An Artificially Engineered Microwave Material for Dielectric Resonator Antennas

Mohammadreza Tayfeh Aligodarz*(1), Atabak Rashidian(2), David Klymyshyn (1)
(1) University of Saskatchewan, Saskatoon, SK, Canada and TRTech, Canada
(2) University of Manitoba, Winnipeg, MB, Canada

Meta-materials are engineered complex structures with controlled electromagnetic properties that are generally hard to find naturally. Thus far, most of the focus in this highly attractive field has been on negative refractive index materials, and their applications. It has been extensively used in different kinds of microwave and antenna structures, e.g. close reflectors for dipoles, coating shells to improve monopoles, and numerous meta-material loaded patch antennas, to name a few.

Based on the Maxwell equations, the value of the effective permittivity of the medium, ε, can be tailored by controlling the degree of polarization, P ($\varepsilon = 1 + P/\varepsilon_0 E$). In this work, instead of using the usual negative refractive index meta-materials, the permittivity of the bulk base material is significantly enhanced (5 times and more) by an array of strongly coupled, small metallic inclusions, due to their high polarity. The lateral size of the inclusions is in the order of $\lambda_0/10$, so they are not self-resonant structures in microwave frequencies. The presented approach is applied for dielectric resonator antenna applications. It provides a rich set of techniques for the design and fabrication of bulk meta-materials with controlled permittivity. It can be used to increase the low-permittivity of polymers using standard metallization methods, instead of, e.g., adding high weight percentages of ceramic powders. In other words, lithographic processes can be used to fabricate relatively high permittivity materials, basically solving the central problem limiting the use of polymers as radiating materials, i.e., their inherent low permittivity. The effective relative permittivity of the material can be designed in a broad range by carefully changing the shape and arrangement of the inclusions. Engineered non-uniform permittivities can be readily realized by non-uniform inclusions. Moreover, if the permittivity of the base material can be tuned in any way, the resulting high-permittivity material will be tunable in the same manner, since the overall meta-material effectively works as a permittivity multiplier.

Based on this approach a number of dielectric resonator antennas with a low-permittivity body embedded with metal inclusions were designed, simulated, fabricated, and tested. The results, which will be discussed in the presentation in details, are in excellent agreement, supporting the proposed method.