A 28 GHz 2x2 Antenna Array with 10 Beams Using Passive Beamforming Network

Firas Abdul Ghani, Abdulkadir Uzun, Heba Ahmed Saleh, Murat Kaya Yapıcı, İbrahim Tekin
Electronics Engineering, Sabanci University
Istanbul, Turkey
{firas, kadiruzun, hebasaleh, mkyapici, tekin}@sabanciuniv.edu

***Abstract*—In this paper, a 2x2 series fed antenna array working at 28 GHz with beam switching capabilities is proposed. The presented antenna design is suitable for 5G user equipments and high data rates applications with low cost, complexity and size. The size of the antenna is 37.2x37.2 mm^2 including the ground plane and it produces 10 different switched beams by using only two simple 3dB/90^0 couplers that create the required amplitudes and phase excitations for the antenna elements. The antenna design is implemented on 0.203 mm thick low-loss (tanδ = 0.0027) Rogers 4003C substrate and it has a measured impedance bandwidth of 0.48 GHz for one of the ports. The antenna has an average realized gain of 9 dBi and 10 dB side lobe level (SLL) for all beams. The antenna is designed and simulated using HFSS and fabricated using regular PCB processing.**

Keywords — 5G Antenna Array, passive beamforming network , switched beams.

I. Introduction

Millimeter wave (mmWave) spectrum and millimeter wave communications have been proposed to be an important part of the 5G mobile network due to availability of large bandwidths and multi-gigabit communication services it offers [1]. According to Friis formula, the propagation loss increases with square of the frequency, and fixed beam direction antenna arrays may not work effectively at millimeter wave frequency band which may which leads to a poor communication link. Smart antennas, as beam-switched phased array antennas, concentrate energy and provide beam-switching in the intended direction and thus can significantly improve the reliability and performance of communication link through improved signal to noise ratio (SNR) at receiver without increasing the transmit power [2]. Beam switched antennas can select and direct its beam for the best reception. This improves the communication range and the frequency re-use performance due to the decrease in interference levels. The switched-beam phased array antennas are used in wide range of applications such as modern radars, satellite systems, automotive industry, wireless non-interfering multiple-output (NIMO) systems and may other applications.

Phased array antennas use two commonly feeding structures, parallel fed and series fed. The parallel fed uses many connecting lines, power dividers, and phase shifters to reach the required amplitude and phase excitations for maximum radiation in the intended direction. Parallel fed configuration suffers from low side lobes (SLL) performance. On the other hand, antenna arrays that use series-fed structure have short transmission lines and better performance and radiation efficiency [3].

In general, phased array antennas producing multiple switched- beams need many active controllers especially power dividers and phase shifters which results in increase complexity and cost for large-scale commercial applications. Passive beam forming networks can be used instead to lower the complexity and cost of such designs. In [4], a two-dimensional beam scanning array antenna for 5G wireless communications is proposed, but simulation results are provided for only 4 beams. In [5], another 2x2 series fed antenna array is proposed with beam steering capability, where the phase shifters are used to provide the necessary phase differences.

In this work, a 28 GHz 2x2 series fed antenna array is proposed as shown in Figure 1. The array produces 10 different switched beams using two simple 3dB/90^0 couplers as a beam forming network to generate the switched-beams in 2-D with an average realized gain of 9 dBi and 10 dB SLL.

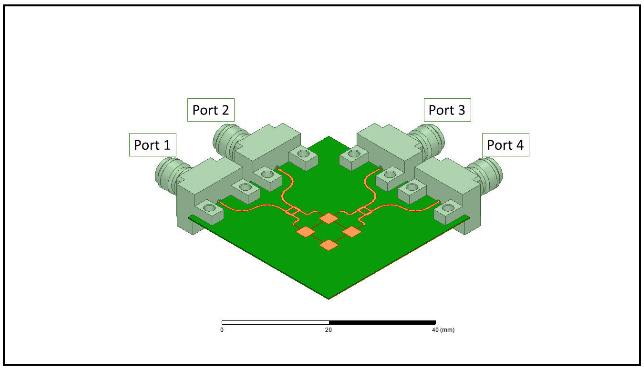

Fig. 1. Proposed antenna array with two quadrature couplers

II. Development of the Antenna

The optimized architecture of the proposed antenna is shown in Fig. 1, where square-shaped radiating patch antenna elements have been used. The edge to edge interelement spacing ($\lambda_g/2$) is 3.4 mm with 0.1 mm width, where λ_g is the guided wavelength at 28 GHz for Rogers 4003C substrate. Each radiating patch is 2.71x2.71 mm^2 and is excited from two orthogonally placed thin feeds (impedance transformer), each feed line has a length of 1.7 mm and width of 0.1 mm. This feeding structure provides high interport isolation at the intended frequency between feeding ports. When such dual-polarized radiating patches with high interport isolation are used in a 2-D symmetric antenna array, it enables the array to have independent 2-D beam scanning capability with low SLL. In order to have compact design, two quadrature couplers working at 28 GHz are used in order to achieve the required phase and amplitude excitation for steered beams. Each coupler act as 3 dB power divider and also provides 90^0 phase shift between the ports.

III. Simulation and Experimental Results

The simulated 10 switched beams are shown in Fig. 2 and Fig. 3. In Fig. 1, if all the ports are excited independently, the four beams shown in Fig. 2 will be generated with the corresponding beam directions in theta and phi.

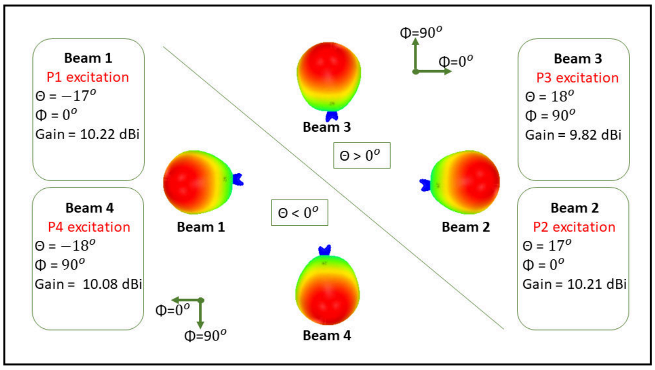

Fig. 2. Four switched beams by individual excitation of ports 1,2,3, and 4

If we use a simple feeding network which will allow excitation of two ports at the same time as described in Fig.3, we can further generate 6 more beams with steering angles different from mentioned in Fig. 3 where only one port is excited. Note that Beams 5 and 6 in Fig.3 are in the same direction with different polarizations.

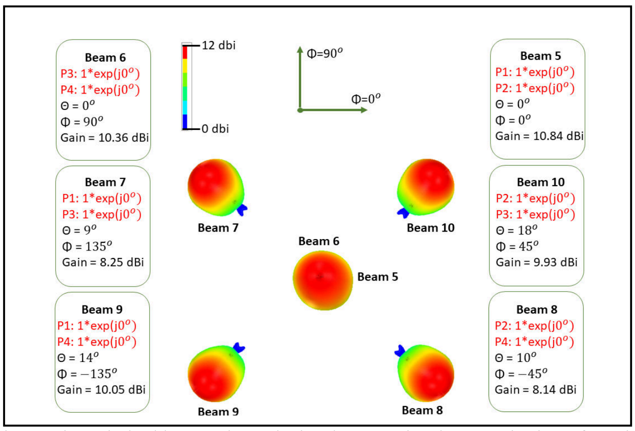

Fig. 3. Six switched beams through simultaneous in-phase excitation of a pair of respective ports

The proposed antenna is fabricated using PCB chemical etching process. The measured and simulated reflection coefficients of the array antenna are shown in Fig. 4. The measured return loss for port 4 is 12.26 dB with 0.48 GHz 10 dB return loss bandwidth, the other ports have very similar measurement results due to the symmetry of the structure. The simulated return loss for each port is more than 10 dB at 28 GHz. More detailed measurement results will be presented at the conference.

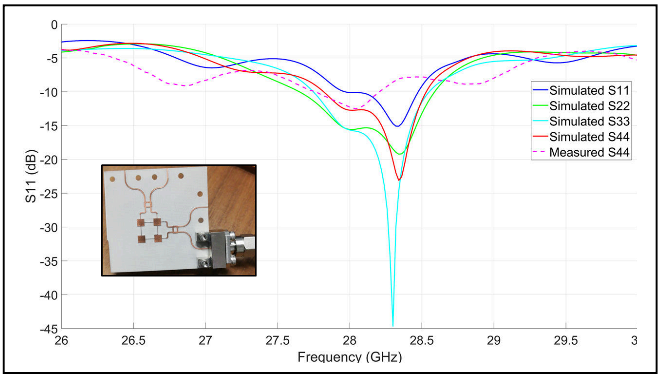

Fig. 4. Reflection Coefficients

IV. Conclusion

In this paper, a 2x2 series fed antenna array working at 28 GHz with beam switching capabilities is proposed. The antenna can generate 10 different beams with single port only and two ports in phase excitations. The antenna is implemented on a Rogers 4003C board and early measurement results show agreement with simulation results. The antenna has an average realized gain of 9 dBi and 0.5 GHz measured impedance bandwidth.

Acknowledgment

This study is supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK), Grant No: 118E842.

References

[1] Y. Niu, Y. Li, D. Jin, L. Su, and A. V. Vasilakos, “A survey of millimeter wave (mm-wave) communications for 5G: Opportunities and challenges,” 2015 [Online]. Available: http://arxiv.org/abs/1502.07228.

[2] E. Topak, J. Hasch, C. Wagner, and T. Zwick, “A novel millimeterwave dual-fed phased array for beam steering,” *IEEE Trans. Microw. Theory Tech.*, vol. 61, no. 8, pp. 3140–3147, Aug. 2013.

[3] Y. Chong and D. Wenbin, “Microstrip series fed antenna array for millimeter wave automotive radar applications,” in *Proc. IEEEMTT IMW*,2012, pp. 1–3.

[4] S. I. Orakwue, R. Ngah and T. A. Rahman, "A two dimensional beam scanning array antenna for 5G wireless communications," *2016 IEEE Wireless Communications and Networking Conference Workshops (WCNCW)*, Doha, 2016, pp. 433-436.

[5] M. Khalily, R. Tafazolli, T. A. Rahman and M. R. Kamarudin, "Design of Phased Arrays of Series-Fed Patch Antennas With Reduced Number of the Controllers for 28-GHz mm-Wave Applications," in *IEEE Antennas and Wireless Propagation Letters*, vol. 15, pp. 1305-1308, 2016.