Ultra-Thin Microwave Transmitarrays Exploiting Polarization-Converting Miniaturized-Element Frequency Selective Surfaces

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In recent years the introduction of miniaturized-element frequency selective surfaces (MEFSSs) has offered new capabilities in designing surfaces that manipulate electromagnetic wavefronts. The ability of MEFSSs to control the phase and amplitude of electromagnetic (EM) waves at the sub-wavelength scale has led to innovative applications in designing new types of reflectarrays, transmitarrays, spatial filters, polarization converters, and more. Another very important property of EM waves is their polarization state. MEFSSs have also been engineered to manipulate the polarization state of the wave by converting linearly-polarized incident waves to circularly-polarized transmitted or reflected waves (S.M.A. Momeni Hasan Abadi and N. Behdad, IEEE Trans. Antennas Propag. **64**, 525, 2016). However, to date, MEFSSs capable of rotating the polarization of a linearly-polarized wave (e.g. by converting vertical to horizontal) have not been demonstrated. Such devices can have applications in polarization conversion as well as designing novel types of low-profile, transmit- and reflect-array antennas.

We present a polarization-converting MEFSS that offers the ability to rotate the polarization of a linearly polarized wave by any desired angle (e.g. from vertical to horizontal) over a very wide frequency band. Typically, polarization rotating periodic structures take advantage of the resonant characteristics of their unit cells. This approach usually limits the device's operating bandwidth significantly. The proposed MEFFS design is based on a 2nd order bandpass MEFSS previously reported in (M. Al-Joumayly and N. Behdad, IEEE Trans. Antennas Propag. **58**, 4033, 2010). The current design exhibits polarization conversion over a very wide bandwidth, which can reach up to 50% in the X-band (8-12 GHz). This novel polarization converting MEFSS provides the ability to design very low profile, wide bandwidth transmitarrays. MEFFS-based transmitarrays are populated with MEFFS unit cells, which manipulate the magnitude and phase of the EM wave and create the appropriate phase compensation over the surface of the array. The design of spatial filters should have the ability to provide a 360^{o} phase variation. Previous designs used higher order spatial filters to achieve higher phase variations. In the proposed design the 2nd order bandpass MEFSS has the ability to provide phase variation of 180° and with the polarization rotation the phase variation can reach up to 360°. Using 2nd order MEFSS spatial filters as the building blocks of the transmitarray provides the opportunity to further reduce the overall thickness of the device without any compromises in phase discretization. Using the previously mentioned design, two transmitarrays were fabricated and experimentally characterized in a near field system. In the first prototype, two polarization conversion unit cells were used which results in phase discretization of 180°. In the second prototype four polarization rotating unit cells were used in order to reduce the phase discretization to 90° and to increase the overall gain of the device.