How to Calculate the Relative Permittivity, Bulk Conductivity, and Loss Tangent from ε_r' and ε_r"

Problem/Description:

What are the equations needed to convert from a complex dielectric constant (ε_r' -j ε_r") to bulk conductivity (σ), relative permittivity, and loss tangent ($tan\delta$) values?

Solution:

In HFSS, in order for the user to create a new material in the library, the user needs two of the three available electrical properties. Specifically, the user would need the relative permittivity and bulk conductivity or the relative permittivity and loss tangent. However, these properties may not be available to the user. It is common for the user to have ε_r' and ε_r" instead. This document shows the equations needed to convert from ε_r' and ε_r" to bulk conductivity (σ), relative permittivity, and loss tangent ($tan\delta$) values.

From electromagnetic theory we know a material's permittivity can be defined as follows.

$$\varepsilon = \varepsilon' - j\varepsilon'' = \varepsilon_0\varepsilon_r = \varepsilon_0(\varepsilon_r' - j\varepsilon_r'') = \varepsilon_0\left(\varepsilon_r' + \frac{\sigma}{j\omega\varepsilon_0}\right) = \varepsilon_0\varepsilon_r'\,(1 - j\,tan\delta)$$

Using these equations, we can define the dielectric loss tangent in terms of the real and imaginary permittivity.

$$tan\delta = \frac{\varepsilon''}{\varepsilon'} = \frac{\varepsilon_r''}{\varepsilon_r'}$$

Likewise, we can define the conductivity in term of the imaginary permittivity.

$$\sigma = \omega\varepsilon_0\varepsilon_r'' = \omega\varepsilon''$$

In the above equations,

$$relative\ permittivity = \varepsilon_r' = \frac{\varepsilon'}{\varepsilon_0}$$

As mentioned before, the user should only define two properties and leave the third one set to zero. Specifically, the user should either:

1. Set relative permittivity (ε_r) and conductivity (σ) while the loss tangent ($tan\delta$) is zero.

Or

2. Set relative permittivity (ε_r) and loss tangent ($tan\delta$) while the conductivity (σ) is zero.

Once the electrical properties are calculated, the user should create the material as shown below

1. In the Project Manager window > Expand “Definitions”

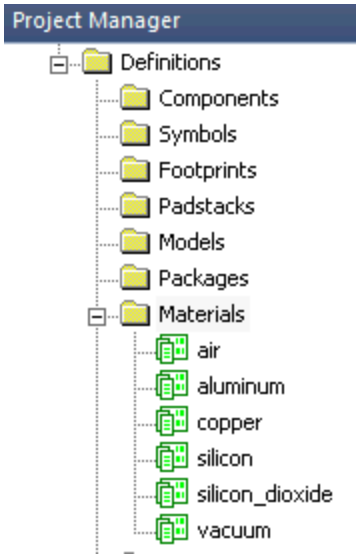

Figure 1: Definitions in the Project Manager window.

2. Right click on “Materials” > Select “Add Definition…”
3. Insert the values of the electrical properties that were calculated in the prior section.

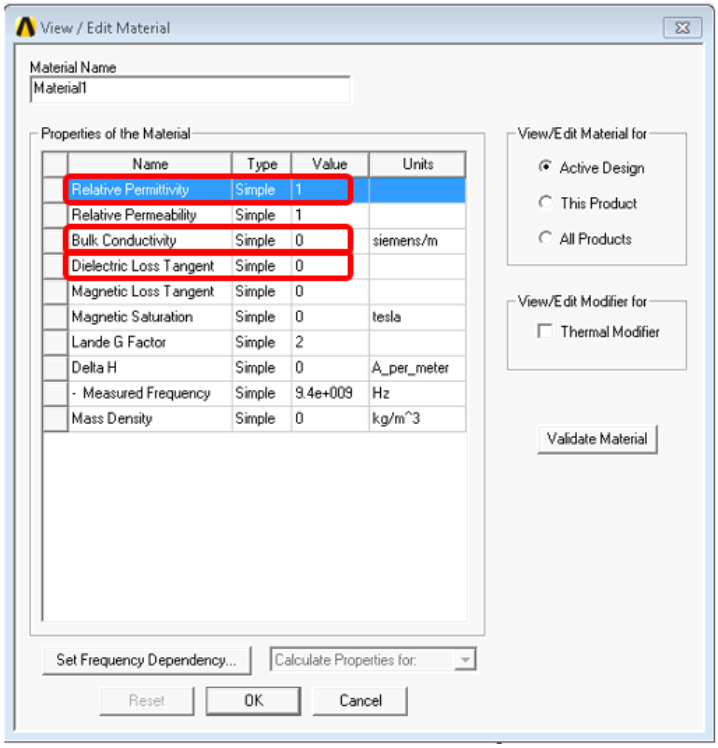

Figure 2: Snapshot of the new material window.

4. Once the user clicks the OK button, the material will be added to the Project Library and ready for use in the project.