Free Space Characterization of Frequency dependent Metamaterials with Complex Electromagnetic Properties

Vasundara V. Varadan* and Anilkumar Tellakula+
* Center for the Engineering of Electromagnetic and Acoustic Materials & Devices, The Pennsylvanaia State University, University Park, PA 16802
+HVS Technologies, Inc., 309 Science Park Road, State College, PA 16803

ABSTRACT

A free space system for the measurement of complex effective permittivity and permeability of metamaterials is described here. Electromagnetic metamaterials are structured composites formed either from periodic or random arrays of scattering elements. The interesting aspect of metamaterials is that they can exhibit a frequency region in which either the real part of permittivity is negative or the real part of permeability is negative or both. The index of refraction can be negative in these materials (V. G. Veselago, Sov. Phys. Usp. 10, 509, 1968.)

We use a free space microwave measurement system, which is suitable for electromagnetic property measurements in the frequency range of 5.8 to 40 GHz (and extendible to 110 GHz). The frequency range is covered using a single connection, single sweep vector network analyzer, along with 3 pairs of spot focused horn lens antennas. This method is based on illuminating the sample with plane waves by focusing the microwave beam to a measurement plane. Hence, a single sample can be characterized over the entire frequency range, unlike other techniques that are limited to a narrow frequency band. Characteristics of metamaterials such as negative angle of refraction can be verified using the oblique incidence measurement capability provided by this setup. The complete system is calibrated using the TRL calibration method modified for free space measurements. The reflection and transmission coefficients (S-parameters) of the metamaterial are measured and inverted using closed form expressions to determine the complex permittivity and permeability. Electromagnetic properties of several metamaterial samples, fabricated by periodic placement of metallic wires in a dielectric medium, are evaluated as a function of frequency and the results will be presented. It is seen that only the real part of permittivity is negative in the frequency range of 5.8 to about 11 GHz. The real part of permeability is approximately 1. It is also observed that the plasma frequency (when permittivity=1) is about 12 GHz.

Additional Information:

1. Commission B (Fields and Waves), B2.Novel and complex media
2. A free space system is used to characterize complex metamaterials over a wide frequency band for the first time.
3. Previous work was mainly on modeling metamaterials and computing electromagnetic properties through simulations.