Properties of the Complex Surface Modes of the Grounded Dielectric Slab with Double Negative Metamaterials

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Double negative metamaterials have attracted intensive interest in recent years for their exotic natures, among which super-resolution is of particular interest. A good approach to study this property is Sommerfeld integrals which represents the Green function in the spectrum domain. The asymptotic methods are widely used in calculation of the Sommerfeld integral and the integral path is deformed. The poles included in the path deformation thus play an important role. For conventional double positive material, the finite number of poles represent the discrete surface modes and they never lie on the first and third quadrants (with $e^{j\omega t}$ time dependence) of the complex k_ρ plane.

With double negative metamaterials, it is found that in addition to finite number of real surface modes, the grounded dielectric slab has infinite number of complex surface modes (P. Baccarelli, *et al.*, IEEE Trans. MTT, vol. 53, pp. 32-44, 2005). These modes appear in Sommerfeld integral as complex poles on the top Riemann sheet of the k_ρ plane and they are symmetrically distributed on all four quadrants. They do not directly contribute to the Sommerfeld integral when one performs it along the real axis. However, when a different path is used, most likely the deformed path will include some complex poles or in a worse case, encounter poles in the integral path. Thus a previous knowledge of the location of the complex poles as well as their residues is deemed valuable.

Our work focuses on the location of the complex poles and their residues. We will present the contributions of the complex surface modes on the near fields and the far fields due to the electric and magnetic sources, which can help us gain further insight into the patch antennas and microstrip lines with double negative metamaterials.