Limitations and Alternatives Concerning Convex PML Absorbers

Kamalesh K. Sainath*[(1)], Fernando L. Teixeira[(1)]
(1) ElectroScience Laboratory, The Ohio State University, Columbus, OH 43212 USA

Using the "complex-space" formalism, we analytically demonstrate the existence of material blueprints corresponding to primitively causal and passive electromagnetic (EM) absorbers ("Perfectly Matched Layer" [PML] media) that geometrically conform to convex cylindrical surfaces. Second, we discuss fundamental practical limitations of such "absorbers"; indeed, we show that the admissible solutions *necessarily* (i.e., to satisfy energy conservation) completely isolate the absorptive region from the externally-incident radiation by means of a non-absorptive and dispersionless EM "cloak." Third, through a modification of the material blueprint design method used to design said cloaked absorber, we derive and numerically validate the performance of two types of *pseudo* PML (PPML) media.

Planar and *concave* curvilinear PML absorbers have successfully been widely used to truncate *external* domain boundaries of computational problems. A natural question arises as to whether one could possibly design *convex* PML media to truncate *internal* sub-regions of a computational domain. Such internal truncation mechanisms could, in some modeling applications, save computing resources via obviating the meshing of sub-regions that are not of interest. One example is truncating the (typically uninteresting) volume surrounded by a ring resonator structure. Past investigations have indicated that, due to primitive causality and passivity considerations, such absorbers could not be established via conventional means.

Here, we choose an unconventional route for PML design through stipulating a PML comprising an absorptive core surrounded by a non-absorptive shell. We show that under normal circumstances, based on the unconventional way in which the absorptive core's material parameters are defined, the absorptive core would induce reflections if it bordered most media (including vacuum). By embedding it within a specially-designed outer dispersionless, non-absorptive shell, however, one can eliminate these reflections and make the overall device perfectly reflectionless. The price to pay, however, is that the outer shell must *necessarily* (to satisfy energy conservation) act as a perfect EM cloak and preclude interaction between the absorptive core and externally incident waves. Since realizing this ideal "absorber" has no practical utility, we next (in essence) simply design the absorptive core's material parameters (i.e., analogously to the cloaked PML case) but let it border vacuum (i.e., "strip off" the outer shell), rendering it a *reflective* PPML. We present FEM and FDTD numerical simulation results which show such PPML media too can act as highly effective absorbers of externally incident EM waves, inducing very little backscattered fields.