Thin Printed Coded Metasurface for Split Beam Generation in Arbitrary Direction

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This paper presents a thin metal-dielectric printed coded metasurface (PCM) for pattern reconfiguration and splitting of the incoming electromagnetic wave. The designed surface consists of printed metal loops on the three dielectric layers separated by an air gap. The overall design is compact and lightweight, operating at 20GHz. Such surfaces can be utilized to generate or split an incoming wave into multiple beams. Multibeam-antennas are crucial elements in massive multiple-input-multiple-output (MIMO) architecture [1]. Multibeam antenna systems operating in the Ka-band are essential for delivering enhanced data transmission rates, wider bandwidth, increased spectrum efficiency, and an improved signal-to-interference ratio. These advancements ensure superior performance and higher data rates for end cellular users. Some metasurface-based beam splitters have been proposed in the literature [2-4], owing to their ease of fabrication. The PCM presented here using thin substrates reduces the antenna's overall weight, making it suitable for lightweight space-constrained applications. Furthermore, the three metal-dielectric layer unit cells employed to represent '1's' or '0°' sequences comprise concentric square loops tilted at $45°$, facilitating easy tuning and enabling diverse combinations of phases separated by 180 degrees. A single metal-dielectric layer with a simple square loop can provide cells with high transmission magnitude ($S_{21} > -3dB$) and $90°$ phase range. Therefore, a minimum of four layers are required to achieve a complete $360°$ phase range. Nevertheless, with the incorporation of four square loops, a full 360° phase range can be attained using only three metal-dielectric layers. For the implementation of PCM, cells with $S_{21} \leq -1dB$ and phase difference of $180°$ are selected. The unit cell is shown in Fig. 1. The performance of the PCM is predicted using the simulations in CST and shown in Fig. 2.

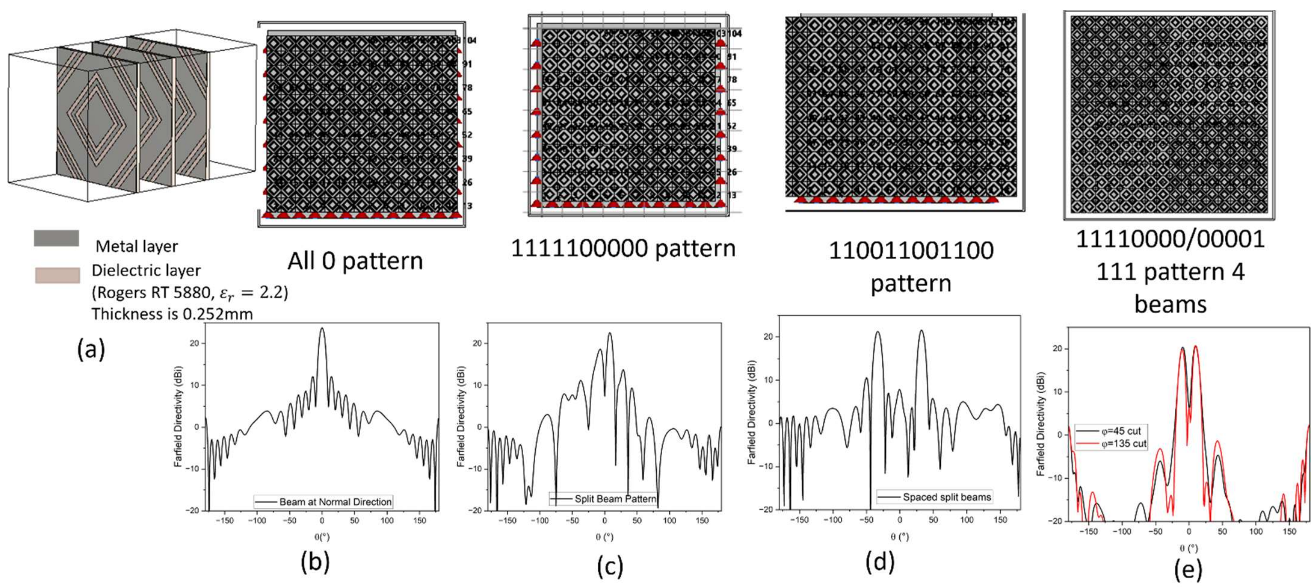

Fig. 1. (a) unit cell, Three different coding surfaces (b) same cells with 0° phase cells (c) Cells with Phase 180° and 0° arranged in pattern (111111000000), (d) Cells with Phase 180° and 0° arranged in a pattern (1100110011001100), (e) Cells with Phase 180° and 0° arranged in a pattern (1100…/000111….)

[1] W. Hong *et al.*, "Multibeam Antenna Technologies for 5G Wireless Communications," *IEEE Transactions on Antennas and Propagation,* vol. 65, no. 12, pp. 6231-6249, 2017, doi: 10.1109/TAP.2017.2712819.

[2] P. Yang, R. Yang, and Y. Li, "Dual Circularly Polarized Split Beam Generation by a Metasurface Sandwich-Based Fabry–Pérot Resonator Antenna in Ku-Band," *IEEE Antennas and Wireless Propagation Letters,* vol. 20, no. 6, pp. 933-937, 2021, doi: 10.1109/LAWP.2021.3067387.

[3] F. Ahmed, M. U. Afzal, K. Singh, T. Hayat, and K. P. Esselle, "Highly Transparent Fully Metallic 1-Bit Coding Metasurfaces for Near-Field Transformation," in *2022 16th European Conference on Antennas and Propagation (EuCAP)*, 27 March-1 April 2022 2022, pp. 1-4, doi: 10.23919/EuCAP53622.2022.9769438.

[4] D. González-Ovejero, G. Minatti, G. Chattopadhyay, and S. Maci, "Multibeam by Metasurface Antennas," *IEEE Transactions on Antennas and Propagation,* vol. 65, no. 6, pp. 2923-2930, 2017, doi: 10.1109/TAP.2017.2670622.