

Designing metasurfaces for infrared-based near-field measurement of incident power density with linear polarization selectivity

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Electromagnetic fields radiated by devices operating in the 6–100 GHz range can be effectively measured using the heating response of a metasurface. This rapid, infrared-based technique leverages electromagnetic losses to produce localized heating, captured with an infrared camera. The proposed method serves as a near-field measurement alternative to traditional techniques relying on probes and vector network analyzers (VNAs). Unlike homogeneous sheets, where heating is distributed across the surface, our approach employs a metasurface with localized elements tailored into various geometrical configurations, optimizing the performance and sensitivity of the measurement system.

An important feature of the metasurface and its periodic structure is the ability to incorporate polarization-selective elements while maintaining minimal impact on the system being measured. This dual focus enhances the versatility and accuracy of the measurement technique.

Polarization selectivity is here achieved by various geometrical configurations within the elements of the metasurface, including dipoles, U-shaped structures, and cross-patterned elements. These geometries exhibit significantly different responses to cross-polarized incident waves. We demonstrate how the design and material choices influence the measured results, highlighting potential limitations in accurately measuring certain devices. Additionally, we discuss how these design factors can introduce unwanted imaging effects, potentially restricting the range of devices that can be effectively characterized provided a specific design.

Minimizing the impact on the transmitting system, such as reflections back to the source, is achieved through careful material selection and composition. Combined with the metasurface element design, this approach yields low reflected power values ($<10\%$) while maintaining absorbed power levels of above 40%. Additionally, we investigate the periodicity of the elements and the influence of their inter-region coupling on the electromagnetic field. To ensure representative measurements, the coupling must not distort the field. These design considerations minimize interference introduced by the measurement system, making it well-suited for applications such as handheld communication devices.

The mechanism of heat generation due to ohmic losses, arising from currents induced by the electromagnetic field, is well understood. However, in this work, we investigate the correspondence between the observed heat, captured by the infrared camera, and the physical quantities of the electromagnetic field. Using simulations and excitations of a Hertzian dipole, we demonstrate that a single element within the metasurface effectively images the squared electric field intensity, whereas the complete metasurface provides a measurement better correlated with the incident power density.

This work highlights the critical role of the element design of the metasurface for infrared-based measurements in the near field. Through an analysis of various metasurface configurations and their simulated responses, it is demonstrated that the dissipated power within the metasurface elements exhibits a stronger correlation with the incident power density than with the electric energy density. While the measurement system captures amplitude-only data, these findings highlight its practicality, non-invasive nature, and effectiveness as a tool for evaluating radiating devices.