mmWave Array Antenna based on Gap Waveguide Technology for 5G Applications

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***Abstract*—The gap waveguide technology has been shown to provide low loss and easy-to-manufacture antenna solutions in the mmWave frequencies. A gap waveguide array antenna with scanning ability within ±45° designed with focus on 5G applications is presented here. The computed active reflection coefficient of the array is less than -10 dB for all scan angles and the broadside gain is 23 dBi. The proposed antenna can be integrated with active components to increase EIRP and coverage range.**

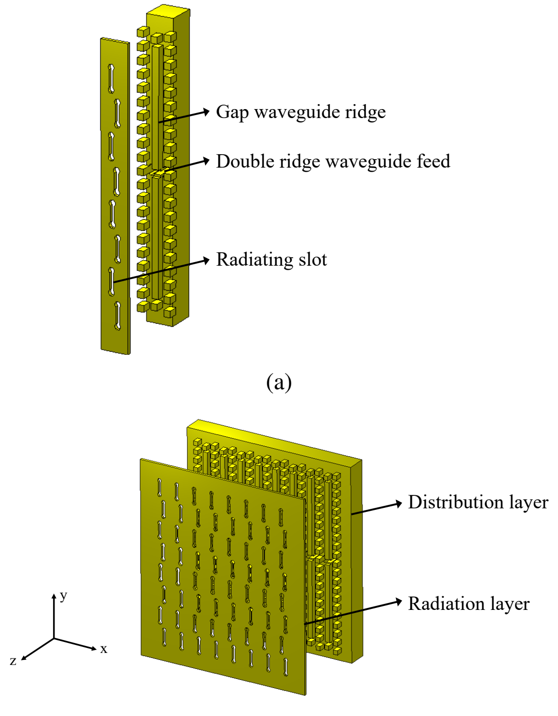
I. Introduction

5G wireless communication systems will support multi-user communications with ever larger bandwidths. Both fixed and mobile terminals may be running applications requiring 1 Gb/s data throughput. However, with the foreseen exponential growth in mobile data traffic, support of 10 Gb/s data rate is to be expected.

Unlicensed wideband frequency chunks in the mmWave bands of the electromagnetic spectrum offer the opportunity to develop new technologies supporting the required massive data rates [1]. Although wide bandwidths are available in the mmWave region, there exist challenges in the implementation of transmission technologies with such wide bandwidths. For example, the existing metal waveguide and substrate-based PCBs antenna technologies suffer from manufacturing difficulties and substantial losses at the mmWave frequencies, respectively [2].

The gap waveguide (Gapwaves waveguide) technology offers a robust and low loss technology which can be employed at mmWave frequencies [3], [4]. Indeed, robust implementation of transmission lines and integration of components without needing an electrical contact between two layers can be achieved. In this way, good performance may be achieved at a reasonable expense.

By using the electromagnetic rejection of the wave propagation in the PEC-PMC parallel plate waveguide, the gap waveguide technology creates a transmission line with confined fields. Commonly, a bed of pins is used for realizing an artificial magnetic conductor. When the gap between the pins and the PEC plane above them is lower than a quarter wavelength no wave can propagate. In this structure, by adding a ridge or a thin conductive strip in the PMC layer, a transmission line can be created which supports the propagation of TEM waves.



(a)

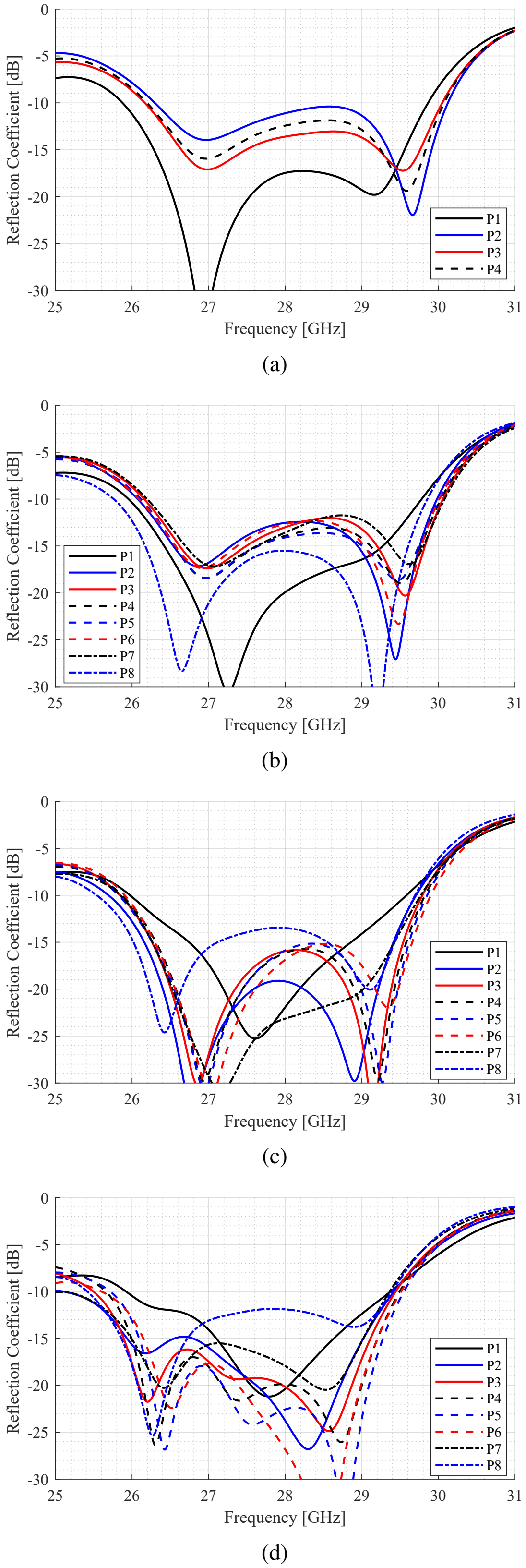
(b)

Fig. 1: Exploded view of (a) the array element and (b) the array antenna.

This paper presents a slot array antenna based on the gap waveguide technology for 5G applications in mmWaves. It is composed of 8 vertical subarrays with 8 non-periodic, series, center-fed and resonant slots. This antenna module can be combined with other units to increase EIRP (Effective Isotropic Radiated Power) and therefore the coverage range too.

II. Antenna Design

The array element comprising 8 slots is shown in Fig. 1a and the corresponding structure of the horizontal linear array antenna consisting of 8 vertical elements is shown in Fig. 1b. As can be seen from Fig. 1a, each element is fed at the center with a double ridge waveguide and with two ridges exciting the 8 radiating longitudinal (along the y-axis) slots. The elements are separated from each other with a row of pins.



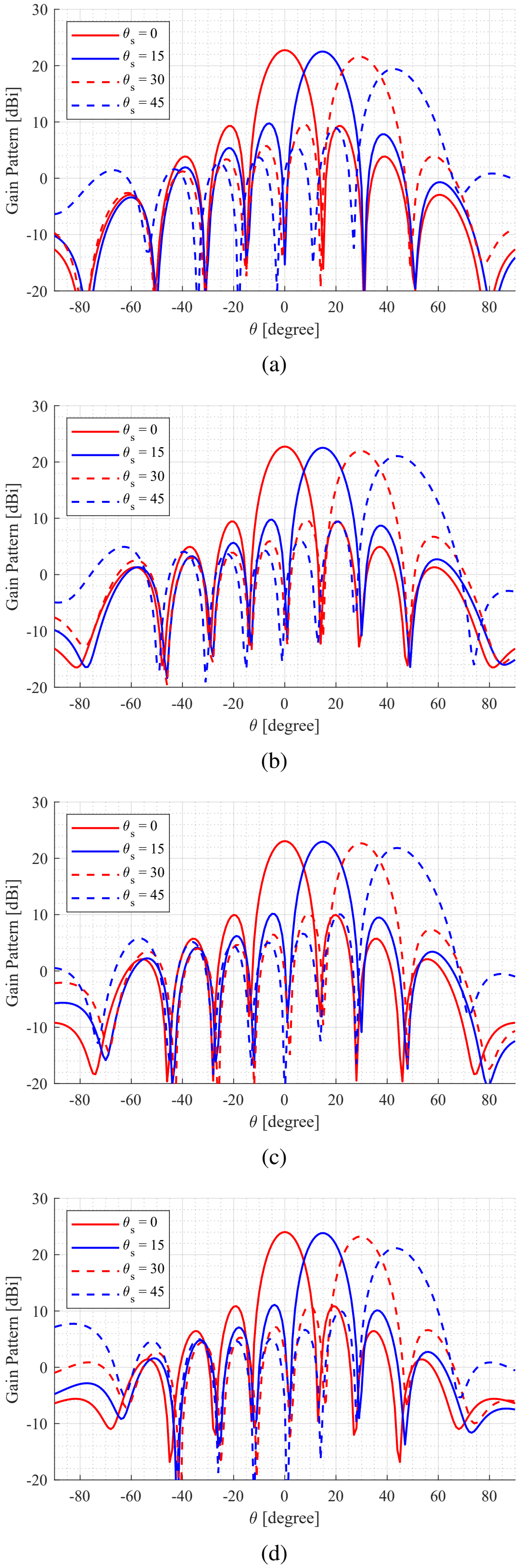
(a)

(b)

(c)

(d)

Fig. 2: Active reflection coefficients of the 8 antenna ports as function of frequency f, when the main lobe of the antenna is steered toward different scanning angles θ_s, (a) 0°, (b) 15°, (c) 30° and (d) 45°.



(a)

(b)

(c)

(d)

Fig. 3: Radiation pattern of the array antenna in the E-plane for different scanning angles θ_s and and different frequencies; (a) 26.5 GHz, (b) 27.5 GHZ, (c) 28.5 GHz and (d) 29.5 GHz

The pins are designed to stop any leakage between the array elements and their stop-band covers the operational frequency bandwidth of the antenna. The slots are non-periodic which provides both a better matching and radiation properties. The formation of the slots provides the possibility to have the same E-plane radiation pattern as well as a similar contribution to the scanning E-plane.

The design of the antenna started with the design of the array element as a unit cell. The optimization of the radiating slots and the gap waveguide line was set out to achieve $|S_{11}| < -10$ dB in the frequency band from 26.5 to 29.5 GHz. Each array element was designed to have minimum coupling to adjacent elements. Then, with placing other array elements and forming the complete array antenna, the final structure of the array antenna was obtained. In the next step, the active reflection coefficients of the antenna elements was optimized to be lower than -10 dB, while the main lobe is steered in the E-plane over the scanning angles within the $\pm 45^\circ$ interval. The spacing between the array elements is half wavelength of the frequency at the center of the covered frequency band.

III. RESULTS

The antenna was simulated and optimized using the Computer Simulation Technology (CST). Fig. 2 shows the active reflection coefficient of the array antenna $\Gamma_{\rm a}$ when the main beam scan angles from the broadside direction to 45°. As can be seen its value stays below -10 dB within the band of interest, i.e., from 26.5 to 29.5 GHz at all the scan angles of interest. The radiation pattern of the array antenna in the E-plane is shown in Fig. 3 for four different frequencies. The total gain of the antenna is 23 dBi computed as the average over the frequency band of operation at broadside angle. As can be seen, side lobe level is at least -10 dB lower than main lobe level in all scan angles and frequencies. There is a grating lobe when the array steers to the 45° scanning angle which is at its highest level at 29.5 GHz. The existence of grating lobes in array antennas can be avoided with proper design of the array.

IV. CONCLUSION

A linear array antenna with 8 elements has been designed based on the gap waveguide technology. Each element has 8 radiating slots and is fed from center. This antenna is suitable for 5G applications in the mmWave frequencies and has the capability to scan the E-plane in the range of $\pm 45^\circ$. The active reflection coefficient of the antenna in all scan angles and all frequencies is less than -10 dB and gain is 23 dBi in broadside angle on average.

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