EXAM I Fall 2001

1

$$P_d = \int_V \frac{1}{2} (\omega \epsilon'') |\underline{E}|^2 dV$$

$$= V \frac{1}{2} (\omega \epsilon'') |\underline{E}|^2$$

$$= V \frac{1}{2} \omega \epsilon' \tan\delta \ |\underline{E}|^2$$

$$10^3 = 10^{-3} \frac{1}{2} (2\pi)(2.45 \times 10^9)$$
$$\cdot (8.854 \times 10^{-12})(81) \cdot (0.1) \cdot |\underline{E}|^2$$

$$|\underline{E}| = 1.354 \times 10^3 \ [V/m]$$

(2)

$$\epsilon_r' = \epsilon_r(\infty) + \frac{\epsilon_r(0) - \epsilon_r(\infty)}{1 + (\omega\tau)^2}$$

$$\epsilon_r'' = \left(\epsilon_r(0) - \epsilon_r(\infty)\right)\left(\frac{\omega\tau}{1+(\omega\tau)^2}\right)$$

$$\epsilon_r(0) = 81$$

At 17 GHz, $\omega\tau = 1$

$$\epsilon_r' = 42$$

Hence

$$42 = \epsilon_r(\infty) + \frac{81 - \epsilon_r(\infty)}{1+1}$$

Hence

$$\epsilon_r(\infty) = 3.0$$

$$\epsilon_r' = 3.0 + \frac{78}{1+(\omega\tau)^2}$$

$$\epsilon_r'' = 78\left(\frac{\omega\tau}{1+(\omega\tau)^2}\right)$$

At 2.45 GHz, $\omega\tau = (1)\left(\frac{2.45}{17}\right)$

$$= 0.1453$$

$$\boxed{\begin{aligned} \epsilon_r' &= 79.413 \\ \epsilon_r'' &= 11.012 \\ \epsilon_{rc} &= 79.413 - j11.012 \end{aligned}}$$

3

$$\alpha_c = \frac{R_s}{2 Z_0} \left[\frac{1}{|I|^2} \int_{C_A + C_B} | J_{sz}(l) |^2 \, dl \right]$$

$$R_s = \frac{1}{\sigma \delta} = \frac{1}{\sigma \sqrt{\frac{2}{\omega \mu \sigma}}}$$

Hence

$$\boxed{\alpha_c \propto \sqrt{f}}$$

$$k_z = k$$

$$\beta - j\alpha = k' - j k''$$

$$\alpha = k''.$$

(4)

a) $\alpha_d \doteq k''$

$$k = \omega\sqrt{\mu_0 \epsilon_0}\,\sqrt{\epsilon_r}\,\sqrt{1 - j\tan\delta}$$

$$\doteq \omega\sqrt{\mu_0 \epsilon_0}\,\sqrt{\epsilon_r}\,(1 - j\tan\delta/2)$$

$$k'' \doteq \omega\sqrt{\mu_0 \epsilon_0}\,\sqrt{\epsilon_r}\,\tan\delta/2,$$

Hence

$$\alpha_d \doteq 2\pi f_1\sqrt{\mu_0 \epsilon_0}\,\sqrt{\epsilon_r}\,\tan\delta/2.$$

$$\boxed{\alpha_d = 0.01519}$$

b)

At 10 MHz

$$\alpha_c = 0.01 / 8.6859$$
$$= 0.0011513$$

At 1 GHz $\alpha_c = (0.0011513)\sqrt{100}$

$$= 0.011513$$

$$\boxed{\alpha_c = 0.011513}$$

c)

$$\alpha = 0,0267$$

So

$$dB/m = (0,0267)(8,6859)$$

$$\boxed{dB/m = 0,232}$$

$$\alpha_d = k_0 \sqrt{\epsilon_r} \left(- Im \sqrt{1 - \tan\delta} \right)$$

Hence $\boxed{\alpha_d \propto f}$

Hence At low frequencies α_c will be larger while at high frequencies α_d will be larger.