Plasmonic Metamaterials with a Negative Refractive Index

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Recently, a 3D negative refractive index (NRI) transmission-line medium was proposed by Hoefer (W.J.R Hoefer et al., IEEE MTT-S Intl. Microwave Symp., 313-316 (2005)) and the authors (A. Grbic and G.V. Eleftheriades, IEEE Intl. Symp. on Antennas Propagation, 2A, 14-17 (2005)). The 3D medium consists of unit cells that are duals of the expanded TLM node. Specifically, the series inductors and shunt capacitors of the expanded TLM node are swapped to yield a physically realizable 3D network consisting of series capacitors and shunt inductors. Using fullwave analysis, the 3D transmission-line medium was shown to exhibit isotropic backward-wave propagation for all directions of propagation and polarization in (A. Grbic and G.V. Eleftheriades, J. Appl. Phys., 98, 043106 (2005)).

This talk will describe two plasmonic NRI metamaterials that have been inspired by 3D transmission-line metamaterials. The first plasmonic metamaterial is arrived at by replacing the inductors in the 3-D NRI transmisison-line medium by spheres made from a plasmonic material, such as silver at optical frequencies. As was shown in (N. Engheta, A. Salandrino and A. Alu, Phys. Rev. Lett., 95, 095504 (2005)), plasmonic nano-spheres behave as inductors at optical frequencies. On the other hand, the capacitive coupling between the plasmonic spheres acts as the series capacitors in the 3-D NRI transmission-line medium. The resulting 3-D plasmonic NRI metamaterial is a face-centered cubic lattice of plasmonic spheres: there are spheres at the corners and in the center of each face. The second plasmonic NRI metamaterial that will be discussed has plasmonic spheres only at the centers of each face of the cubic unit cell, and not at the corners. Once again, the plasmonic spheres act as inductors and the capacitive coupling between them provides the necessary series capacitance. The unit cell of this second metamaterial in many ways resembles the dual of the symmetrical condensed TLM node.

The operation of the two proposed plasmonic NRI metamaterials will be explained and compared. The usefulness of combining 2-D and 3-D electrical network theory with the concepts of nano-inductors and nano-capacitors introduced by Engheta will be demonstrated.