A SCATTERING METHOD OF ANALYSIS FOR WIDE RADIATING SLOT EXCITED BY A MICROSTRIP LINE

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In this report, a rigorous mathematical model for input impedance and radiation characteristics of a wide slot in the ground plane of microstrip line(feed-line) is described.

Wider bandwidth, less interaction via surface waves, better isolation and negligible radiation from feed network are among those main advantages which make printed slot antenna a suitable element for planar arrays.

Based upon the assumptions that electric field in the slot has a single component varying sinusoidally along the slot, variational formulation [1] and moment method [2] have been applied to this problem. These approaches are suitable for very thin slots where the field variation across the width of slot or the electric field component along the longer dimension of the slot may be neglected [3] and the total effects of the slot on the microstrip feed line can be lumped into a voltage discontinuity (series impedance) located at the center of slot. For wide slots which have more attractive features like wider bandwidth and less sensitivity to dimensional and positional tolerances the above assumptions are not valid. The wide slots have been studied experimentally [4]. The mathematical formulation presented in our report is rigorous and does not have the above mentioned limitations.

The geometry under investigation is illustrated in Fig.1. Slot is excited by a quasi-TEM fundamental microstrip mode incident field supported by J_{inc} from the right.

Far from the slot location current density on the microstrip is that of fundamental mode. In proximity of wide slot the higher order modes are excited and their total effects can be represented by a scattered current J_{sc} with a finite support. Now if the reflection coefficients for the fundamental mode is denoted by "R" then the current density on the microstrip is given by:

$$\bar{J}_{ms}=\bar{J}_0(\exp(-jkz)+R\exp(jkz))+\bar{J}_{sc}=\bar{J}_{inc}+\bar{J}_{sc} \qquad (1)$$

Where $\bar{J}_{sc}$ vanishes outside some finite neighbourhood around the slot. If the slot electric field is denoted by $\bar{E}_{sl}$ we can decompose the original problem into "interior" and "exterior" problems as shown in Fig.2. In the exterior problem surface magnetic current $\bar{M}_s=\bar{E}_{sl}\times\hat{x}$ placed on a PEC radiates into half space x>h, and in the interior problem fields are generated by $-\bar{M}_s$ and $\bar{J}_{ms}$.

Invoking the continuity of tangential magnetic field across the slot and the fact that E_z vanishes on the microstrip, the following set of coupled integral equations for $\bar{M}_s$ and $\bar{J}_{ms}$ is derived:

$$\bar{H}^{ext}(\bar{M}_s)=\bar{H}^{int}(-\bar{M}_s)+\bar{H}^{int}(\bar{J}_{ms}) \qquad (2)$$

$$\bar{E}_z(\bar{J}_{ms})+\bar{E}_z(-\bar{M}_s)=0 \quad \text{on the microstrip} \qquad (3)$$

Which is solved by method of moments for unknowns $R,\bar{J}_{sc}$, and $\bar{M}_s$. To this end, (2) and (3) should be expressed in terms of Green's functions of a multi-layer inhomogenous dielectric region:

$$\bar{H}^{ext}(\bar{M}_s)=\iint_{slot} \bar{\bar{G}}^{MM}_{ext}(\bar{r}_{sl};\bar{r}'_{sl})\bar{M}_s(\bar{r}'_{sl})d^2\bar{r}'_{sl}$$

$$\bar{H}^{int}(-\bar{M}_s)=\iint_{slot} \bar{\bar{G}}^{MM}_{int}(\bar{r}_{sl};\bar{r}'_{sl})\bar{M}_s(\bar{r}'_{sl})d^2\bar{r}'_{sl}$$

$$\bar{H}^{int}(\bar{J}_{ms})=\iint_{M.S.} \bar{\bar{G}}^{ME}_{int}(\bar{r}_{sl};\bar{r}'_{ms})\bar{J}_{ms}(\bar{r}'_{ms})d^2\bar{r}'_{ms}$$

$$\bar{E}_z(\bar{J}_{ms})=\iint_{M.S.} \bar{\bar{G}}^{EE}_{int}(\bar{r}_{ms};\bar{r}'_{ms})\bar{J}_{ms}(\bar{r}'_{ms})d^2\bar{r}'_{ms}$$

$$\bar{E}_z(-\bar{M}_s)=\iint_{slot} \bar{\bar{G}}^{EM}_{int}(\bar{r}_{ms};\bar{r}'_{sl})\bar{M}_s(\bar{r}'_{sl})d^2\bar{r}'_{sl}$$

Where $\bar{\bar{G}}^{UV}_{\text{"ext" or "int"}}$ are appropriate Green's functions relating tangential electric or magnetic fields at various interfaces to electric and magnetic type surface currents, on the microstrip or slot in "interior" and "exterior" problems. $r^{(')}_{ms}$ and $r^{(')}_{sl}$ are (source) observation points on the microstrip and slot. These Green's functions may be derived by "Spectral domain immittance approach" [5] in a very convenient manner, and the results are given in closed form expressions in Fourier Transform Domain(FTD). Therefore it is more suitable to apply method of moments to the above set of coupled integral equations in FTD rather than in a space domain. For this purpose, first we expand the $\bar{J}_{ms}$ and $\bar{M}_s$ in terms of appropriately chosen basis functions:

$$\bar{J}^{+-}_{sc} = \hat{z} \sum_{n=1}^{N} I_n \bar{J}_n (x,y) = \hat{z} \sum_{n=1}^{N} I_n \sin k_e (h_m - | y - y_n |)/w_m \sin k_e h_m \qquad (4)$$

$$\bar{M}_s = \hat{y} \sum_{P=1}^{P} a_p \bar{M}_{yp} (x,y) + \hat{x} \sum_{q=1}^{Q} b_q \bar{M}_{xq} (x,y) \qquad (5)$$

$$\bar{M}_{yp} (x,y) = \frac{\begin{matrix}\sin \\ \cos\end{matrix} (m' \pi x/w)}{\pi \sqrt{(w/2)^2 - x^2}} \cdot \frac{\sin k_{sl} (h_{sl} - | y - y^{sl}_{n'} |)}{\sin k_{sl} h_{sl}}$$

$$\bar{M}_{xq} (x,y) = \frac{\sin(q\pi y/L)}{\pi \sqrt{(L/2)^2 - y^2}} \cdot \cos(\pi x/w) \qquad q=1,3,5,\ldots$$

Where k_e and k_{sl} are propagation Constants along the microstrip and slot, y_n and $y^{sl}_{n'}$ are centeral points of piecewise sinusoidal variations defined over subintervals of widths h_m and h_{sl}, and p denotes any possible combination of indices m' and n'. The dimensions of slot are w and L and the width of microstrip is w_m. The edge singularity has also been taken into account.

Since the width of microstrip line is much smaller than a wavelength, $\hat{J}_{ms}$ is assumed to have only an axial (z) component.

Substituting (4),(5) back into (2),(3) and taking moments, with respect to all basis functions (Galerkin Method) a set of linear equations for unknown I_n, a_p, b_q and R are derived:

$$[G][U]=[V]$$

Where a typical element of matrix G which is of order N+P+Q+1 is the "reaction" between mth basis function of J_{sc} or M_s and nth test function which is taken to be identical to nth basis function. [U] is the vector of unknowns and the vector [V] contains reaction between incident microstrip field and basis functions.

As it was mentioned earlier the matrix elements can conveniently be expressed in FTD where the integrations are with respect to spectral variables k_x and k_y.

One of the basic advantages of FTD is that after determination of R and the unknown expansion coefficients, far radiated field of slot, which can be expressed in terms of fourier transform of M_s is readily obtained.

More detailed description of our method, issues related to convergence and accuracy and some initial results of its application to sample cases will be discussed at the Conference.

References:

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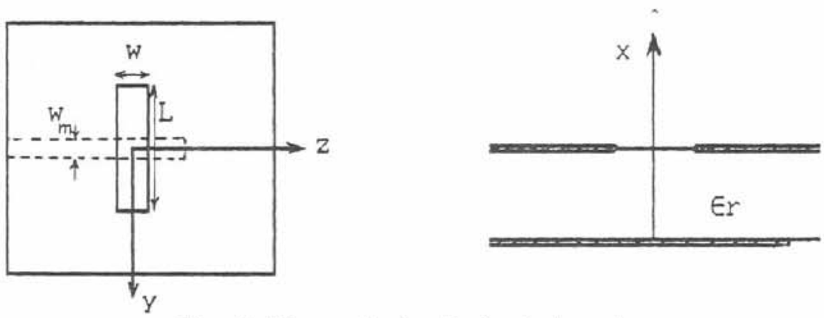

Fig.1 Microstrip fed slot antenna

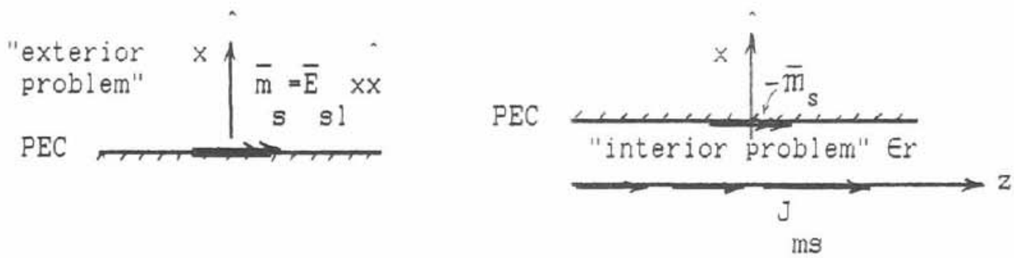

Fig.2 "Exterior" and "Interior" problem