A NOTE ON A NARROWLY SLITTED PARALLEL PLATE WAVEGUIDE FILLED WITH A DIELECTRIC.

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유전체로 채워진 평행평판 도파관의 좁은 틈에 관한 소고

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When a TEM wave whose electric field amplitude is assumed to be unity is incident upon the slit as Fig.1, an integral equation can be set up for the Y-component magnetic current My.

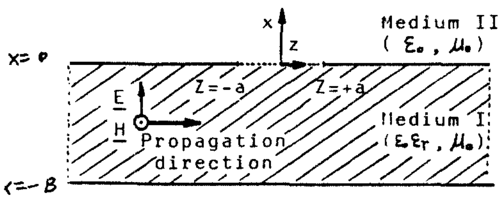

Fig.1. Geometrical structure

Choosing the approximate Neumann Green functions in each region I, II and imposing the continuity of magnetic field in the slit, one can obtain

$$\frac{k}{2\eta}\int_{-a}^{a} M_y(z')\, H_0^{(2)}(k|z-z'|)\, dz' \quad \cdots\cdots\cdots (1)$$

$$-\int_{-a}^{a} M_y(z')\, G(z,z')\, dz' + \frac{1}{\eta_I} e^{-jk_I z} \; ; \; \begin{matrix} -a \leq z, z' \leq a \\ x, x' = 0 \end{matrix}$$

Here $k = \omega\sqrt{\mu_o\varepsilon_o}$, $\eta = \sqrt{\frac{\mu_o}{\varepsilon_o}}$ and ω , μ_o , ε_o denote angular frequency, permeability, permittivity of free space respectively and $H_0^{(2)}$ means the Hankel function of the second kind of index zero and $k_I = \omega\sqrt{\mu_o\varepsilon_o\varepsilon_r}$, $\eta_I = \sqrt{\frac{\mu_o}{\varepsilon_o\varepsilon_r}}$ and ε_r means the relative dielectric constant of medium I and G means the Green function in the region I, represented by

$$G = -\frac{1}{2\eta_I b} e^{-jk_I|z-z'|} - \frac{jk}{\eta_I b}\sum_{n=1}^{\infty} \frac{e^{-\sqrt{(\frac{n\pi}{b})^2 - k_I^2}\,|z-z'|}}{\sqrt{(\frac{n\pi}{b})^2 - k_I^2}}$$

If $k_I b < \pi$ such that only TEM mode can propagate and the slit width is sufficiently narrow relative to the waveguide height b, i.e, $2k_I a \ll k_I b < \pi$ then $H_0^{(2)}$ and G can be replaced by their small argument approximations as follows

$$H_0^{(2)}(k|z-z'|) \cong -j\frac{2}{\pi}\left\{\ln\left(\frac{k|z-z'|}{2}\right) + \gamma + j\frac{\pi}{2}\right\} \cdots (2)$$

$$G(z,z') \cong -\frac{1}{2\eta_I b} + \frac{jk_I}{\eta_I b}\left\{\ln\left(\frac{\pi|z-z'|}{b}\right) - \sum_0\left(\frac{k_I b}{\pi}\right)\right\} \cdots (3)$$

Where r denotes Euler's constant and $\sum_0(x)$ means

$$\sum_0(x) \cong \frac{1}{\sqrt{1-x^2}} - 1 + 0.1010x^2 + 0.0138x^4 - \cdots$$

One also approximate the incident magnetic field Hy. inc by a two term Taylor series

$$H_{y.inc} \cong \frac{1}{\eta_I}\left(1 - jk_I z\right) \cdots\cdots\cdots\cdots\cdots (4)$$

By substitution of (2),(3),(4) into (1), one can obtain the approximated integral equation after some algebraic manipulations.

$$C_1\int_{-a}^{a} M_y(z')\ln|z-z'|\,dz' + C_2\int_{-a}^{a} M_y(z')\,dz' = \frac{1}{\eta_I}\left(1 - jk_I z\right)$$

where $C_1 = -\frac{jk}{\eta\pi} - \frac{jk_I}{\eta_I\pi}$

$$C_2 = \frac{1}{2\eta_I b} - \frac{j}{\pi}\left\{\frac{k}{\eta}\ln\frac{k}{2} + \frac{k}{\eta}\varepsilon_r\ln\frac{\pi}{b} + \frac{k\gamma}{\eta} + j\frac{k\pi}{2\eta} - \frac{k_I}{\eta_I}\sum_0\left(\frac{k_I b}{\pi}\right)\right\}$$

Using the method which C.M.Butler & D.R.Wilton used in their work,[1] one can obtain the magnetic current My(Z') as a solution

$$M_y(z') = \frac{1}{\eta_I\pi\left(C_1\ln\frac{a}{2} + C_2\right)}\cdot\frac{1}{\sqrt{a^2 - z'^2}} + \frac{jk_I}{\eta_I\pi C_1}\cdot\frac{z'}{\sqrt{a^2 - z'^2}} \quad \cdots (5)$$

From the calculated magnetic current, one can obtain the magnetic field of reflected TEM wave and the magnetic field reflection coefficient T_H at the reference plane Z=0. Making use of the relation between TH and the series admittance $\bar{Y}$ normalized in the transmission line with its characteristic admittance Yc unity, one can obtain the equivalent circuit admittance of the slit.

$$\bar{Y} = -\frac{1+\Gamma_H}{2\Gamma_H} = \bar{G} + j\bar{B} \ ....(6)$$

here $\bar{G}$,$\bar{B}$ mean the normalized radiation conductance and susceptance respectively. The study of the slit in the parallel plate waveguide filled with an air was undertaken by some authors.(2)

Here equivalent circuit parameters $\bar{G}$,$\bar{B}$ of the slit in the parallel plate waveguide filled with a dielectric(ε_r=2.55) are computed and compared with those in case of ε_r=1 in Fig. 2.3 respectively. It is interesting to compare this result $\bar{G}$ with that of study(3) (2. eqn(12)) on the radiation conductance of the microstrip antenna.

When we dont normalize the radiation conductance G. We obtain $G=\frac{1}{120\lambda}$ (mho/m) (λ : wavelength in the free space).

Though the configuration in the work(3) is not the same as that under consideration here, two approximate expressions are same.

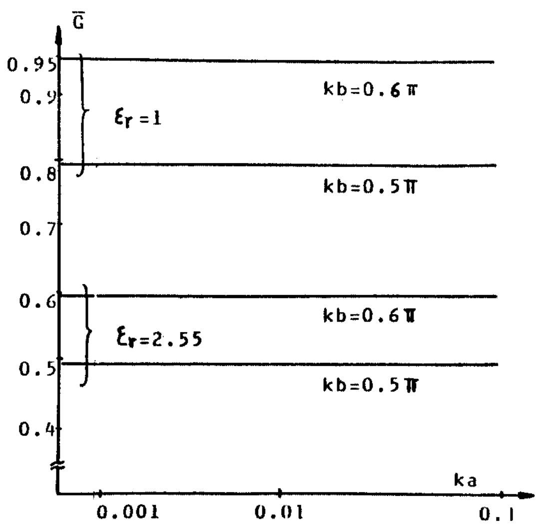

Fig.2. Normalized conductance

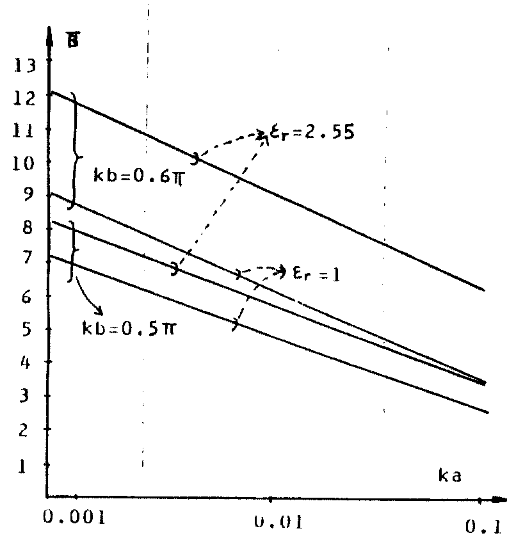

Fig.3. Normalized susceptance

References

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