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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

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

where β = propagation constant on the line
Z_0 = characteristic impedence of the line
ω = angular frequency

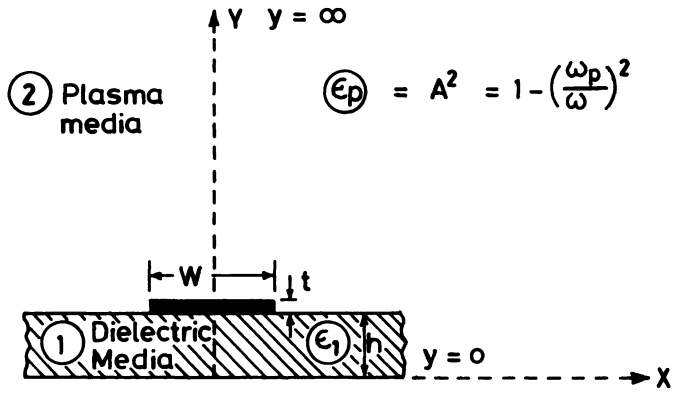
FORMULATION

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

$$\epsilon_p = A^2 = 1 - \left(\frac{\omega_p}{\omega}\right)^2 \tag{2}$$

where A is the plasma parameter

If ϕ (x, y) = static potential distribution in microstrip structure



MICROSTRIP IN PLASMA MEDIUM

FIGURE 1

then $\tilde{\phi}(\beta, y)$ = Fourier transform of $\phi(x, y)$

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

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

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

In Fourier transform domain, the boundary conditions are

at $y = 0$ $\tilde{\phi}(\beta, 0) = 0$ (5)

$y = \infty$ $\tilde{\phi}(\beta, \infty) = 0$ (6)

At interface

$$\tilde{\phi}(\beta, h + 0) = \tilde{\phi}(\beta, h - 0) \tag{7}$$

and $$\epsilon_p \frac{d\tilde{\phi}}{dy}(\beta, h + 0) = \epsilon_1 \frac{d}{dy}\tilde{\phi}(\beta, h - 0) - \tilde{f}(\beta) \tag{8}$$

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

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

Hence

$$\tilde{f}(\beta) = \int_{-\infty}^{\infty} f(x)\, e^{j\beta x}\, dx \tag{9}$$

Solving the above, we have

$$\Phi(x, h) = Ce^{-\beta h} = \frac{\tilde{f}(\beta)}{\beta(\epsilon_1 \coth \beta h + \epsilon p)} \tag{10}$$

Hence the fourier transform of potential distribution is given as:

$$\tilde{\phi}(\beta, h) = \frac{\tilde{f}(\beta)}{\beta(\epsilon_1 \coth \beta h + ep)} \tag{11}$$

Line capacitance C is obtained using symmetry as

$$\frac{1}{C} = \frac{1}{\pi\, \epsilon\, Q^2} \int_0^{\infty} \frac{\{\tilde{f}(\beta)\}^2}{\{\epsilon p + \epsilon_1 \coth \beta h\}\, \beta h}\, d(\beta h) \tag{12}$$

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

$$f(x) = \begin{cases} |x| & -\omega/2 \le x \le \omega/2 \\ 0 & \text{elsewhere} \end{cases}$$

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

If $\beta h = x$, then $d\beta h = dx$.

Hence

$$\frac{1}{C} = \frac{\frac{1}{\pi\epsilon_0} \int \left[\frac{f\left(\frac{x}{h}\right)}{Q}\right]^2}{[\epsilon p + \epsilon r_1 \coth x]x}\, dx \tag{14}$$

or

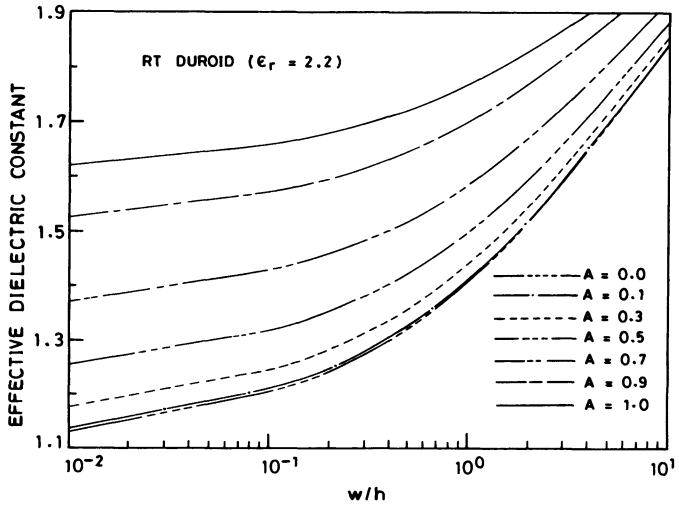


FIGURE 2

$$\frac{C}{\epsilon_0} = \frac{\pi}{\int 2\left[\dfrac{\sin\left(\dfrac{x}{2}\dfrac{\omega}{h}\right)}{\dfrac{x}{2}\dfrac{\omega}{h}}\right] - \left[\dfrac{\sin\dfrac{x}{4}\dfrac{\omega}{h}}{\dfrac{x}{4}\dfrac{\omega}{h}}\right]^2 dx}{(\epsilon p + \epsilon r_1 \coth x)x} \tag{15}$$

The effective permittivity of microstrip is given by

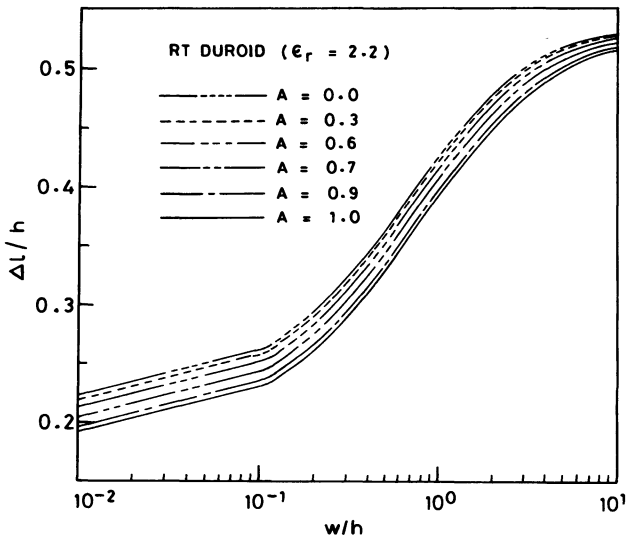


FIGURE 3

$$\epsilon_{eff} = \frac{C}{C_0} \tag{16}$$

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

$$\epsilon_{eff} = \frac{\epsilon_r + \epsilon p}{2} + \frac{\epsilon_r - \epsilon p}{2} \frac{1}{\sqrt{1 + \frac{12h}{\omega}}} \frac{\omega}{h} \geq 1 \tag{17}$$

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

$$\frac{\Delta\ell}{h} = 0.412 \cdot \frac{\epsilon_e + 0.3}{\epsilon_e - 0.258} \cdot \frac{\frac{\omega}{h} + 0.262}{\frac{\omega}{h} + 0.813} \tag{18}$$

NUMERICAL RESULTS

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

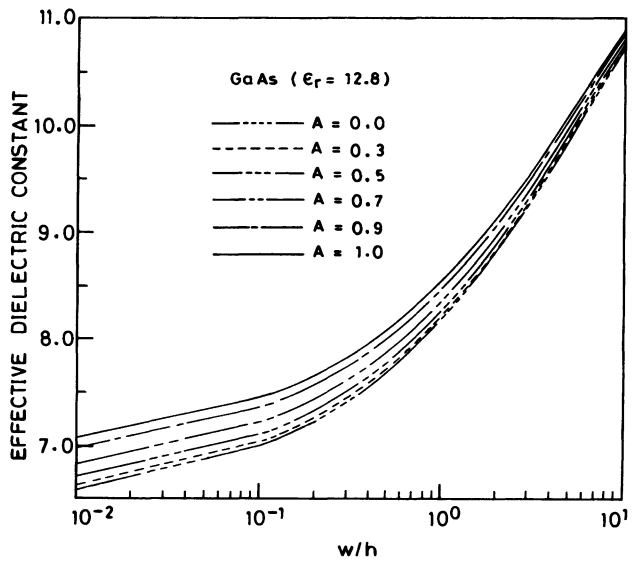


FIGURE 4

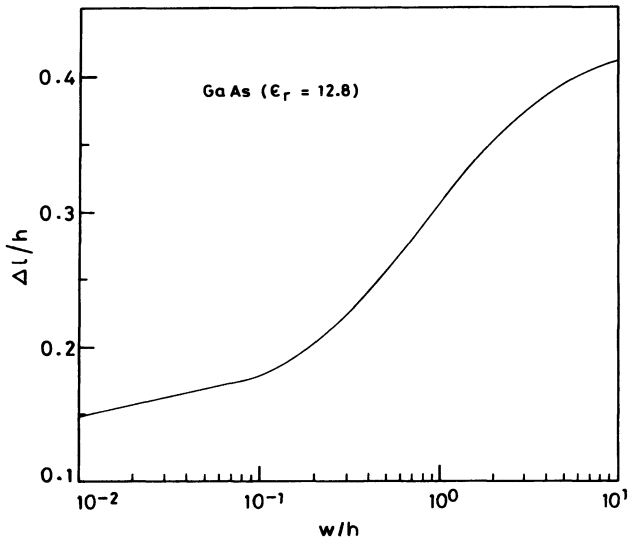


FIGURE 5

CONCLUSIONS

Calculations of length extension ($\Delta\ell$) 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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