Characterization of Metamaterials as General Bianisotropic Effective Media

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Left-handed metamaterials are currently realized as a succession of unit cells within which metallic inclusions are printed. Because of the small size of these unit cells compared to the operating wavelength, the characterization of left-handed metamaterials as effective media has been a major research topic for the last few years. At first, uniaxial parameters were sought [1, 2], independently of the inclusions used within the unit cell. Later, it was was shown that a uniaxial representation is not accurate for some designs of inclusions, and non-zero bianisotropic terms were identified in the constitutive relation tensors [3]. Those terms were first estimated based on equivalent capacitances and inductances generated within the unit cell, thus providing a qualitative representation of their behavior with frequency.

The purpose of this presentation is two-folded. First, we provide a rigorous mathematical scheme for the retrieval of the uniaxial and bianisotropic parameters predicted in [3]. The formulation is based on the measurements of the complex reflection and transmission coefficients of a plane wave impinging onto the metamaterial at three incidences with two polarizations each [4]. In each case, the reflection and transmission coecients are expressed analytically, upon which the index of refraction and impedance are redefined to match a unique relation. This relation is then inverted using the same method as the one used for a uniaxial only retrieval [2] and yields the unknown consitutive tensors as function of frequency.

The second purpose of this presentation is to lift all assumptions on the constitutive tensors of the metamaterial. The starting point is therefore very general, where all nine complex parameters of the four constitutive matrices are unknown. Through the multiple measurements of complex reflection and transmission coefficients and the application of optimization algorithms, we show how to retrieve 72 frequency dependent unknown consitutive parameters.

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