Design and fabrication of transmissive metasurface for 300-GHz-band beamforming in Beyond 5G wireless networks

NTT Device Technology Labs, NTT Corp.[1], °Adam Pander[1], Daisuke Kitayama[1], Hibiki Kagami[1], Hiroyuki Takahashi[1]

E-mail: adam.pander@ntt.com

In recent years, sub-terahertz frequency bands (30 ~ 500 GHz) have brought major attention due to their high potential for higher transmission data rates and larger bandwidths in wireless transmission. Especially, millimeter waves from 30 GHz to 300 GHz became a major development target for high-capacity networks with data rates over 100 Gb/s [1]. However, with increased operating frequencies, the degradation of SNR and data rates occurs due to increased atmospheric attenuation, non-line-of-sight propagation, and free space path losses. To address these challenges, high-directivity and high-gain antennas with reconfigurable radiation characteristics are needed. Among the beamforming techniques, metamaterial-based designs, both passive and active, are intensively studied as alternatives to more complex designs, like phased arrays [2].

In this study, to cope with various demands for the radio coverage extension in Beyond5G wireless communication, passive multilayer metasurfaces with radius size-controllable transmission phase variation are experimentally realized. Fig. 1(a) shows a general schematic of the phase gradient of metamaterial cells that results in the beam steering of the incident wave during the transmission through the metasurface. Different-sized metamaterial cells were combined in a way that the metasurface exhibits a desired transmission phase gradient across its surface, allowing for beamforming of the incident wave into a predesigned direction (0 ~ 38° in this work). Fig. 1(b) shows an example of a fabricated metasurface device with gradient metamaterial cells. Except for the beamforming characteristic, the device also shows good flexibility and optical transparency, making it a promising candidate for application to various surfaces, including curved geometries or windows. The inset of Fig. 1(b) shows simulation and experimental results of the near-***E***-field distribution maps, that were in good agreement, confirming the correctness of the design and high precision of fabrication. Fig. 1(c) shows far-field results obtained for various beamforming angles at 300 GHz. The main lobes showed as-designed beam steering angles for all metasurface devices.

In addition to the ***E***-field distributions of the presented devices, the data transmission rate measurements were also carried out. For the link distance of 25 cm and without a Tx power amplifier, the achieved data rates of above 70 Gb/s for different metasurfaces were larger than previously presented beamformers, including phased arrays at 300 GHz band. These results can be used for the coverage extension of the indoor-to-outdoor transmission at sub-THz frequency bands in future Beyond5G networks.

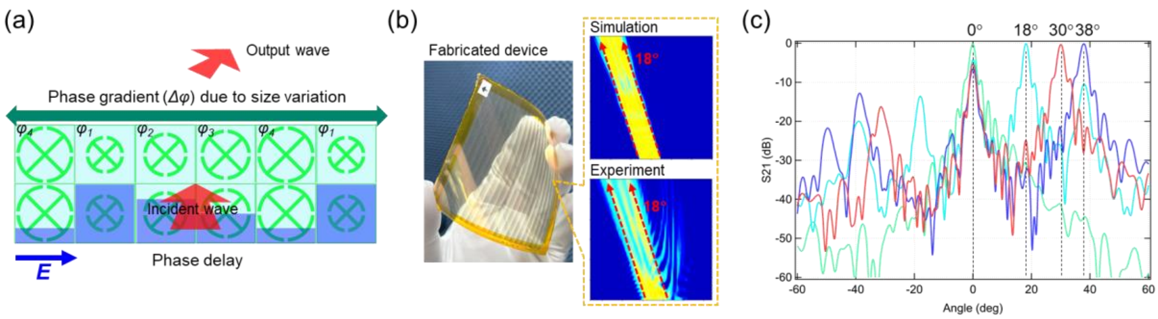

Fig. 1. (a) Schematic of transmission phase gradient in beamforming metasurfaces. (b) Fabricated device and simulation and experimental results of near-***E***-field distributions. (c) Far-field measurement data.

Reference

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[2] D. Kitayama, *et al.*, Alignment-free twisted-split-ring metasurface on single substrate with 2π phase range for linearly polarized sub-terahertz wave, Opt. Express **31**(13), 20769-20786, 2023.