Design of Angle-Sensing Infrared Detectors Based on Coupled Nano Antennas

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Imaging systems operating at the infrared (IR) through visible bands are used in numerous civilian and military applications. In certain demanding applications, imaging systems operating at such wavelengths are frequently used in less-than-desirable operational conditions. For example, IR imaging systems may need to be used in environments where the visibility is drastically degraded by the presence of sea spray, dense fog, or sand and dust particles. In such situations, it becomes difficult or impossible to perform the necessary sensing, imaging, and detection tasks using conventional IR or visible imaging systems. Conventional imaging systems work primarily by measuring the irradiance of the incoming wave. In doing so, these systems do not take advantage of other attributes of the incoming EM wavefront such as the frequency, polarization, angle-of-arrival, and the complex wavefront of the incoming radiation. These additional attributes often contain information beyond the irradiance of the scene that may be exploited to perform sensing and imaging in degraded environments. Therefore, developing techniques for designing new types of optical detectors that can sense these additional properties of the incoming radiation is of great interest in developing the next generation of IR/visible imaging systems.

In this paper, we present the design of an angle-sensing optical detector operating at the long wave infrared band (wavelength of 10.6μm). The detector is designed based on the concept of biomimetic antenna arrays (N. Behdad, et al., IEEE Antennas Wireless Propag. Lett., 10, 361-364, 2011) and is composed of two coupled patch antennas. The antennas are fabricated on a thin, ground-plane-backed SiO_2 layer grown on top of a Silicon wafer. In addition to the direct coupling between the two antennas, a passive, external coupling network is used to improve the angular response of the system. The antennas are coupled to micro-bolometer detectors used to detect the IR radiation. The two-element coupled nano-antenna array is designed such that the output power of each antenna is made sensitive to the angle of incidence of the EM wave. Therefore, by measuring the ratio of the currents flowing through the two detectors, the angle of incidence of the wave can be determined. Using this concept, no coherent measurement is needed to detect the angle of arrival. Simulation results indicate that over an incidence angle ranging from -60° to 60°, a dynamic range of about 30 dB can be achieved. In the presentation, we will discuss the principles of operation of these detectors as well as details of their design procedures. We also present simulated and measured results of prototype detectors and discuss envisioned methods in which such detectors can be used in new sensing/imaging systems operating at the IR through the visible frequency bands.