RESONANT PROPERTIES OF CONDUCTING POLYHEDRAL SPHERES WITH POLYGON MESH SURFACES

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Abstract A spherical polyhedron constructed from open surface polygons is an electromagnetic wave resonator that can be excited by an external plane wave. After an initial transient, a plane wave pulse achieves a balance of EM wave energy entering the sphere though the surface polygons and the internal EM wave leaking out of the sphere through the same polygons. The resonant frequencies of the porous sphere are primarily determined by the radius of the sphere and, to a lesser degree, by the size of the openings in the surface of the sphere. The strength of the internal electric fields is influenced by the width of the conducting edges that comprise the polyhedron frame. With thin edges, the internal resonance is too weak to produce large electric fields. With thick edges that nearly close the openings in the sphere, not much of the external electric field is available to excite the internal fields and again they are weak. The optimum edge width is found where the external EM wave field excites the strongest internal field amplitudes. The WIPL-D EM simulation model is used to determine the optimum porous resonator for a polyhedron with 180 vertices, 92 open polygon faces, and 270 conducting edges [1]. With a sphere radius of 5 meters, the resonance for the TM_{101} like mode occurs at a frequency of 25.228 MHz with edges having a radius of 225 mm. Excited with a right-hand-circular EM wave at 1 V/m, the internal resonant electric field is calculated to be 91.5 V/m. The Q of this resonator is 885 assuming infinitely conducting edges. With this high Q, an EM pulse takes about 100 micro seconds to build up a large electric field inside the sphere. Other spherical cavity modes were simulated to provide different distributions of electric fields on the interior of the porous spherical cavity resonator (PSCR). The PSCR may be used to greatly increase the electric fields in a high power radio beam for the purpose of plasma generation. For certain wavelengths, the porous sphere becomes a resonator with large internal electric fields. At resonance, the radar cross section increases by over 40 dB. The radar wavelength is small relative to the size of the surface holes. The resonator theory is being tested at 2.45 GHz using an open-face, sphere with 960 vertices and tuned conducting edges. The large variations in RCS with frequency are studied with inside a compact range, anechoic chamber at the Naval Research Laboratory.

To compute the fields inside the spherical polyhedron mesh, the method-of-moments solution of the electric field integral equations is solved for a conducting structure. The polyhedron sphere is designed in Mathematica V7.0 using the geometric algorithm described by Bernhardt et al. [2]. The nodes and wire map is imported into WIPL-D [5] as a three dimensional object with constant radius, conducting edges. At each frequency of a range of frequencies, the electric and magnetic fields are computed in a plane containing the electromagnetic wave normal and one orthogonal dimension. The numerical computations are sorted by the largest electric field amplitudes. With a fixed edge radius, the peak electric field amplitudes are found at discrete frequencies.

The numerical computations are sorted by the largest electric field amplitudes. With a fixed edge radius, the peak electric field amplitudes are found at discrete frequencies. Using a 960 vertex sphere in Fig. 1 with 10 mm radius edges and 5 m internal radius, the largest internal electric fields are obtained at frequencies just below the spherical cavity resonant frequencies for the TM_{101}, TM_{102}, and TE_{101} modes.

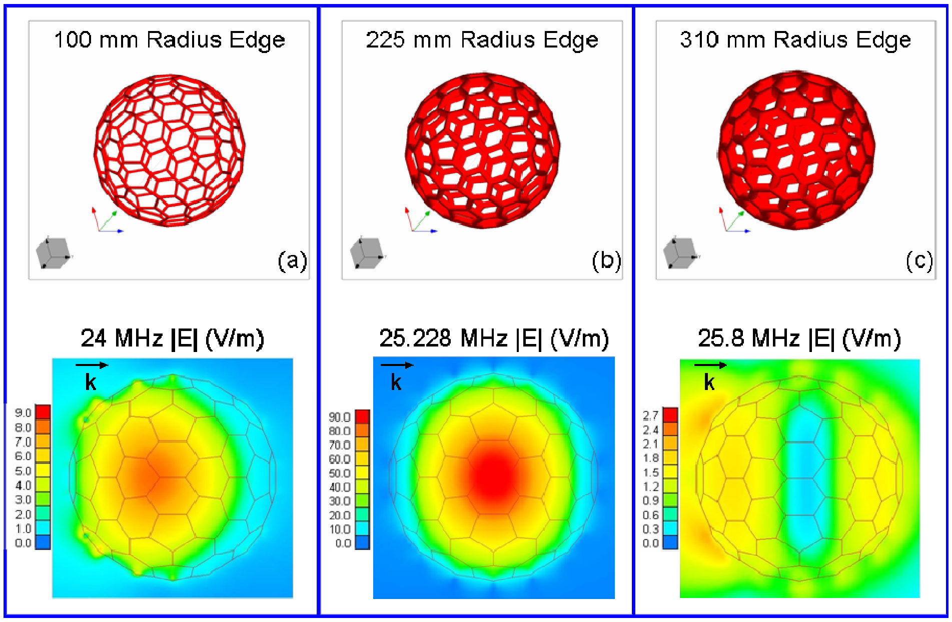

Fig. 1. V180 polyhedron sphere used as a porous cavity resonator with an external plane wave with right-hand-circular polarization and wave amplitude of 1 V/m. The mechanical diagram shows the edge radius affects the internal electric fields and resonance frequency.

Adjusting both the radii of the edges and the transmitted frequency provides an optimization of the cavity resonance. Figure 1 illustrates the effects of increasing the edge radius and reducing the size of the openings into the sphere. Both the internal electric field amplitude and the resonant frequency for maximum fields vary with this procedure. The excitation of the porous cavity resonator with an external plane wave involves leakage of the external field into the interior and leakage of the internally excited field to the exterior. If the edge radius is too small (Figure 1a), the spherical resonator is not able to prevent the internal fields from passing through the mesh and the internal electric fields are small. If the edge radius is too large as in Figure 1c, the incident plane wave cannot efficiently couple through the surface mesh to excite the interior.

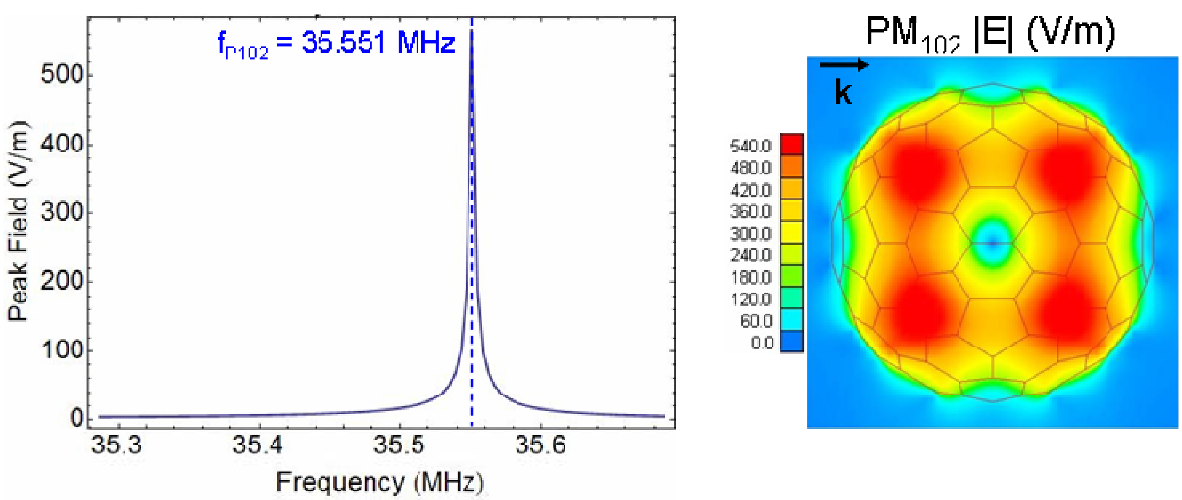

Figure 2. High-Q resonance for the PM102 mode of the porous spherical cavity resonator. The internal electric fields are produced in two rings aligned along an axis parallel to the incident plane wave.

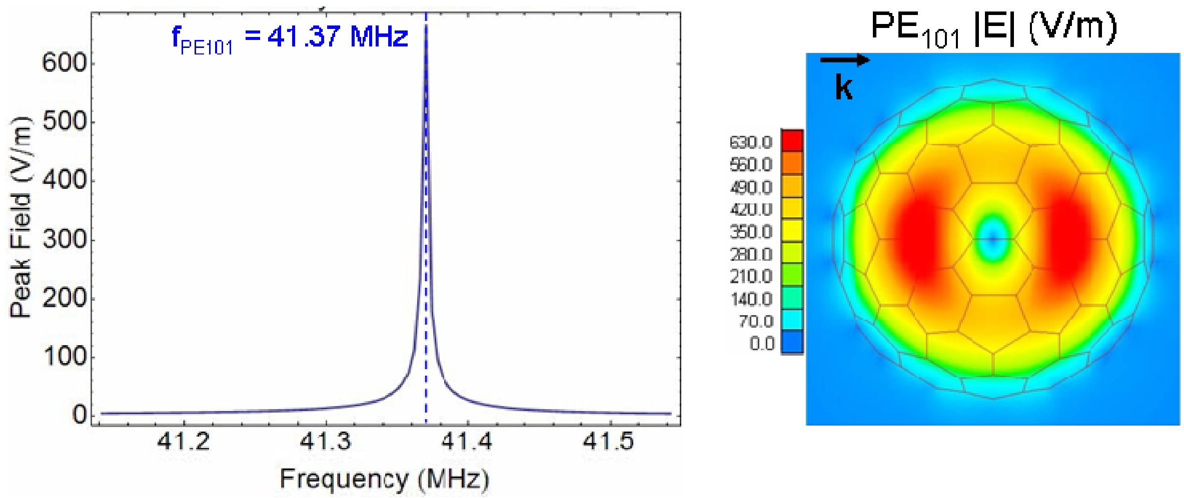

Figure 3. High-Q resonance for the PE101 mode inside the polyhedron wire mesh. The internal electric fields resemble the TE_{101} fields shown in Figure 1c.

Other modes of porous conducting spherical resonator (PCSR) were investigated with a combination of Mathematic V7.0 and WIPL-D to find optimum designs and maximum internal electric fields. In each case, the resonant frequency for the PSCR was slightly less than for the spherical cavity resonator. The electric field patterns were similar for both spherical cavities, but the PSCR had spatial modes that extended outside the surface of the sphere. This increase in mode size or wave-length is responsible for the decrease in the corresponding resonant mode frequency. The cavity resonance and internal electric field patterns for the PM102 and PE101 modes are shown in Figure 2 and 3, respectively.

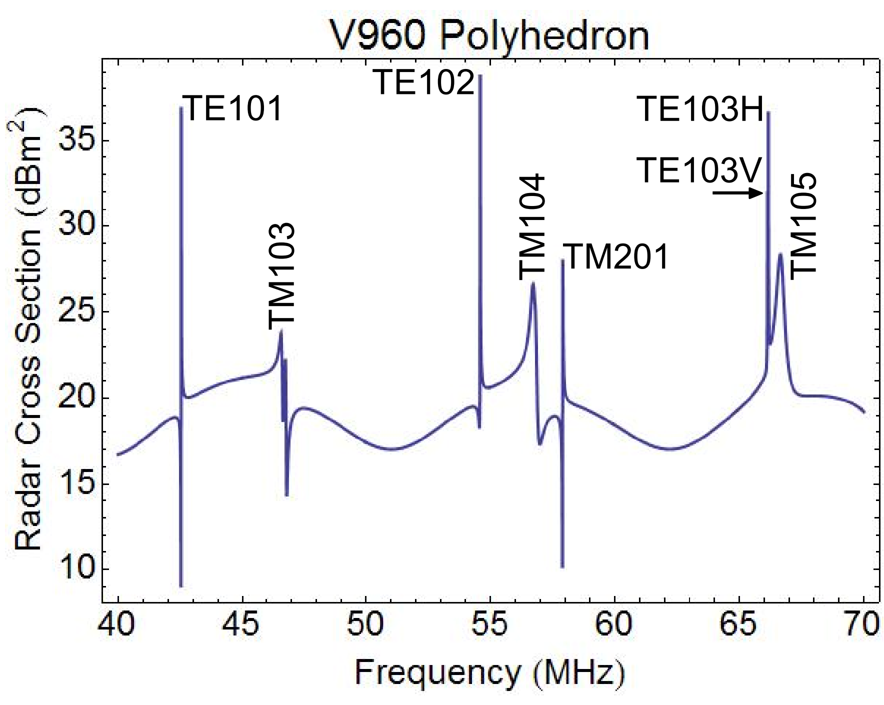

Figure 4. Backscatter radar cross section for a monochromatic electromagnetic wave scattered from the 5-m radius sphere with 89 mm radius edges. The radar cross section is enhanced by 10 to 17 dB for the TE10n spherical cavity modes.

Finally, the resonant sphere has been shown to have greatly enhanced radar cross section at the resonant frequency. As the tuned resonator is scanned frequency, resonant modes are picked up where, in steady state, the sphere re-radiates an enhanced amplitude (Figure 4).

Conclusions

Iterative use of Mathematica V7.0 for mechanical structure and WILD-D for electromagnetic fields provides a powerful tool to study the excitation of the spherical polyhedron mesh for production of large amplitude electric fields inside a porous cavity resonator. Tests of this resonator are planned at NRL Plasma Physics Division to determine if internal breakdown of the neutral atmosphere can be produced by external excitation with high power microwave frequencies. Radar backscatter in a compact-range will also be conducted on resonant sphere mode. The PSCR for this test will have a radius of about 4.5 cm for operations near 2.45 GHz.

Acknowledgement

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