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Metamaterial-inspired Near-Field Resonant Parasitic Paradigm: Electrically Small Antennas from Microwaves to Optics

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Extended Abstract

The introduction of metamaterials and metamaterial-inspired structures into the tool set of RF engineers has led to a wide variety of advances in discovery within the fields and waves research areas. The enhanced awareness of complex media, both naturally occurring and artificially constructed, which has been stimulated by the debut of metamaterials, has enabled paradigm shifts in terms of our understanding of how electromagnetic (and acoustic, thermal, structural, ...) devices and systems operate and our expectations of their performance characteristics. These shifts include the trends of miniaturization, enhanced performance, and multi-functionality of antenna systems for wireless platforms and sensors.

A number of advances in the use of metamaterial-inspired constructs to improve the overall efficiency, bandwidth, and directivity performance of electrically small antennas (ESAs) in the VHF, UHF and microwave regimes will be reviewed. Several metamaterial-inspired resonant near-field parasitic (NFRP) ESA designs have been fabricated and tested; these measurement results are in nice agreement with predictions [1-8]. While initial efforts emphasized simply high overall efficiencies without using any external matching networks [1], more recent NFRP designs have also explored the ability to exhibit multi-functional performance, enhanced bandwidths, and higher directivities. Multi-functionality is achieved by combining multiple NFRP elements in an electrically small package. Enhanced bandwidths are achieved in an electrically small system by augmenting the NFRP element of the antenna or scatterer internally with non-Foster (active) circuit devices, which, in our cases, have been implemented as negative impedance convertor (NIC)-based inductors and capacitors [2]. Since there are a variety of applications for which it is desirable to have higher directivity and/or a large front-to-back ratios, i.e., to have the radiated power emitted primarily into one hemisphere, we have recently developed a variety of higher directivity NFRP ESAs. Higher directivities are obtained by incorporating structured grounds [3] and by adding more NFRP elements. In particular, combinations of electric and magnetic multipole NFRP elements have led to electrically small NFRP Huygens sources [4-6]. Additional augmentations have produced efficient, broad-bandwidth, high directivity NFRP ESAs [7, 8].

While these RF engineering paradigm shifts will be reviewed, it will be emphasized that the same concepts have been extended to optical nano-antennas [9], even realizing a Huygens source nanoparticle laser [10]. These optical NFRP electrically small designs will be discussed briefly.

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