OPEN-CIRCUIT END EFFECT OF MICROSTRIP LINE CONFIGURATION IN PLASMA MEDIUM

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The extension in length for open microstrip configuration in plasma media is determined using spectral domain technique under quasi static approach [1, 2]. The results were verified by modifying Hammerstad equation for plasma media. Good agreement is found between the two results.

INTRODUCTION

The ideal field patterns of a open-circuited microstrip line are distorted with fringing electric fields. The fringing fields and the increase in electrostatic energy as a result of the extra stored energy is modeled by a capacitive termination $C_F$. The fringing capacitance at the termination of the line is equivalent to extending line by $\Delta \ell$ as given by the expression

$$\Delta \ell = \frac{1}{\beta} \tan^{-1} (Z_0 \omega C_F)$$  \hspace{1cm} (1)

where $\beta$ = propagation constant on the line
$Z_0$ = characteristic impedance of the line
$\omega$ = angular frequency

FORMULATION

The microstrip in plasma medium is shown in Fig. 1 where $\varepsilon_p$ is the dielectric constant of plasma medium defined as

$$\varepsilon_p = A^2 = 1 - \left(\frac{\omega_p}{\omega}\right)^2$$  \hspace{1cm} (2)

where $A$ is the plasma parameter

If $\phi (x, y) = \text{static potential distribution in microstrip structure}$
then $\phi(\beta, y) = \text{Fourier transform of } \phi(x, y)$

$$= \int_{-\infty}^{\infty} \phi(x, y) e^{i\beta x} \, dx$$

Assuming in media (1) $\phi = Ae^{\beta y} + Be^{-\beta y}$ \hspace{1cm} (3)

& in media (2) $\phi = Ce^{-\beta y} + De^{\beta y}$ \hspace{1cm} (4)

In Fourier transform domain, the boundary conditions are

at $y = 0$ \hspace{1cm} $\phi(\beta, 0) = 0$ \hspace{1cm} (5)

$y = \infty$ \hspace{1cm} $\phi(\beta, \infty) = 0$ \hspace{1cm} (6)

At interface

$\phi(\beta, h + 0) = \phi(\beta, h - 0)$ \hspace{1cm} (7)

and $\epsilon_r \frac{d\phi}{dy}(\beta, h + 0) = \epsilon_i \frac{d}{dy} \phi(\beta, h - 0) - \tilde{f}(\beta)$ \hspace{1cm} (8)

Taking $f(x)$ as the change distribution on the strip conductor, total charge on strip conductor

$$Q = \int_{-\infty}^{\infty} f(x) \, dx$$

Hence
\[
\tilde{f}(\beta) = \int_{-\infty}^{\infty} f(x) e^{ix} dx
\] (9)

Solving the above, we have

\[
\Phi(x, h) = C e^{-\beta h} = \frac{\tilde{f}(\beta)}{\beta (\epsilon_1 \coth \beta h + \epsilon_p)}
\] (10)

Hence the Fourier transform of potential distribution is given as:

\[
\tilde{f}(\beta, h) = \frac{\tilde{f}(\beta)}{\beta (\epsilon_1 \coth \beta h + \epsilon_p)}
\] (11)

Line capacitance \( C \) is obtained using symmetry as

\[
\frac{1}{C} = \frac{1}{\pi \epsilon Q^2} \int_{0}^{\infty} \frac{[\tilde{f}(\beta)]^2}{[\epsilon_p + \epsilon_1 \coth \beta h] \beta h} d(\beta h)
\] (12)

Taking approximately trial function for \( f(x) = |x| \) which gives capacitance as maximum

\[
f(x) = \begin{cases} 
|x| - \omega/2 & \text{if } -\omega/2 \leq x \leq \omega/2 \\
0 & \text{elsewhere}
\end{cases}
\]

\[
\frac{\tilde{f}(\beta)}{Q} = 2 \left[ \frac{2 \sin \left( \frac{\beta \omega}{2} \right)}{(\beta \omega)} \right] - \left[ \frac{\sin \left( \frac{\beta \omega}{4} \right)}{\beta \omega} \right]^2
\] (13)

If \( \beta h = x \), then \( d\beta h = dx \).

Hence

\[
\frac{1}{\pi \epsilon_0} \int \left[ \frac{f \left( \frac{x}{h} \right)}{Q} \right]^2 dx
\]

or

\[
\frac{1}{C} = \frac{1}{[\epsilon_p + \epsilon_1 \coth x]x} dx
\] (14)
The effective permittivity of microstrip is given by

\[
\frac{C}{\varepsilon_0} = \int_0^{\pi} \frac{\sin \left( \frac{x \omega}{2h} \right)}{\sin \left( \frac{x \omega}{4h} \right)} \left[ \frac{\sin \left( \frac{x \omega}{2h} \right)}{\sin \left( \frac{x \omega}{4h} \right)} \right]^2 \, dx
\]

(\epsilon_p + \epsilon_r \coth x)x

The effective permittivity of microstrip is given by
\[ \epsilon_{\text{eff}} = \frac{C}{C_0} \]  

(16)

where \( C \) and \( C_0 \) are the capacitances per unit length of line with and without dielectric. The effective dielectric constant is also given as

\[ \epsilon_{\text{eff}} = \frac{\epsilon_r + \epsilon_p}{2} + \frac{\epsilon_r - \epsilon_p}{2} \left( \frac{1}{\sqrt{1 + \frac{12h}{\omega}} + 1} \right) \]  

(17)

And line extension \( \Delta \ell \) as given by Hammerstad is [3]:

\[ \frac{\Delta \ell}{h} = 0.412 \frac{\epsilon_r + 0.3 \frac{\omega}{h}}{\epsilon_r - 0.258 \frac{\omega}{h}} + 0.262 + 0.813 \]  

(18)

NUMERICAL RESULTS

The results were obtained solving equations 15, 16, 17, and 18 numerically and are plotted in Fig. 2 to 5.
CONCLUSIONS

Calculations of length extension ($\Delta l$) in plasma medium for various plasma parameter values ($A = .1,.3,.5,.7,.9$) in an open microstrip configuration are obtained using spectral domain technique under quasi static approach [4,5] and by modifying Hammerstad equation for plasma media. Good agreement is found between the two results.

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REFERENCES
