# Resonance Simulation of a PEC cylindrical cavity

## 1. Description

Resonance is a common phenomenon which runs through almost every branch of physics. Without resonance we wouldn't have radio, television, music, or swings on playgrounds. Of course, resonance also has its dark side. It occasionally causes a bridge to collapse, a helicopter to fly apart, or other inconveniences. The major resonance form that is relevant to HFWorks studies is the electromagnetic resonance.

HFWorks generates an EM matrix for the structure contatining information on its natural modes of vibration. These modes can then be found mathematically. That is what the Eigenmode solver does. It checks out at what frequency a structure can resonate. If losses are included (finite conductivity, dielectric loss, etc.) then the resonance is weakened and a quality factor can be found by relating the stored energy to the dissipated energy per cycle [1].

Figure 1: Cylindrical cavity

## 2. Simulation

As mentioned earlier, we are doing a Resonance study. The user may choose the number of modes. The number of modes defines the number of the resonance frequencies. Checking the "lowest frequency guess" check-box will only include low user-assigned frequency range, because normally the number of modes is infinite.

Most applications where resonance analysis is required aim at computing the resonant frequencies, Q-factors, and electric field distribution. These applications include: Design of filters, Oscillators, Tuning elements...etc. This type of simulation is mostly used for the modal solutions of the electric field and their distributions for each resonant frequency.

## 3. Solids and Materials Load/ Restraint

In this example, we deal with a cylindrical cavity. The boundaries are assigned a PEC boundary condition. An IEC (Imperfect Electric Conductor) boundary could be assigned along with dielectric losses instead: this case would be more realistic and computing the Q factors would be possible. The interior part of the cylinder is filled with air. The solver will determine the frequencies at which the structure resonates.

| Nbr. | Part Name | Material Name | Permittivity Type | Permeability Type | Conductivity Type |
|---|---|---|---|---|---|
| 1 | Cylinder-1-Body 1 (Imported1) | Air | Lossy Isotropic | Lossy Isotropic | Isotropic |

## 4. Meshing

Meshing is performed on the three faces of the cylinder, and should be accurate enough so that the solver takes into account the cylindrical form of the object. The user can play around with the global mesh size in order to find a compromise between the results accuracy and the simulation time..

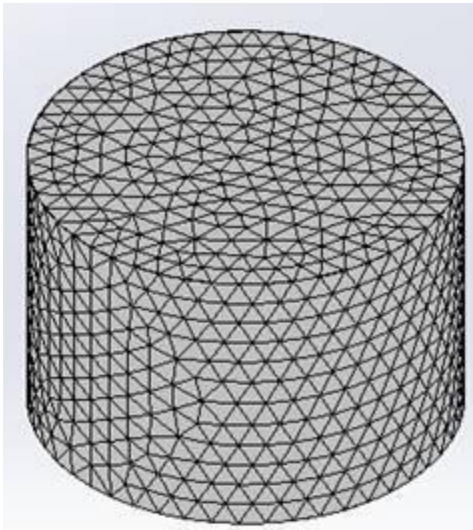

Figure 2: Mesh of the cavity cylinder

## 5. Results

The output results concern the electric field distribution, (magnitude, orientation, fringe-like surfaces) and can be visualized within HFWorks. These plots can be then automatically illustrated within a report generated by HFWorks in an HTML or a Word Document.

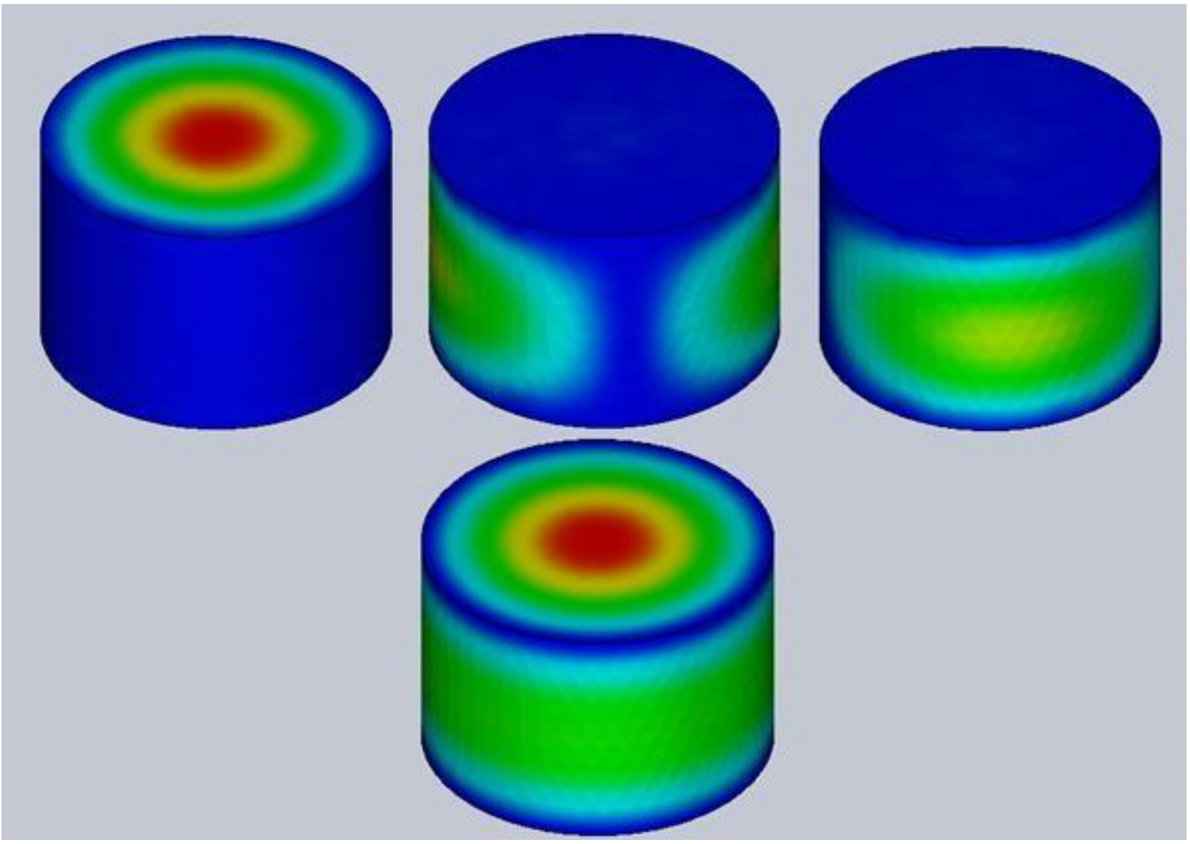

Figure 3: Electric field's fringes for the different modes (from 1 to 4)

HFWorks allows the user to plot the electric and magnetic field for each mode inside the structure by using the section clipping feature.

The previous example represents an ideal case where we have no dielectric or metal losses. In order to model a more realistic example, we can replace the PEC boundary condition by a IEC (Imperfect Electric Conductor: conductivity and roughness values can be set) and a dielectric loss can be added.

Moreover, we can select a particular segment between two predefined points in SolidWorks and plot the electric field between them. The distance will be displayed in the default unit. Here is an example:

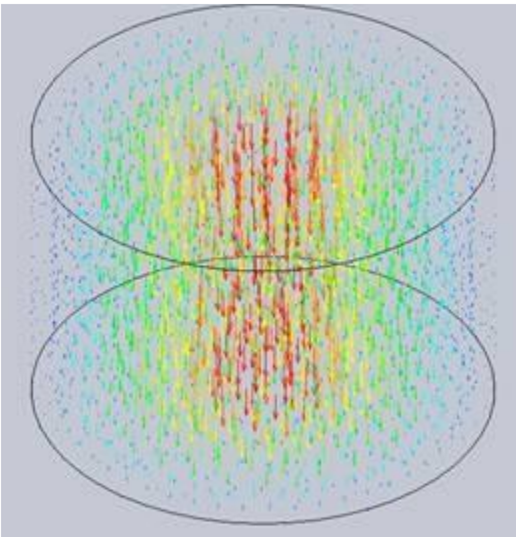

Figure 4: Electric field distribution for the dominant mode

Concerning the Q factor, its physical significance is reflected in this formula:

$$Q = 2\pi \cdot \frac{Energy\ Stored}{Energy\ dissipated\ per\ cycle} = 2\pi f_r \cdot \frac{Energy\ Stored}{Power\ Loss}$$

For each mode, HFWorks calculates the quality factor to have an idea about the system's energetic performance: The figure below shows the convenient parameters for each mode:

Exporting tables to files of different formats is possible as well. Thus, the output data files can be used for other simulations within other programs. A set of file extensions is available: Text, Touchstone, Excel Sheets, Circuit Simulator File and Super Compact Data.

Resonance Results

| | Frequency (Mhz) | Q-Dielectric | Q-Conductor | Q-Effective | Stored Energy |
|---|---|---|---|---|---|
| Mode 1 | 3.050074e+003 | 0.000000e+000 | 2.539261e+003 | 2.539261e+003 | 8.627909e-015 |
| Mode 2 | 3.793707e+003 | 0.000000e+000 | 2.939197e+003 | 2.939197e+003 | 9.162588e-015 |
| Mode 3 | 3.793992e+003 | 0.000000e+000 | 2.926548e+003 | 2.926548e+003 | 9.131514e-015 |
| Mode 4 | 4.268292e+003 | 0.000000e+000 | 2.127818e+003 | 2.127818e+003 | 8.501758e-015 |

## 6. References


[1 ] "Coupled Resonator Filter Realization by 3D-EM Analysis and Space Mapping", IEEE MTT IMS-2002, Seattle USA, WMB Workshop

[2 ] Volume Mesh Generation and Finite Element Analysis of Trabecular Bone Magnetic Resonance images 2007 Ángel Alberich-Bayarri, David Moratal, Luis Martí-Bonmatí, Manuel Salmerón-Sánchez, Ana Vallés-Lluch, Laura Nieto-Charques, José J. Rieta, Member, IEEE

[3 ] Eigenmode Analysis of Boundary Conditions for the One-Dimensional Preconditioned Euler Equations David L. Darmofal, Pierre Moinier, Michael B. Giles§