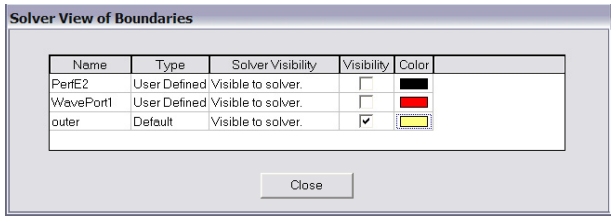
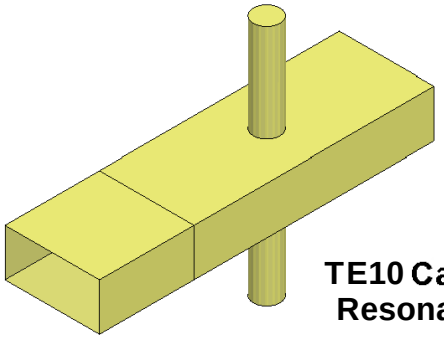
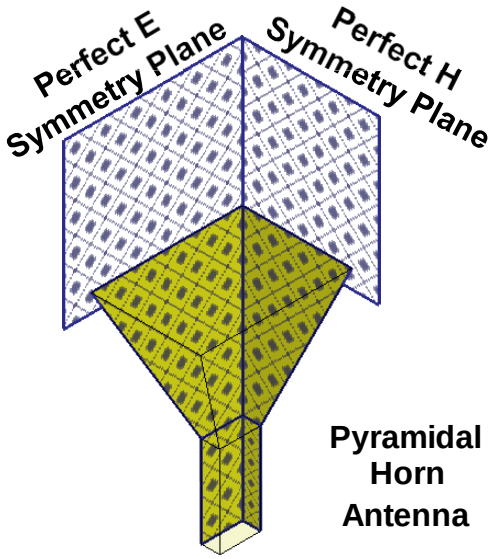
Excitations and Boundary Conditions

- **Excitations and Boundary Conditions**
  - Majority of HFSS errors are related to improper usage of excitations and boundary conditions
  - Boundary conditions are important because they significantly impact electromagnetic solution
    - They determine model scope
      - To truncate infinite space to finite volume, HFSS applies PEC boundary to surface surrounding geometric model
    - They can reduce model complexity
      - Boundary conditions can be used to reduce solution time and computing resource demands





TE10 Cavity Resonator



Pyramidal Horn Antenna

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User-Defined Boundary Conditions

- **Surface approximations**
  - Perfect E surface
  - Perfect H surface
  - Finite conductivity surface
  - Impedance surface
  - Layered impedance
  - Lumped RLC boundary
  - Symmetry planes
  - Radiation (absorbing) boundary surface
  - Perfectly matched layer (PML)
    - Strictly not boundary condition, but effectively behaves like one
  - Master/slave (linked or periodic) boundaries
  - Screening impedance
- **Excitations**
  - Wave ports (external)
  - Lumped ports (internal)



$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

$$\nabla \cdot D = \rho$$

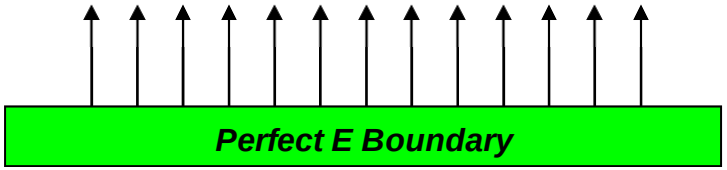
$$\nabla \cdot B = 0$$

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Perfect E and Perfect H Boundaries

- **Perfect E is perfect electrical conductor (PEC)**
  - Forces E-field perpendicular to surface
  - Represents metal surfaces, ground planes, ideal cavity walls, etc.
  - Infinite ground plane option simulates effects of infinite ground plane in post-processing radiated fields
- **Perfect H is perfect magnetic conductor (PMC)**
  - Forces H-field perpendicular to surface and E-field tangential
  - Does not exist in real world
  - Useful boundary constraint for electromagnetic models
  - Represents openings in metal surfaces, etc.
- **Parameters**
  - None

E-field Perpendicular to surface



When you define a solid object as a 'perf_conductor,' a Perfect E boundary condition is applied to its exterior surfaces.

E-field Parallel to surface



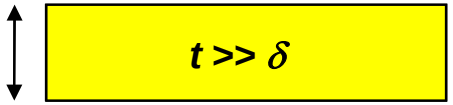
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Four Surface Loss Modeling Methods

- **All methods utilize an equivalent surface impedance applied to the field as it travels across the surface**

$$E_{tan} = Z_s(\hat{n} \times H_{tan})$$

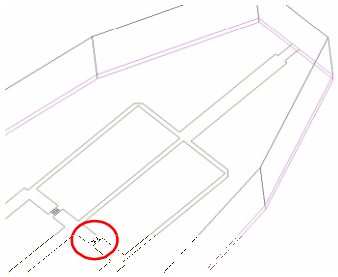
Finite Conductivity



$$Z_s = \frac{1+j}{\sigma\delta}$$

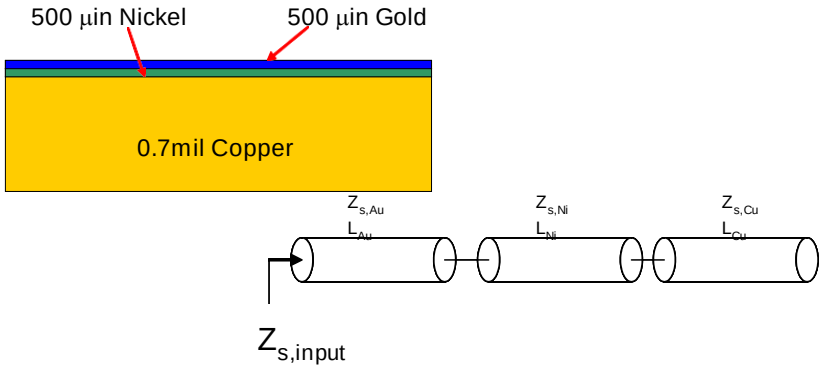
$$\delta = \sqrt{\frac{2}{\omega\sigma}}$$

Impedance



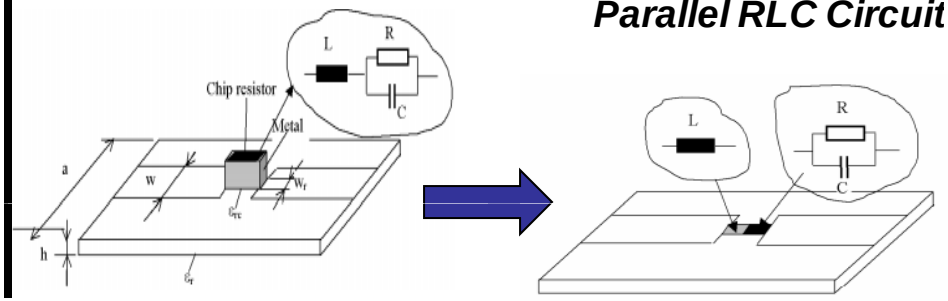
Z_s specified as Ω/sq

Layered Impedance



Lumped RLC

Parallel RLC Circuit



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Finite Conductivity Boundary

- **Lossy electrical conductor**
  - Forces E-field perpendicular to surface
  - Surface impedance includes resistive and reactive surface losses
- **Used for non-ideal conductor analysis**
- **Infinite ground plane option simulates effects of infinite ground plane in post-processing radiated fields**
- **Parameters**
  - Conductivity (S/m)
  - Relative permeability (unitless)



Good conductor in skin depth regime

When you define a solid object as a non-ideal metal (e.g. copper or aluminum), and it is set to 'Solve Surface', a finite conductivity boundary is applied to its exterior faces.

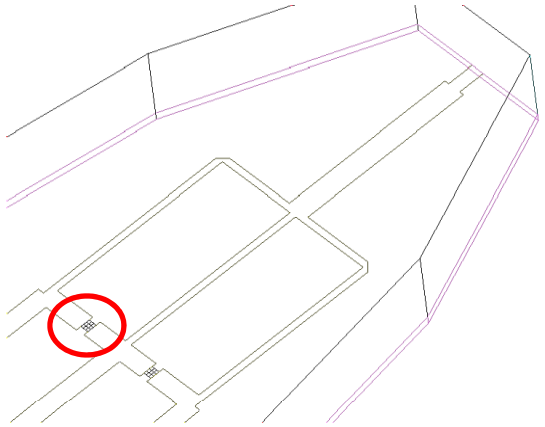
$$\delta = \sqrt{\frac{2}{\omega\sigma\mu}} \quad \Rightarrow \quad Z_s = \frac{1+j}{\sigma\delta} \quad \Rightarrow \quad \boldsymbol{E}_{tan} = Z_s(\hat{n} \times \boldsymbol{H}_{tan})$$

Skin Depth **Surface Impedance** **Field Relationship**

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Impedance Boundary

- **User-defined surface impedance**
  - Represents thin film resistors or reactive loads
- **Infinite ground plane option simulates effects of infinite surface in post-processing radiated fields**
- **Calculate required impedance from desired lumped value, width, and length**
  - Length (in direction of current flow) ÷ width = number of "squares"
  - Impedance per square = desired lumped impedance ÷ number of squares
- **Parameters:**
  - Resistance (Ω/square)
  - Reactance (Ω/square)



Example: Resistor in Wilkinson Power Divider

Resistor is 3.5 mils long (in direction of flow) and 4 mils wide. Desired lumped value is 35 Ω.

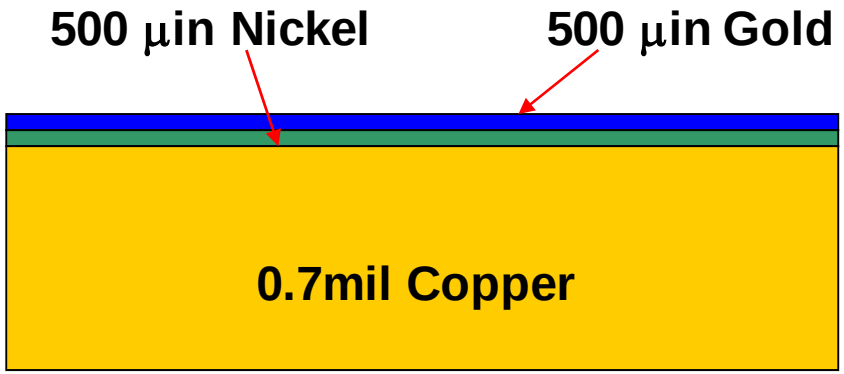
$$N = \frac{3.5}{4} = 0.875$$

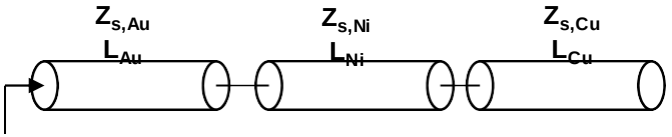
$$R_{sheet} = \frac{R_{lumped}}{N} = \frac{35}{0.875} = 40\ \Omega / square$$

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Layered Impedance Boundary

- **Models multiple thin layers in a structure as single impedance surface**
  - Effect is same as impedance boundary, except that HFSS calculates surface impedance based on data entered for layered structure
  - Surface roughness can be included
  - Plating layers can be modeled by using an equivalent surface impedance
- **Not available for fast frequency sweeps**
- **Parameters**
  - Layer thicknesses
  - Material properties
  - Surface roughness (optional)





$Z_{s,input}$

$$Z_{inputk} = Z_{wk}\frac{Z_{inputk+1}ch(\gamma_k d_k) + Z_{wk}sh(\gamma_k d_k)}{Z_{inputk+1}sh(\gamma_k d_k) + Z_{wk}ch(\gamma_k d_k)}$$

Impedance of the layered structure is calculated by recursively calling the impedance calculation formulation from transmission line theory

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