A Generalized Fourier Transform Applied to Propagation in Irregular Stratified Chiral Media

Paul E. Crittenden*
Department of Mathematics and Statistics
University of Nebraska-Lincoln
Ezekiel Bahar
Department of Electrical Engineering
University of Nebraska-Lincoln

Generalized Fourier transforms appropriate for the expansion of the electromagnetic fields scattered at a rough interface between two chiral materials with laterally varying electromagnetic properties are derived. The transforms are used to obtain the generalized telegraphists equations for scattering in chiral media. The telegraphists equations are a set of coupled ordinary differential equations for the forward and backward wave amplitudes of the z-component of the magnetic field and the y-component of the electric field.

Schelkunoff (S. A. Schelkunoff, *Bell Syst. Tech. J.*, **31**, 784–801, 1952) derived a similar set of equations using a rigorous method of mode matching in irregular achiral waveguides. Unlike the discrete waveguide mode spectra, the spatial wave spectra in this work are continuous and discrete. A similar set of equations for achiral media, which also included discrete and continuous wave spectra, was derived by Bahar (E. Bahar, *Canadian J. of Phys.*, **50**, 3132–3142, 1972) and has been solved numerically and iteratively. From a solution to the generalized telegraphists, the field transforms can be found and inverted to find the diffusely scattered fields. Solutions to the generalized telegraphists equations could be obtained using assumptions appropriate for particular applications. In deriving the generalized telegraphists equations, no assumptions are made about the characteristics of the surface, the frequency of the source, or the location of the source and observation point. Therefore, they provide an advantageous starting point for deriving solutions to a very broad class of problems.

Chiral media are materials with a handedness. They interact differently to left and right circularly polarized electromagnetic waves, allowing one or the other to propagate with a faster phase velocity. The root cause of chirality is believed to be imbedded helical substructures (of either macromolecules, molecules, or DNA, depending on the wavelength). Manmade chiral materials have also been fabricated by imbedding conducting helices in an achiral host. With a rigorous solution for electromagnetic wave propagation in irregularly stratified chiral materials, the discrimination between different chiral media and the optimization of the electromagnetic characteristics of artificial chiral media is possible. Possible military applications include the detection of films of biological weapons sprayed on the surface of battlefields and the optimization of manmade chiral materials for stealth technology. Space exploration applications could include detecting life on other planets and the pre-screening of interplanetary space vehicles. The eye consists of layers of chiral media, that alternate between left and right handedness. This leads to an application in biology. Pharmaceuticals, food additives, and fertilizers, made from the same ingredients, can have vastly different properties if the molecular structures are left or right handed. In electrical engineering, waveguides with organic chiral cores are investigated for use in integrated optical devices, including polarization transformers, modulators and directional couplers (W. N. Herman, *J. of the Opt. Soc. of Am. A*, **18**, 2806–2818, 2001). In all of these settings, small variations in the cross sections could significantly affect electromagnetic wave propagation.