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

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Introduction: This work presents the use of COMSOL Multiphysics for electromagnetic simulation of a plasma-based frequency selective surface (FSS) structure that can provide significant shielding in harsh environments. A second-order structure containing encapsulated plasma elements is introduced, with plasma modeled as homogeneous negative permittivity dielectric material. The structure is transparent at X-band in the off state and blocks energy in the on state. Performance of an infinite array was simulated using Floquet boundary conditions. Off state performance is stable in terms of frequency and bandwidth across wide incidence (scan) angles, and significant switchable attenuation is predicted in the on state.

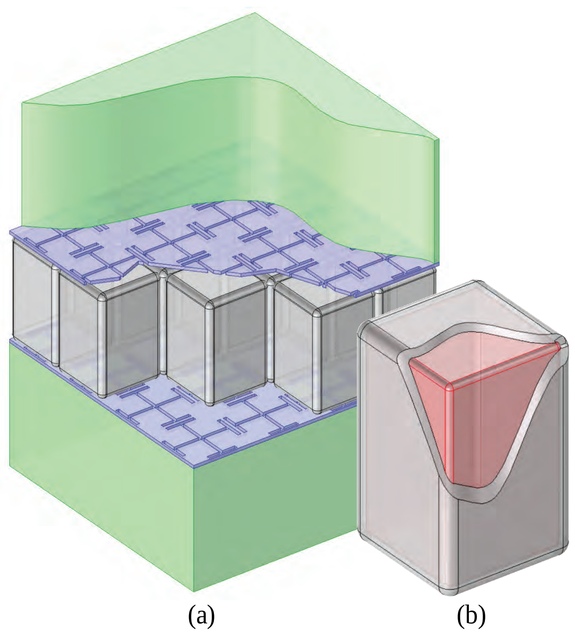

Figure 1. (a) Successive layers of the proposed structure composed of outer dielectric layers (green) encasing two FSS layers (blue) and a plasma-shell array (gray). (b) A sectioned plasma-shell shows internal plasma (red).

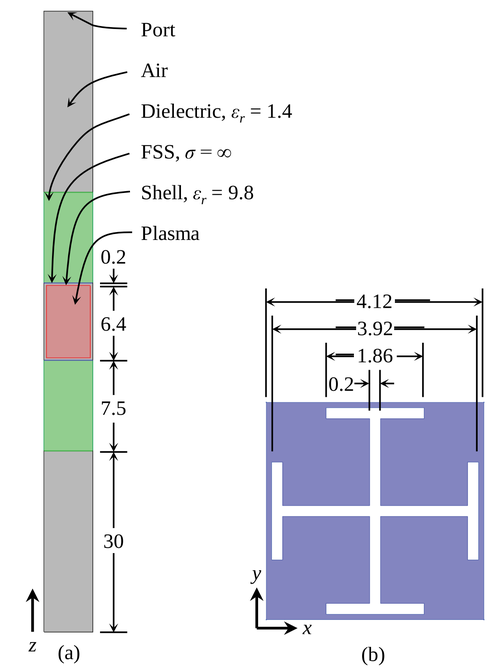

Figure 2. Dimensioned geometry of: (a) structure profile showing air box, dielectric (green), shell, and plasma (red); and (b) FSS Jerusalem cross with 0.2 mm slot (all units mm).

COMSOL Model: COMSOL Multiphysics 4.3b and RF Module were used to simulate the EM structure.

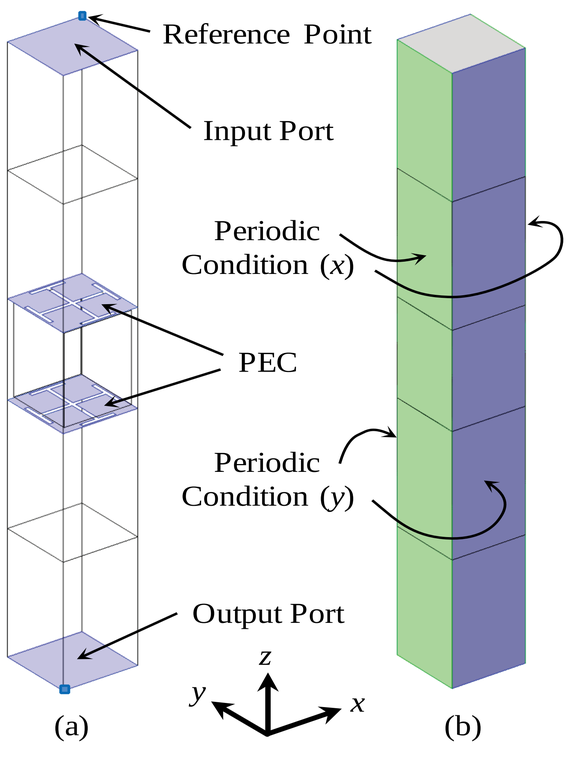

Figure 3. Model boundary conditions for (a) periodic ports and conductive FSS layers; and (b) periodic boundary conditions for Floquet port simulation.

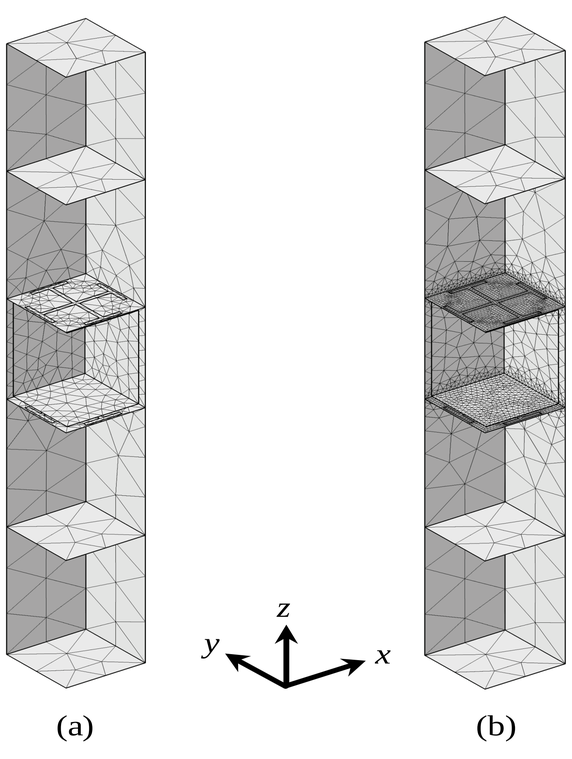

Figure 4. (a) Initial mesh settings were refined at the FSS surfaces to create an accurate (b) final mesh.

Results: Simulation time versus number of CPU cores was investigated using a computer running Windows 7 Pro with two 8-core Intel Xeon E5-2687W processors, 64 GB DDR3-1600 memory, and a solid state hard drive. Simulation time is shown in Fig. 5 and no further speedup is evident using more than eight cores. The simulated results of the proposed FSS structure demonstrate excellent electrical performance (i.e., S_{21}) and scan stability up to 70º for both vertical and parallel wave polarizations.

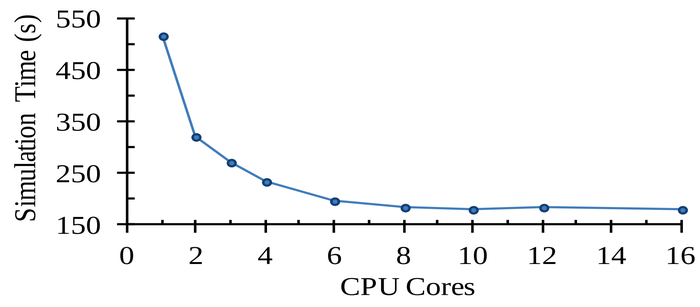

Figure 5. Simulation time is minimized using 8 cores.

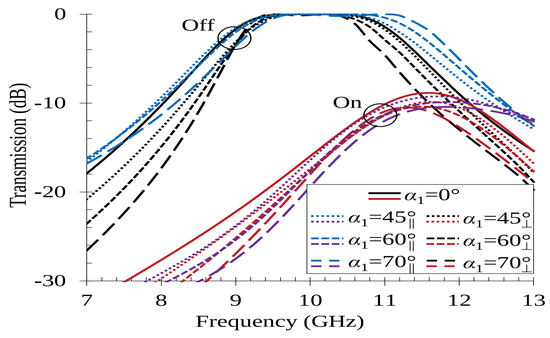

Figure 6. Transmission performance of the structure shows scan stability up to 70°for all polarizations and 3 dB bandwidth of 1.73 GHz at 9.93 GHz. Average on state attenuation is 18.4 dB.

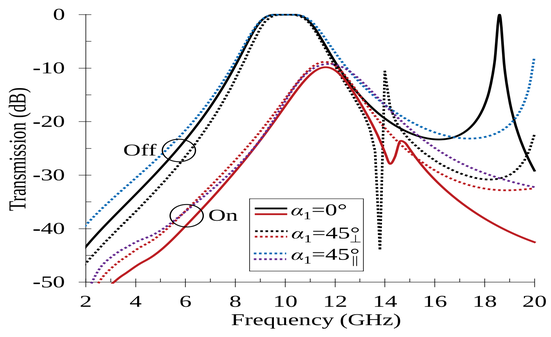

Figure 7. The wideband frequency response shows a null outside the passband at 14 GHz and first spurious response at 18.5 GHz.

Conclusions: Plasma-shells are an engineered material capable of direct integration into existing structures to allow implementation of low-loss HPM/EMP protection. IST has used plasma-shell RF properties in previous research to implement planar microwave filter-limiters, large-area plasma apertures, and FSS limiters.

Future Work: Possible future applications of plasma-shells in RF structures include plasma-based metamaterials, reflectarrays with integral HPM/EMP protection, waveguide filter-limiters, and other plasma-tunable devices.

References:

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