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Equivalent Circuit Analysis of Stacked Metasurface Absorber for Broadband Measurement of Field Distributions

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We have developed a technique to measure and visualize the two-dimensional (2-d) field distributions of radio waves, using a thin metasurface absorber with a mushroom structure [1]. A matrix of square metal patches was arranged on the surface of a grounded dielectric substrate. Lumped resistors were inserted between the surface patches to absorb incident waves at the resonance frequency of the metasurface, where the surface impedance was matched with the incident wave impedance. The voltages on the 2-d matrix of lumped resistors were detected to obtain the 2-d electric field distribution incident on the absorber surface at around the resonance frequency. Though the inherent resonance frequency of the metasurface was in the GHz range, lumped capacitors were inserted parallel to the resistors to decrease it down to several hundreds of MHz. In designing the metasurface absorber, we evaluated the absorption characteristics by an equivalent circuit analysis and electromagnetic simulations, so that the optimum absorption and measurement performance was achieved in a certain frequency range. Using a 20-mm square patch, for example, we achieved a frequency response of 500 MHz to 800 MHz for measurement. However, it was difficult to obtain a wider frequency response using the metasurface absorber with the conventional mushroom structure.

In this study, the lumped capacitors for adjusting the resonance frequency in the conventional structure were removed, because such an additional capacitance made the bandwidth smaller. Instead, an additional mushroom layer with metal patches and vias on a dielectric substrate (called the second layer) was added on the conventional single-layer mushroom metasurface (the first layer). A lumped resistor was placed on the backside of the ground plane, and connected between the via in the first layer and the via in the second layer. Using electromagnetic simulations, the structure (called a “stacked metasurface absorber”) was found to show a dual-resonance feature that enabled us to obtain a broadband absorption and measurement of radio waves in a broad frequency range of 300 MHz to 1.9 GHz. The mechanism of the broadband absorption was then analyzed using an equivalent circuit. As a result, the absorber was represented possibly by a combination of a couple of LC resonant structures which exhibited a dual-resonance feature. Circuit parameters were adjusted to give the frequency characteristics of the absorption and the voltage on each resistor calculated by the equivalent circuit to be consistent with those obtained in the simulations. This makes it possible to design a novel sensor to measure the 2-d electric field distributions with a broadband frequency response.

References

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