Rapid and Robust Numerical Plane-Wave Expansion of Distributed Source Fields in Planar-Stratified Media with Arbitrary Anisotropic and Lossy Layers

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We propose robust, rapid numerical plane wave expansion-based techniques to calculate the scattered, time-harmonic electromagnetic (EM) field emitted by distributed radiators embedded within planar-stratified environments containing arbitrary anisotropic and lossy media.

The scattered EM field explicitly contains information about the inhomogeneity structure of the environment surrounding the radiator, and hence is typically the signal of interest in (for example) remote sensing applications and forward modeling studies to optimize planar antenna placement near metallic platforms. Historically, myriad approaches attempted such calculations: for example, *a posteriori* subtraction of the analytically-computed "direct" (i.e., homogeneous medium) field from the numerically-calculated total field. However, as discussed in (K. Sainath and F.L. Teixeira, *Phys. Rev. E*, Vol. 90-6, 2014), these techniques are not robust for a wide range of source-observation point separations and medium types. As a result, what is needed is an *in-situ* scattered field extraction technique that, in the Fourier (i.e. wave number) domain, uses the direct fields to excite the scattered fields but then robustly extracts out the direct fields when computing the scattered field. In contrast to previous scattered-field extraction methods, our method applies readily for sources (either Hertzian *or* distributed) radiating in generally anisotropic and lossy media, for any range of source and observer separation (even co-located source and receiver points), and for time-harmonic fields.

Furthermore, many applications (e.g., aperture synthesis-based antenna design optimization, forward modeling of more complex, distributed radiators used for remote sensing instruments) can greatly benefit from the calculation, within the Fourier domain itself, of the time-harmonic EM fields emitted by *distributed* (rather than Hertzian) radiators embedded within environments containing generally anisotropic and lossy media. This is in contrast to a brute force spatial discretization of the radiator, such as approximating it via a Hertzian dipole ("pulse") basis. However, while the scattered field, distributed radiator calculation problem is in fact well-posed, the distributed radiator introduces exponentially rising terms that, if not properly recognized and mitigated during the computation process, can lead to inaccurate results or even numerical overflow. We discuss our proposed methodology to mitigate these drawbacks in the spectral domain calculation. We also explain two reasons why one can obtain a one order of magnitude reduction in calculation time (versus spatially discretizing the radiators) for one-dimensional (e.g., wire antennas) radiators, or alternatively two orders of magnitude reduction in calculation time for two-dimensional radiators (i.e., aperture antennas).

To validate the method, we exhibit and validate numerical results concerning wire and aperture antennas radiating both in free space and over ground planes coated by isoimpedance metamaterial substrates. We also apply the scattered field extraction and distributed radiator computation algorithms to model geophysical prospection of suboceanic hydrocarbon reserves using controlled-source electromagnetic techniques (CSEM) employing wire antenna transmitters.