Reflection, Transmission and Excitation of a Slab of Arbitrary Permittivity and Permeability

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We have examined reflection and transmission at the vacuum interface of a slab of material or metamaterial with arbitrary permittivity ε and permeability μ. Our objective is to understand the range of properties that could be provided by such materials. The material is assumed uniform and isotropic. Excitation sources include plane waves and the radiation from an idealized line source. Since the p-polarization and s-polarization cases can be treated as equivalent by interchanging permittivity and permeability (with allowance for a change in sign of reflection coefficient), we concentrate on the p-polarization case. For a line source, this is an idealized line of magnetic current. Then, we have categorized the small loss cases by studying reflection properties in the 2-dimensional plane of Real(ε) versus Real(μ).

We present a systematic characterization of the poles, zeros, and branch points involved in the reflection coefficient from a semi-infinite half space of metamaterial. We divide the Real(ε) — Real(μ) plane into a sequence of regions based on the magnitude of S^2 and the index of refraction. The complex quantity S is defined following Wait as k_x/k_o at the pole of the reflection coefficient, where k_x is the transverse propagation constant along the slab surface. S may also be regarded as a generalized sine of the angle of incidence. In each different region we find the asymptotic behavior from the poles and branch cuts. We classify these various contributions in the classical forms of primary wave, reflected wave, surface wave, Zenneck wave, and lateral wave. We have found unusual combinations such as a region with forward surface wave and backward lateral wave or with backward surface wave and backward lateral wave. We discuss the range of the parameters ε and μ to give the conditions for the existence of forward or backward surface waves, forward or backward lateral waves, Zenneck waves, relations to Brewster's angle and the locations of the poles in the proper and improper Riemann surfaces.