A 2-layer 45°-Slant-Polarised Phased Array Antenna with Baffles Based on Gap Waveguide Technology for mmWave 5G Systems

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***Abstract*—A 45° slant-polarised gap waveguide phased array antenna designed with focus on mmWave 5G is presented. Baffles are used to reduce grating lobes. The total efficiency of the array is greater than -0.7 dB, and the average broadside gain is 24.2 dBi in the band from $26.5-29.5$ GHz.**

***Keywords*—Gap-waveguide, Phased array, mmWaves, 5G**

I. Introduction

The 5th generation (5G) communication systems will also operate on millimeter Wave (mmWave) frequency bands in order to satisfy the demands for higher data rates. For example, the $26.5-29.5$ GHz band will be used in several countries, e.g., the USA, Japan and South-Korea. On one hand, the number of antenna elements required to direct energy to a user is large, while on the other hand the array antennas need to have a small form-factor and a low manufacturing complexity in order to keep costs low.

Slotted waveguide array antennas are well-known to provide high-gain, high-efficiency and low-profile antennas. Their flat structure, low weight and the possibility to use electronic steering to rapidly change the main beam direction make these antennas attractive for many applications [1]. An important issue with slotted waveguide antennas at mmWave frequencies is the complex manufacturing process. This may result in very high costs and to leakage if the gaps between different parts are not fully sealed. One proposed solution is to use a substrate integrated waveguide (SIW) [2]. One of the drawbacks of a SIW antenna is the increased dielectric loss due to the substrate. A way to remedy the leakage without using a substrate is the gap waveguide technology. The gap waveguide technology has emerged as an excellent candidate to provide a fair trade-off between cost and manufacturing complexity [3].

II. Antenna Design

To reduce manufacturing complexity the antenna is designed with only two layers. Fig. 1 shows the gap-waveguide distribution and the radiation layers. The distribution layer is fed from the middle, which functions as a H-type T-junction, and includes a wedge. There is no cavity layer, so the radiation layer with slots is placed directly on the distribution layer. The slots are slanted 45° to enable the easy addition of an orthogonal polarization when necessary.

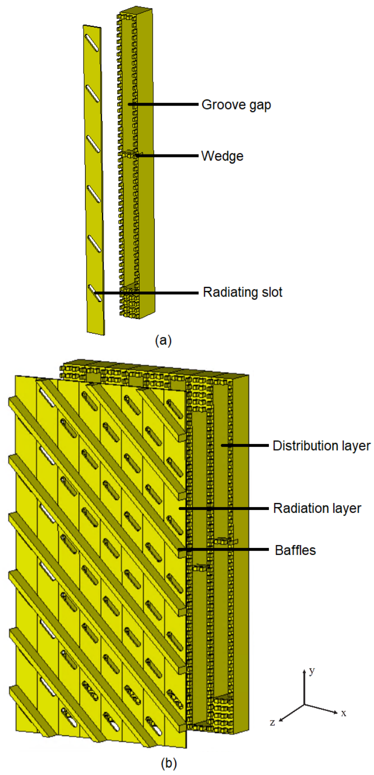

Fig. 1: Exploded view of (a) an element and (b) the array antenna.

To increase the azimuth field-of-view and the spatial selectivity, a phased array comprising eight similar elements is proposed. To prevent grating lobes, the maximum distance between the elements is limited. For a scan angle of $\theta = 45°$ a maximum distance of 0.58λ is allowed. In a horizontally-oriented gap-waveguide this is not possible since the width of the waveguide plus the width of the pins is already exceeding this value. Therefore, a vertical polarized waveguide

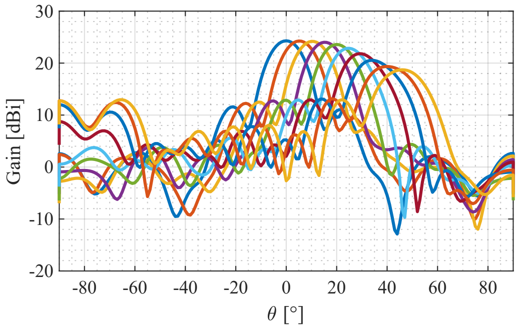

Fig. 2: Radiation pattern of the array antenna in azimuth plane for different scanning angles at 28 GHz.

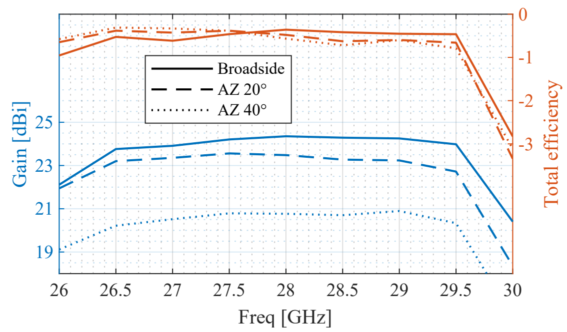

Fig. 3: Co-polar gain and total efficiency vs. frequency.

will be used. It is possible to create vertical gap-waveguide structures by using a groove-gap waveguide [4]. In this case, slots can only be placed on the waveguide every at a distance of λ from each other instead of 0.5λ. The former will result in grating lobes in the elevation plane. To avoid this, a shift of 0.5λ is added to every other element. Furthermore, baffles are used to reduce grating lobes in the D-plane [5].

III. Results

The designed array antenna is simulated and optimized using the CST MWS software. Fig. 2 shows the realized co-polar gain patterns in the azimuth plane for different steering angles. For the $0°$ steering angle, the average realized gain is 24.2 dBi. Increasing the steering angle reduces the gain, e.g., a 3 dB gain drop occurs at $35°$. Fig. 3 shows the total efficiency for different steering angles, which remains equal to -0.7 dB within the frequency range of interest. The effect of using baffles can be seen in Fig. 4. A 5 dB reduction, from -6 dB to -11 dB, of the unwanted grating lobe levels relative the main lobe can be observed by comparing Fig. 4a and Fig. 4b showing the radiation patterns without and with baffles, respectively, when scanning to a $10°$ angle in the azimuth plane.

IV. Conclusion

A $45°$-slant-polarised phased array antenna based on the gap waveguide technology is proposed. The array has only two layers, the feed distribution layer, and the radiating layer with 8 elements and 6 slots each. The average gain of the array is 24.2 dBi with a per-element gain of 15.2 dBi in the broadside direction, and the total efficiency is above -0.7 dB. Performance is maintained from $26.5-29.5$ GHz, which makes it suitable for mmWave 5G applications.

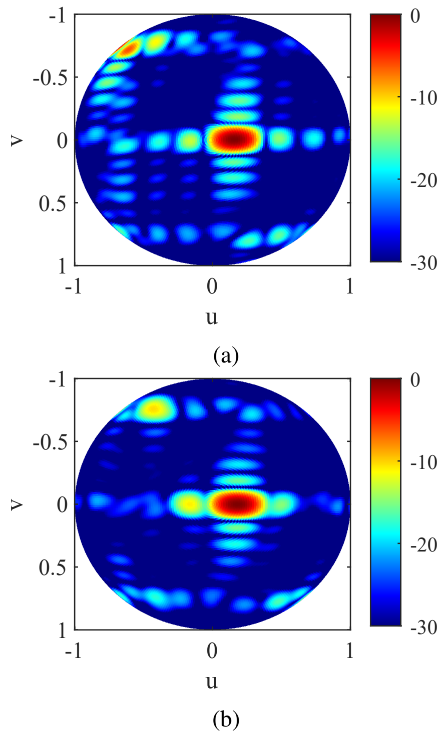

Fig. 4: UV-plane array radiation pattern when scanning to $10°$, (a) without baffles, and (b) with baffles.

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