Industrial Applications of Metamaterials at Raytheon

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Abstract-This paper discusses the metamaterials currently under investigation for applications at Raytheon. Electro-optical metamaterial devices for reducing dark current, improving device performance and functionality and enhancing capability will be discussed. Some longer wavelength (RADAR) metamaterials will also be discussed briefly in the context of technologies of interest. Finally future directions for metamaterials of interest will also be touched upon.

Raytheon is a large defense contractor with a product portfolio that is diverse covering radar, communications, missiles and effects, reconnaissance, imaging, and homeland security. Raytheon has been pursuing the application of metamaterials to this portfolio for a number of years, as Raytheon’s products cover wide spans of the electromagnetic spectrum and could benefit greatly from advantages provided by these materials. This paper will discuss some of the applications that metamaterials are being applied to, and investigate the benefits that arise from the use of metamaterials. The topics covered will include photon trapping structures for reduced dark current and improved operating temperature, metamaterials for all-dielectric monolithic focusing optics, frequency selective surfaces/perfect absorbers, and some metamaterial for radar applications, which will be discussed in the presentation though aren’t included in this summary.

For Raytheon’s electro-optic (EO) products sensitivity and signal-to-noise are key driving requirements, as our applications often push the state of the art. Often there are secondary system trades associated with achieving these requirements, such as system size, weight, power and cost (SWAP-C). For example IR detectors are often cooled to cryogenic temperatures to lower the dark current so that the noise associated with the dark current is below the photon shot noise. Metamaterials may instead allow designs that achieve this level of performance at higher temperatures. The PT-SQUAD program from DARPA [1] investigated reducing the absorber volume by etching a photonic crystal into the detector (Figure 1a), allowing reduced dark current and improved NEdT (Figure 1b). Another promising metamaterial concept for achieving this is plasmonic resonators [2], where volume is removed from the absorber, which decreases the quantum efficiency, but an additional plasmonic resonator buys back the lost QE (as illustrated in Figure 2a,b, after [2]). A similar technology for achieving this volume reduced concept is frequency selective surfaces or perfect absorbers, which sandwich an IR absorber in a metal geometric structure. This couples to certain frequencies, as discussed in [3 & 4]. Very thin absorbers can be achieved with this concept, as illustrated in Figure 3 and 4, and offer the promise of dual band detection as in Figure 4. Applications of metamaterials to optical elements in Raytheon optoelectronic products will also be discussed, as well as metamaterial to RADAR applications.

By using these examples, the industrial application of metamaterials to Raytheon’s product line will be shown to seek to improve state of the art performance. The application of these new and novel materials generally enables fundamental trades in system design to be disconnected or provided an orthogonal interaction, making the trade superfluous or varied. The benefit of this is often realizing system performance goals at better SWAP-C, or improved performance beyond state of the art for a given SWAP-C.
Figure 1a: A Mesa with a photon trap etched into it.

Figure 1b: NEDT as a function of pixel design (illustrated in inset).

Figure 2a: Plasmonic resonator on a quantum dot IR detector after [2].

Figure 2b: Improved responsivity from inclusion of plasmonic resonator, after [2].

Figure 3: Perfect absorber formed from a metamaterial including an IR absorber, after [3].

Figure 4: Dual band frequency selective surface with two metamaterials resonating at different wavelengths combined in one unit cell, after [4].

REFERENCES