**Lab 4：Waveguide**

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| **Introduction**  The direct translation of TEM is "transverse-electric-field-magnetic-field", which means that the electric and magnetic fields have components only in the plane perpendicular to the direction of propagation of the electromagnetic field energy (i.e., transverse), which means that there are no electric and magnetic components in the direction of propagation (i.e., longitudinal). In this mode, an electromagnetic wave is a transverse wave, consistent with the concept of free-space electromagnetic waves that we were introduced to in high school. Coaxial line can transmit this mode of electromagnetic waves, and the transmission of DC signals or low-frequency signals is not fundamentally different, the concept of current, voltage are also applicable, it is easy to imagine; other two-conductor type of transmission line (such as ribbon line, microstrip line) as a long line transmission of electromagnetic waves can be approximated as the TEM mode.  The direct translation of TE is "transverse-electric field", which means that the electric field (E-field) has components only in the transverse direction, but the magnetic field (H-field) has components in both the transverse and longitudinal directions, so it is also called "H-mode".  The term "mode" here refers to a specific field distribution structure of the electromagnetic field. A more fundamental understanding is that, given the ideal boundary conditions, constraint equations, solving the partial differential equations describing the spatial distribution of electromagnetic fields in the waveguide cavity (i.e., Maxwell's equations), the use of the method of separation of variables and the method of eigenfunctions of a particular set of special solutions; because of the special solutions corresponding to the eigenvalues are discrete, so through the design of the boundary conditions that is, the dimensions of the waveguide, it can be made that some of the special solutions to become the only solution, thus simplifying the subsequent design and calculation. This simplifies the subsequent design and computation.  Since rectangular waveguides separate variables in a right-angle coordinate system and circular waveguides separate variables in a cylindrical coordinate system, the physical meaning of the corresponding "modes" is different.  For rectangular waveguide, TEmnp mode refers to the distribution of longitudinal magnetic field in the cavity along the x, y, z direction (i.e., length, width, height direction) to form m, n, p complete half-cycle waveforms.  So，  **TE10 Mode:**  The TE10 mode is the fundamental mode of the waveguide, where the dominant electric field is transverse (T) to the direction of propagation and has one half-wave variation along the width of the waveguide (E10).  This mode has a single electric field maximum and a single magnetic field maximum within the waveguide cross-section.  The TE10 mode has the lowest cutoff frequency and is the most commonly used mode in waveguide applications.  **TE20 Mode:**  The TE20 mode is the first higher-order mode of the waveguide. It has two half-wave variations along the width of the waveguide and no variation along the length of the waveguide.  This mode has a node at the center of the waveguide in the transverse electric field distribution.  The TE20 mode has a higher cutoff frequency compared to the TE10 mode.  **TE01 Mode:**  The TE01 mode is the first higher-order mode in the vertical direction, with no variation along the width of the waveguide and one half-wave variation along the length of the waveguide.  This mode has a nodal plane along the width of the waveguide at the center.  The TE01 mode has a higher cutoff frequency compared to both the TE10 and TE20 modes.  **TE11 Mode:**  The TE11 mode is the mode with one half-wave variation along the width and one half-wave variation along the length of the waveguide.  This mode has a single nodal diameter along the width of the waveguide and correspondingly no variation along the height of the waveguide.  The TE11 mode has a higher cutoff frequency compared to the TE10, TE20, and TE01 modes.  **Lab results & Analysis**：  For **13GHz**：  **TE10**        **TE20:**        **TE01:**        **For 15GHz：**  **TE10：**        **TE20：**        **TE01：**        **S-parameters** | |
| **Experience**  **Screenshot：**    **Questions：**  At first I didn't understand what TE was at all, and at the same time the lack of familiarity with HFSS brought a big obstacle to the simulation experiment. Because the frequency sweep range is large and delicate, it takes a long time, so the anxiety in waiting for the simulation result is also a big part of the difficulties in this experiment.  **Harvest：**  Got a better understanding of TE waves in rectangular waveguides:  In my own words, TE waves refer to transverse electric field modes. TE modes refer to the way the electric field is distributed in the waveguide, and these modes can be derived from the correction equations (using Maxwell's equation and the gradient equation to derive them). In TE modes, the longitudinal magnetic field is zero, while the transverse electric field is present. TE modes have a single longitudinal mode number, n, and a transverse mode number, m. The distribution of the electric field in the TE modes depends on the size and shape of the waveguide cross-section. For a rectangular waveguide, the electric field in the TE mode exists in the transverse direction (x and y directions) and the magnetic field is zero in the longitudinal direction (z direction).TE modes can be further subdivided into different modes such as TE10, TE20, TE01, etc., which each have specific characteristics of electric field distribution in the transverse and longitudinal directions. | |
| **Score** | 100 |