A Stepped Coaxial Waveguide Fixture for Material Characterization

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Electromagnetic material characterization is the process of determining the complex permittivity $(\varepsilon_r = \varepsilon_r' - j\varepsilon_r'')$ and permeability $(\mu_r = \mu_r' - j\mu_r'')$ of a material. In this study, a two-port cell is proposed for the dielectric characterization of soil and contaminated soil at a frequency range of 100 MHz to 1 GHz. The cell is a split coaxial circular waveguide with a step discontinuity where the dielectric sample is placed at the center. The step discontinuity is necessary to match the coax-to-coax adaptor dimensions to the dimensions of the test cell. The geometry of the cell is axisymmetric and sized to meet construction requirements and sample dimensions. At the input and output ports only the TEM mode propagates. Higher order modes will exist in the region of the discontinuity and must be included in the inversion formulation. A mode-matching technique is implemented to accommodate those higher-order modes.

The extraction of the S-parameters from the coaxial waveguide with the dielectric sample is conducted using the mode-matching technique and validated numerically by means of the Finite Element Method (FEM). Port boundary conditions are applied at the input and output port boundaries to accomplish mesh closure. The Thru-Reflect-Line (TRL) calibration technique is used for both experiments and computer simulations. The sample permittivity and permeability are obtained using a two-dimensional root-search inversion algorithm. Different moisture and contaminant concentrations will be simulated. A mode-matching scheme for the analysis of the stepped coaxial waveguide is presented as a verification of finite element results. Theoretical S-parameters obtained from the modal analysis are compared with those obtained from the FEM simulations.