Realization of Programmable Chessboard Mushroom-type Metasurface for Beamforming Applications

A. Abraray\(^1\), R. A. M. Pereira\(^1\), K. Kaboutari\(^1\), and S. Maslovski\(^1,2\)

\(^1\)Instituto de Telecomunicações, Aveiro, Portugal
\(^2\)Department of Electronics, Telecommunications and Informatics, University of Aveiro, Aveiro, Portugal

Abstract — In this work, we report on a prototype realization of a reconfigurable reflectarray-type metasurface and investigate its potential for beamforming applications. The studied programmable metasurface (PMS) comprises a chessboard-like array of metallic patches placed over a grounded dielectric slab with metallic vias connecting the patches to a network of \(x\)- and \(y\)-controlling lines. Tunability is achieved with nonlinear capacitive loads — varactor diodes — inserted between the corners of the metallic patches that form the chessboard structure. The direction of the reflected beam is changed by applying differential voltages necessary to create a given reflection phase gradient on the metasurface. With an inexpensive modification that adds capacitive memory to the network of controlling lines, each unit cell of the PMS can be addressed and programmed separately.

The analytical model of such a chessboard Sievenpiper mushroom-type PMS with memory was developed by us previously \([1, 2]\). By using this analytical model and the SIMULIA CST Studio Suite software we have investigated several variants of the proposed PMS concept. Based on these studies, the design parameters and dimensions have been optimized for the frequency range from 3 to 6 GHz for potential 5G+ applications. A prototype PMS that operates in this range has been built. With this prototype, we have realized and tested experimentally a few simple one-dimensional beamforming scenarios, in which we have used a resistor chain-based voltage divider to create differential voltages. The performance of the prototype has been tested in an anechoic chamber in a bistatic configuration with a pair of horn antennas communicating through the reflecting PMS. Experimental results have demonstrated that a PMS prototype with just \(3 \times 10\) controllable elements is already sufficient to redirect the beam in different directions.

In the next series of experiments, we aim to control the PMS with a custom-build FPGA-based controller. By using such controller we will be able to create arbitrary voltage distributions among the full set of PMS control lines. Such a setup will allow us to realize more complex beamforming scenarios. Moreover, the current results have shown that a PMS with a larger size might be needed in order to decrease the influence of parasitic scattering effects. Developing the new experimental setup is underway. The complete system will include a digitally-controlled multichannel voltage driver board, an FPGA board to produce a set of Pulse Width Modulated (PWM) input signals for the bias voltage drivers and a laptop PC converting the phase gradient data to the PWM control data given to the FPGA by a USB serial link.

ACKNOWLEDGMENT

This work has been funded by Fundação para a Ciência e a Tecnologia (FCT), Portugal, under the Carnegie Mellon Portugal Program (project ref. CMU/TIC/0080/2019). The authors also acknowledge funding by FCT/MCTES through national funds and when applicable the EU funds under the project UIDB/50008/2020-UIDP/50008/2020.

REFERENCES