Scan Angle Stability of a Second-Order Plasma-Switched Frequency Selective Surface

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Abstract

Large-area, lightweight electromagnetic protection (EP) structures are needed to protect sensitive microwave sensors and communications systems from high-power microwave (HPM) and electromagnetic pulse (EMP) threats [1-2]. Plasma-based active structures can provide significant shielding in harsh environments [3-4]. This paper investigates the use of COMSOL Multiphysics® for electromagnetic simulation of a second-order frequency selective surface (FSS) structure [5] shown in Figure 1 containing encapsulated plasma elements. FSS performance in terms of center frequency and bandwidth must be stable across different scan (incidence) angles in order to be useful in microwave systems. In the on state, negative permittivity plasma within the structure must produce high attenuation without compromising performance. The periodic structure was modeled as one unit cell using Floquet periodic boundary conditions to simulate the frequency response of an infinite array. Gas plasma was modeled as a homogenous lossy dielectric slab using complex dielectric coefficients [6]. A meshing study will be performed, and then simulation time will be evaluated versus number of cores for a 16-core Xeon server. The preliminary model and mesh are shown in Figure 2. Broadband performance of the evaluated structure will be presented across multiple scan angles and polarizations. Preliminary model results are shown in Figure 3 for off and on states at normal incidence. Fields will be visualized to provide physical insight into the structure in off and on states. Electric fields in the preliminary model in Figure 3 show strong gradients at the center of the FSS elements and total reflection of incident energy in the on state. Simulations will show excellent overall performance and scan angle stability in the off and on states. Future work will involve coupled multiphysics modeling of other domains relevant to this device: steady-state and transient plasma modeling within the plasma-shell, thermal modeling of high-power events, and structural strength modeling. This approach enables a complete simulation-based design approach for the development of a practical plasma-based electromagnetic structure for shielding applications.

Reference

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Figures used in the abstract

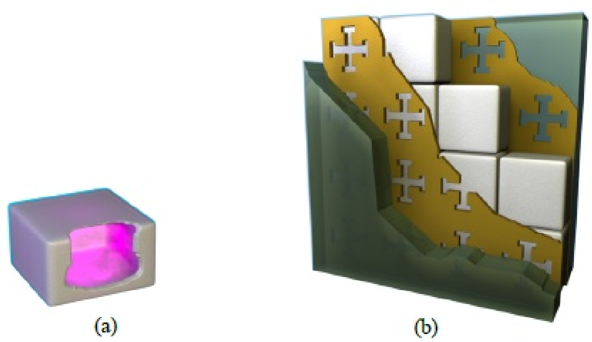

Figure 1: Figure 1: Proposed electromagnetic shielding device, consisting of: (a) hollow gas-filled plasma-shells that can be ionized and filled with internal plasma. The complete structure (b) encloses shells between two conductive patterned layers that are transparent in the off state and completely block RF energy in the on state.

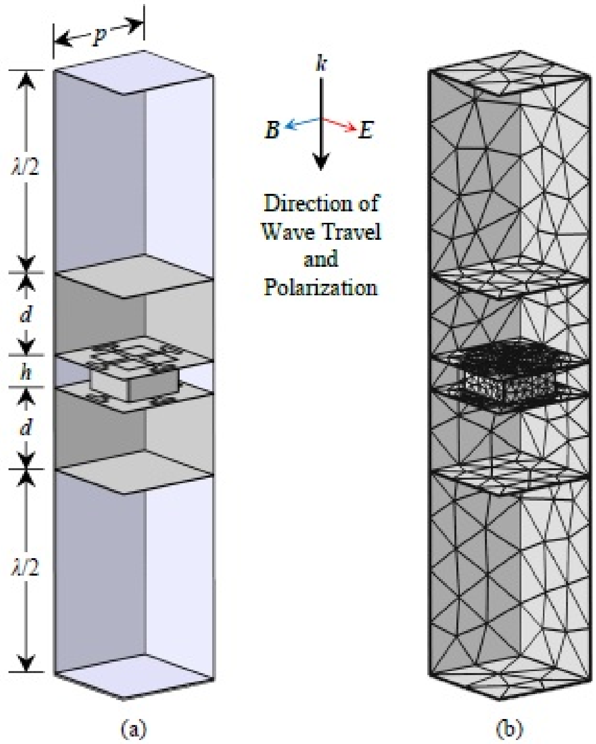

Figure 2: Figure 2: Parameterized Floquet port (a) geometric model, and (b) meshed model for second-order structure.

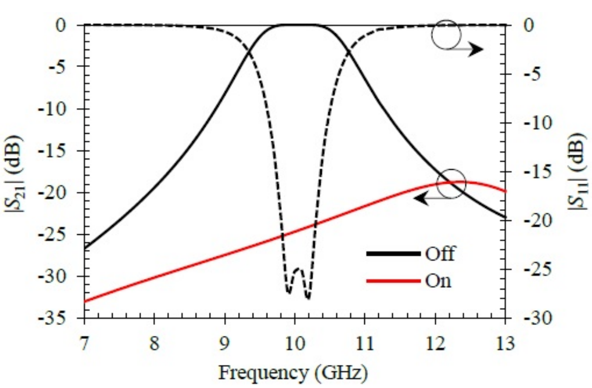

Figure 3: Figure 3: Preliminary results for a structure with 10 GHz center frequency at normal incidence. Average switchable attenuation is 24.5 dB.

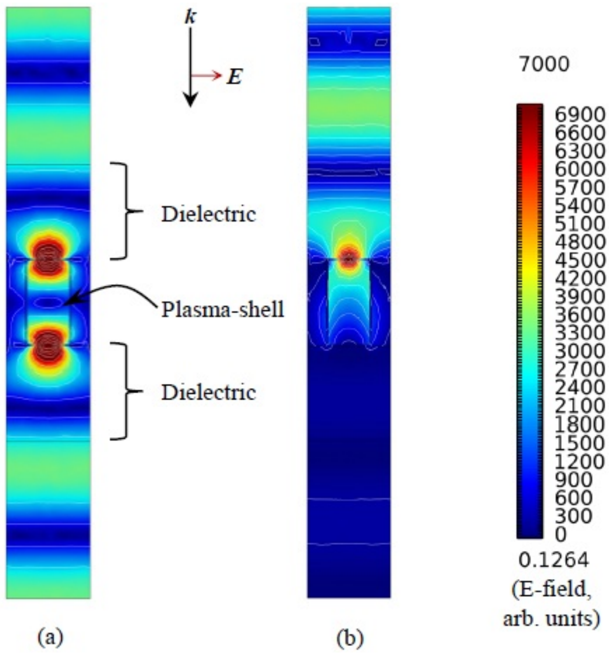

Figure 4: Figure 4: E-field distribution within the structure at 10 GHz, in (a) off state where energy passes through the structure, and (b) on state where plasma completely reflects incident energy. Fringing electric field lines are highlighted in white.