Circularly Polarized Planar Helix Phased Antenna Array for 5G Mobile Terminals

Syrytsin, Igor A.; Zhang, Shuai; Pedersen, Gert F.

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Circularly Polarized Planar Helix Phased Antenna Array for 5G Mobile Terminals

Igor Syrytsin, Shuai Zhang, and Gert Frølund Pedersen [1]

***Abstract*—In this paper, a planar helix mobile phased antenna array is proposed for 5th generation communication systems with operating frequency of 28GHz. The proposed array displays circular polarization in the endfire direction. Over 65 degrees of axial ratio beamwidth and 7GHz of axial ratio bandwidth has been achieved in the proposed design. The coverage performance of the proposed phased antenna array has also been studied by using the coverage efficiency metric. Coverage efficiency of 50 % at 5 dBi gain is achieved by the proposed phased mobile antenna array.**

1 INTRODUCTION

Recently the interest in the frequency bands higher than 3.5 GHz has grown both in the industry and in the university research groups. The frequency bands in cm and mm-wave range will probably become a valuable solution for the upcoming 5G communication systems [1]. The bigger bandwidth is needed to support the high data rate, thus 28 GHz frequency band is proposed for the 5G mobile communication systems. In [2] it has been proposed to use the high gain antennas both at the mobile and base stations to compensate for the high path loss, associated with the cm and mm-wave frequencies. However, directional high gain antennas have a very low spatial coverage. A phased array can solve coverage issue by implementing beam scanning option. Several phased antenna arrays have already been designed for the mobile terminal applications. Promising coverage performance has been obtained for the mobile terminals in designs [3]–[5]. However, the cm and mm-wave propagation channel measurements have shown the existence of polarization dependency in the indoor NLOS channels. At 28 GHz the measurements carried out in [6] have shown that the received signal strength can vary drastically when the polarization of the receiver and transmitter antennas are altered. If a phased array can change polarization dynamically, the increase up to 10 dB in received signal strength can be achieved [6]. However, the polarization switching usually complicated and lossy at the high frequencies because of the high insertion loss of the feeding network and switches. On the other hand, a circularly polarized antenna does not require switches. Furthermore, in [7] it has been shown that a circularly polarized antenna can facilitate the decrease in the delay spread of the wideband channel.

In this paper, the circularly polarized antenna array for the 5th, generation communication systems has been proposed. The antenna has been simulated in CST Microwave Studio using an FDTD solver with over 3million mesh cells. A circular polarization performance of the proposed phased antenna array is verified by calculating the axial ratio beamwidth and bandwidth. Furthermore, the coverage efficiency of the phased array is also calculated.

2 GEOMETRY

The geometry of the proposed antenna is based on straight-edge connections method described in [8]. The geometry of the proposed antenna element is shown in Figure 1. The bottom PCB layer is displayed in blue color, the top layer is displayed in green color, and vias are displayed in red color. In application, a simple microstrip transmission line could be used to feed the antenna. The clearance of 9 mm is required in order to implement the antenna on in the mobile terminal. The Rogers RT5880 substrate of 1mm thickness has been used in this design.

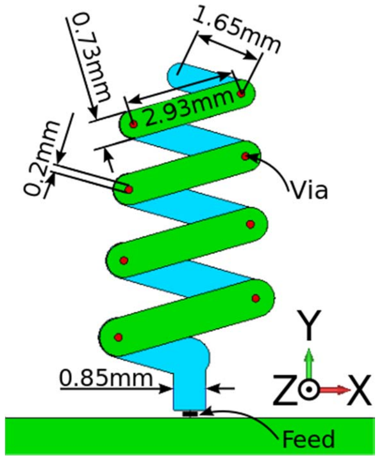


Figure 1. Antenna array element geometry.

The proposed array element has been combined in an array of 8 elements and placed on the edge of the ground plane of 60 mm width and 120 mm height, as shown in Figure 2. The spacing between elements has been chosen to a half wavelength in order to reduce the gratin lobe magnitude. The elements have been placed in the center of the mobile on purpose. Such element placement will reduce the edge effects of the ground plane, and ensure that embedded radiation patterns of all elements are similar. In simulation, simple discrete ports have been used in order to feed the array elements.

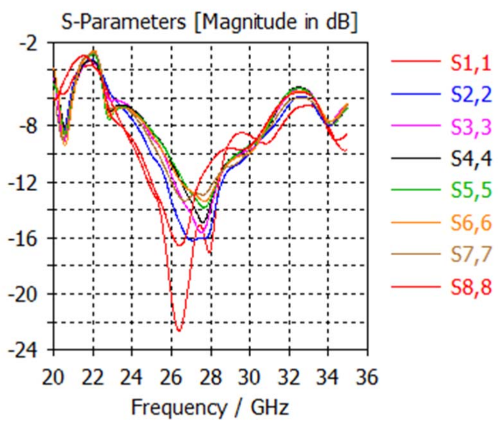
3 PHASED ANTENNA ARRAY PERFORMANCE

The embedded reflection coefficients of the array elements are shown in Figure 3. (a). It can be clearly

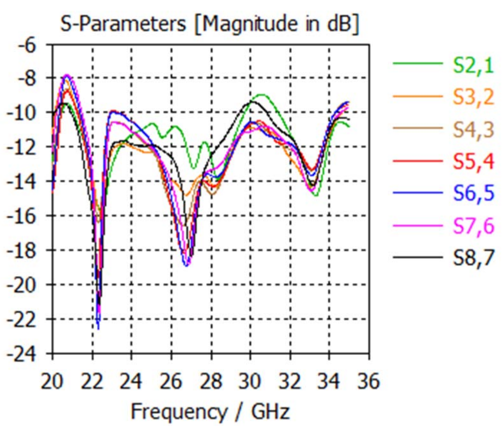
[1] Department of Electronic Systems, Aalborg University, Aalborg, Denmark,
e-mail: (sz@es.aau.dk, igs@es.aau.dk, gfp@es.aau.dk).
[2] Bang & Olufsen, Denamrk
e-mail: mse@bang-olufsen.dk

seen that not all the antenna elements are radiating at the center frequency of 28GHz. Around 2GHz of -10 dB bandwidth has been achieved by this design. In Figure 3., (b) the isolation between the antenna elements has been illustrated. It has been only chosen to show the highest isolation, which is between the neighboring elements. At least -10 dB of isolation has been achieved in the band of interest.

Figure 2. Phased antenna array configuration on the ground plane.



(a)



(b)

Figure 3. Plots of (a) reflection coefficients of array elements and (b) isolation between neighboring array elements.

To illustrate the endfire nature of the proposed phased antenna array it has been chosen to show the 3D radiation patterns for different scan angles in Figure 4. It can clearly be seen that phased antenna array has a high gain for all the scan angles.

The axial ratio scan angle (beamwidth) of the phased antenna array and the maximum gain for the different scan angles are shown in Figure 5. For the scan angle of 65 degrees, the axial ratio is under the 3dB, which it considered as a circular polarization requirement in this paper. The maximum gain of over 10.5 dBi has been achieved through all the scanning range of the proposed phased array.

Furthermore, to investigate the performance of the phased antenna in the frequency range of the interest, the maximum gain and axial ratio have been calculated from 20 to 33GHz in Figure 6. The axial ratio bandwidth is calculated for the frequency range where the axial ratio is under 3dB. The proposed phased antenna array has the axial ratio bandwidth of 7GHz from 25 to 32 GHz. However, the maximum realized gain at the frequencies lower than 26.5 GHz is lower than 10dBi. From the phased mobile antenna arrays a gain of at least 10dBi is expected in order to counteract the high path loss at 28GHz.

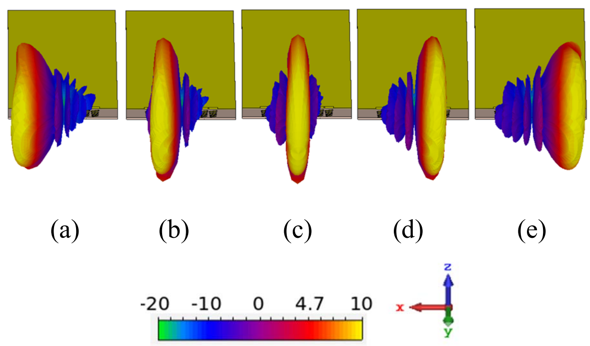


Figure 4. Radiation pattern of the proposed phased antenna array for (a)

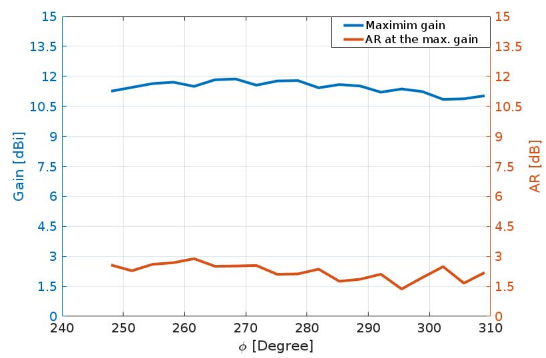


Figure 5. Maximum gain and the axial ratio at the boresight of the phased antenna array for different scan angles φ.

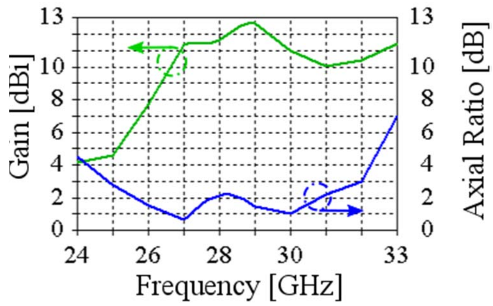


Figure 6. Maximum gain and axial ratio of the array at the scan angle of 0°.

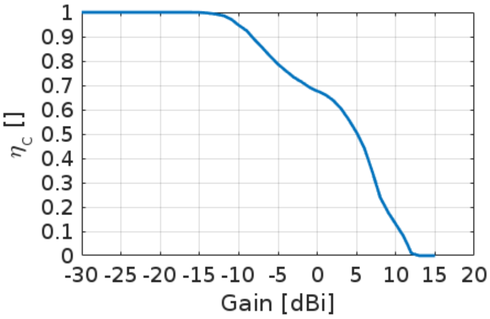


Figure 8. Coverage efficiency of the proposed phased antenna array.

To investigate the coverage performance of the proposed phased antenna array it has been chosen to first calculate the total scan pattern, and then calculate the coverage efficiency. The total scan pattern is calculated for all possible scan angles of a phased antenna array. The total scan pattern of the proposed phased mobile antenna array is shown in Figure 7. It can clearly be seen that the main beam of the phased array can be scanned from 240 to 320 degree in phi direction. However, the coverage outside of that region is very low, because of the endfire nature of the array.

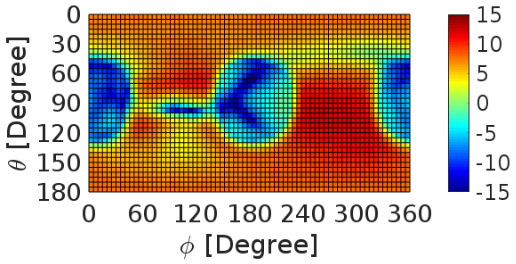


Figure 7. Total scan pattern of the proposed phased antenna array.

The coverage efficiency is calculated from the total scan pattern in Figure 7. The coverage efficiency is defined as the ratio between the total solid angle and the coverage solid angle [3]. The coverage efficiency is shown in Figure 8. It can be noticed that a coverage efficiency of 0.5 (50%) can be achieved at the gain of 5 dBi. However, this can be doubled if another phased antenna array is placed on the opposite side of the ground plane. Then, that two arrays could work as a switchable antenna array system to increase the coverage efficiency.

4 CONCLUSION

In this paper, a phased circular polarized helix antenna array with endfire radiation pattern is proposed. The antenna array has a planar two-layer structure with vias connecting the two copper layers. The proposed phased antenna array has an axial ratio beamwidth of 65 degrees with a gain over 10 dBi. Furthermore, the axial ratio bandwidth of the proposed array of around 7GHz has been achieved. The planar helix phased antenna array can cover 50% of space with a gain of 5 dBi.

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