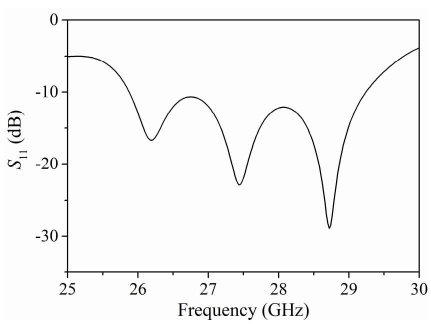
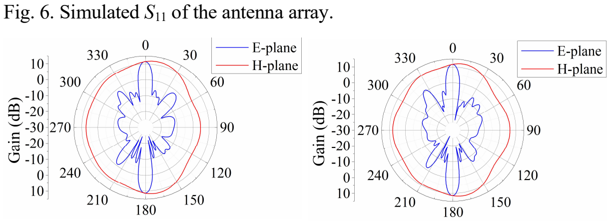


Fig. 6. Simulated S_{11} of the antenna array.



(a). 26GHz (b). 28GHz

Fig. 7. Simulated radiation pattern of the antenna array at two different frequencies (a) 26GHz, (b) 28 GHz.

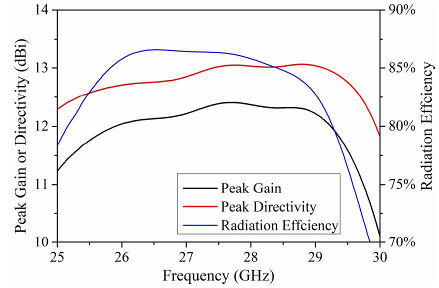


Fig. 8. Simulated peak gain, directivity and radiation efficiency of the array.

TABLE I. Comparision of Antenna Arrarys at 28GHz

Works	**Key Parameters**			
	Types of Pattern	***Operating Frequency***	***Gain***	***Nbre. of Elements and Dimensions***
[6]	Omni-directional	27-29GHz (Fig. 4)	>10dBi	1×8 50mm×100mm
[7]	Directional	26.9-29.2GHz	>21dBi	5×6 96.5mm×102mm
[8]	Directional	26.8-28.4GHz	>9.5dBi	2×2 32mm×36.5mm
[9]	Omni-directional	27.1-28.6GHz	>12dBi	1×8 17.3×67.1mm
This work	**Omni-directional**	**25.8-29.3GHz**	**>12dBi**	**1×4 23.2mm×68mm**

IV. Conclusion

In this work, an omni-directional antenna and its array are proposed. The array is suitable for 5G applications, and can work both at 26GHz and 28GHz 5G frequency bands. Furthermore, it exhibits a high gain, better than 12dBi, with just four elements. Successful comparison with existing designs demonstrated the good performance of the proposed device in both terms of bandwidth and gain.

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