RF Polymer Composites for Electromagnetic Systems

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Design of polymer composites with specific engineered electromagnetic properties are of use in a variety of physical electromagnetic systems above 100 MHz. In physical electromagnetic systems such as GPS, radomes, WiFi, etc., proper choice of the material can be transformative in that it can yield considerably better performance. Of interest in this work is the possible development of low-loss magneto-dielectric composites. This project investigates various aspects of material systems, starting with possible composite designs, to design of measurement techniques, to development of finite element models for complex waveguide and conformal antenna configurations that use these materials.

RF polymeric composites offer a new design space to radio frequency (RF) engineers. Specifically, the current interest in magneto-dielectric polymer nanocomposites is due to the fact that these materials can have non-trivial permeability and permittivity. Such material properties offer designers the ability to miniaturize certain common passive RF components, such as antennas, radomes, and transmission lines. The rationale for using these materials is that at a given frequency, the wavelength in the material is smaller than that in air or in a non-magnetic material with identical permittivity.

In this work, progress has been made in understanding the design principles for magneto-dielectric composite materials. The methods investigated are suitable for layered media and for medial comprised of rods of inclusions within a polymer matrix. These methods permit the simulation of composite materials to predict viable compositions and volume fractions to achieve desired results.

Generally, it was found that layered designs resulted in a higher effective permeability relative to rods. In both cases, the material is anisotropic due to the structure of the inhomogeneity. This will impact design of RF components since such anisotropy must be considered in the design due to the fact that anisotropic materials “look” different to different orientations of the dynamic electric and magnetic fields. The finite element method is well suited for analyzing anisotropic materials; however, it is noted that the wave matrix-based simulation also accounts for anisotropy.

Secondly, measurement techniques were developed for assessment of magneto- dielectric materials. This includes noninvasive, contact measurement techniques, as well as more traditional waveguide (e.g. geometrically prescriptive) methods. These methods are important since measurement fixtures and inversion techniques are generally not well developed for magneto-dielectric materials.

Thirdly, the radiation performance of candidate magneto-dielectric materials was evaluated using full-wave, rigorous computational electromagnetics computer programs. A significant conclusion is that the enhanced bandwidth realized by the most promising of these materials is attributed to loss mechanisms rather than inherent design features. This indicates that significant work on synthesis methods is still needed.