Multimode network equivalence of waveguide discontinuities using full-wave method of moments for spatial power combining

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Scope of the presentation

- Introduction to Spatial Power Combining
- Development of full-wave method of moments for electric-type (patch, strip) antenna inside oversized waveguide
- Multimode network equivalence of oversized waveguide discontinuities
Waveguide-based spatial power combining

- Receiving Antenna Array
- Amplifier Array
- Transmitting Antenna Array
- Active Antenna Arrays
- Input Power
- Spatially Fed
- Oversized Waveguide
- Spatially Combined
- Output Power
Modeling Issues

• Oversized waveguide to accommodate large active antenna arrays

• Oversized waveguides: several high-order propagating waveguide modes in addition to the TE10 dominant mode.

• But commercial softwares can only model waveguide structures for TE10 mode only.
• **Hence it is necessary to develop a program which can characterize the enclosed metallic strip for multimode case.**
Development of full-wave method of moments

**Spectral Dyadic Green’s functions**

- The spectral dyadic Green’s functions for the layered waveguide is given below.

\[
\hat{G}_{\text{ev}}(k, z, z') = \frac{jZ_1''Z_2'' \tan \gamma_2 h (\hat{k} \times z)(\hat{k} \times z)}{Z_1'' + jZ_2'' \tan \gamma_2 h} + \frac{jZ_1'Z_2' \tan \gamma_2 h (\hat{k})(\hat{k})}{Z_1' + jZ_2' \tan \gamma_2 h}
\]

\[
Z(z) = \frac{1}{Y(z)} = \begin{cases} 
Z^e &= \frac{k_z(z)}{\omega \varepsilon_i(z)} \\
Z^h &= \frac{\omega \mu_i(z)}{k_z(z)} 
\end{cases}
\]

\[
k^2_z(z) = \omega^2 \mu_i \varepsilon_i - k^2_i
\]
The spectral dyadic Green’s functions can be transformed into their space domain counterparts:

\[ G_{ij}(i, j; i', j') = \sum_{m=0}^{M+1} \sum_{n=0}^{N+1} \tilde{G}_{ij}(k_x, k_y) \phi_{mn}^i \phi_{mn}^j \]

\[ \phi_{mn}^x = \sqrt{\frac{\varepsilon_{0m}}{a}} \sqrt{\frac{\varepsilon_{0n}}{b}} \cos(k_x x) \cos(k_y y) \]

\[ \phi_{mn}^y = \sqrt{\frac{\varepsilon_{0m}}{a}} \sqrt{\frac{\varepsilon_{0n}}{b}} \sin(k_x x) \cos(k_y y) \]

\( \varepsilon_{om} \) and \( \varepsilon_{on} \) are Neuman indices where \( \varepsilon_{om} = 1 \) for \( m=0 \) and \( \varepsilon_{om} = 2 \) for \( m \neq 0 \).
Electric Field Integral Equation (EFIE)

\[ \hat{z} \times E(r) + j \omega \mu \hat{z} \times \left( \int_{\text{strip}} \hat{G}^{EJ}(r, r') \cdot J(r') \, dS' \right) = 0 \]

The vector EFIE can be reduced to a coupled set of scalar integral equations as below:

\[ E_x(x, y) = j \omega \mu \left( \int_{\text{strip}} G_{xx}(x, y; x', y') J_x(x', y') \, dx' \, dy' \right) + \int_{\text{strip}} G_{xy}(x, y; x', y') J_y(x', y') \, dx' \, dy' \]

\[ E_y(x, y) = j \omega \mu \left( \int_{\text{strip}} G_{yx}(x, y; x', y') J_x(x', y') \, dx' \, dy' \right) + \int_{\text{strip}} G_{yy}(x, y; x', y') J_y(x', y') \, dx' \, dy' \]
Galerkin’s Method

- Galerkin’s method is applied to the EFIE to transform the integral equations into matrix systems of linear equations
- Piece-wise sinusoidal and pulse functions are used as basis and testing functions
- \([Z][I]= [V]\)

where

\[
[Z] = \begin{bmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{bmatrix} \quad [I] = \begin{bmatrix} I_x \\ I_y \end{bmatrix} \quad [V] = \begin{bmatrix} V_x \\ V_y \end{bmatrix}
\]
**Matrix systems of linear equations**

where the matrix components are given by

\[ Z_{ij} = j\omega\mu\sum_{m=0}^{M+1} \sum_{n=0}^{N+1} \tilde{j}_i(k_x, k_y)\tilde{G}_{ij}(k_x, k_y)\tilde{j}_j(k_x, k_y) \]

\[ V_x = -\int_{\text{strip}} J_x(x, y)E_x(x, y)dxdy \]

Ix and Iy are the unknown current coefficients
Appropriate electromagnetic program

- An EM program is developed to characterize enclosed metallic strips.
- Initial results obtained for waveguide dimension $a=0.02286$, $b=0.01016$, strip dimension $w=0.009271$, $l=0.007112$.
- Strip is placed at the centre of the over-moded waveguide. Substrate of $\varepsilon_2=2.33$, layer thickness $h=0.00136$, $\varepsilon_1=1.0$, $\varepsilon_3=1.0$. 
Multimode Network Equivalent

Multimode Network Equivalence for metallic strip enclosed inside oversized waveguide
Thank you

Have a Nice Day!