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Design of a non-invasive FSS sensor for monitoring radio waves

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Thin metasurface structures have been used as electromagnetic field sensors for radio-frequency (RF) waves. The 2-d distributions of RF electric field incident on a thin metasurface absorber were picked up by a mushroom-type metasurface structure, which had a dense matrix of square metal patches on a grounded dielectric substrate. Lumped resistors interconnecting the surface patches in the x- and y-directions were used to absorb incident RF waves, and to measure their electric field components (E_x- and E_y-polarizations). In this case the surface patches worked as a 2-d array of short dipole sensors terminated with the lumped resistors [1]. Another component of electric field perpendicular to the surface (E_z) was picked up by an additional resistor inserted at the bottom of each of the "vias" connecting the surface patches and the ground plane, which worked as a detector of the potential difference between them [2]. On the other hand, RF magnetic field distributions were measured with another type of metasurface structure, on which a 2-d array of the unit cells with metal loop structures were arranged. Each unit cell consisted of three metal loops orthogonal to each other, to detect the x-, y-, and z-components (H_x, H_y and H_z) of a magnetic field vector. The induced voltage on each loop was monitored using a resistor inserted in a small gap on the loop [3]. In either case the voltages on the resistors were picked up by RF detectors implemented on the backside of the metasurface structure, to measure the 2-d distributions of RF electromagnetic field vectors incident on the surface. Such obtained field distributions should give useful information for in-situ and real-time monitoring and localization of RF noise sources. These metasurface sensors were basically intended to absorb the incident waves, but the existence of complicated metal structures caused a certain disturbance to the original electromagnetic field distributions.

We have been trying to design a new metasurface sensor based on frequency-selective surfaces (FSSs), which is almost transparent to incident RF waves, and at the same time being capable of measuring the 2-d distribution of electromagnetic fields on the surface. This would make it possible to monitor the RF field distributions with disturbing the original electromagnetic environment as minimum as possible. A preliminary structure working as such a "non-invasive" 2-d field distribution sensor was designed as a combination of a patch-type capacitive FSS and a grid-type inductive FSS. Lumped resistors were embedded in the structure to generate the voltages proportional to the incident electric field components. When the amount of power absorbed by the resistors is as small as possible relative to the power flux of the incident wave, we can monitor non-invasively the original electric field distribution. In the presentation we will discuss the design and performance of the new FSS sensor using an equivalent circuit analysis and electromagnetic simulations.

1. S. Yagitani, R. Kanaura, M. Ozaki, and T. Imachi, "Numerical analysis and visualization of spherical waves absorbed by a thin metamaterial absorber," Proc. ICEAA 2017, September 2017, pp.808-809, doi:10.1109/ICEAA.2017.8065372.

2. S. Yagitani, K. Shimizu, S. Nishi, A. Sakano, H. Segawa, T. Tsubota, T. Imachi, and M. Ozaki, "Measurement of electric field vector distribution with a metasurface structure," Proc. URSI GASS 2021, September 2021.

3. S. Yagitani, T. Tsubota, H. Segawa, T. Imachi, and M. Ozaki, "Magnetic field distribution measurement with a metasurface structure," Proc. URSI AP-RASC 2019, March 2019.