Sample Problem on Coaxial line

Problem on Coaxial Line : Comparison of air-filled & Teflon-filled Lines (1

From p.57 Eq.(2.32)

$$Z_0 = \sqrt{\frac{\mu}{\epsilon}} \frac{\ln(b/a)}{2\pi} = \frac{60}{\sqrt{\epsilon_r}} \ln(b/a)$$

For 50 Ω <u>air-filled line</u> $b/a = 2.3$

For $Z_0 = 50\ \Omega$ <u>Teflon-filled line</u> $\epsilon_r = 2.08$ $b/a = 3.326$

<u>From p.81</u>

$$\alpha = \frac{1}{2}\left[\frac{R_s}{\eta \ln b/a}\left(\frac{1}{a}+\frac{1}{b}\right) + \omega\epsilon''\eta\right] \times 8.686 \text{ dB/m}$$ (See p.64)

$$\equiv \alpha_c + \alpha_d$$

For an <u>air-filled line</u> $\alpha_d \simeq 0$; Take $a = 1$ mm ; $b = 2.3$ mm

$$\alpha_c = \frac{1}{2} \frac{R_s}{2\pi Z_0}\left(\frac{1}{a}+\frac{1}{b}\right) \times 8.686 \text{ dB/m}$$

From Eq.(1.98) p.27,

$$R_s = \frac{1}{\sigma \delta_s} = 1.988\sqrt{\frac{f_{MHz}}{\sigma}}$$

$\sigma = 5.813 \times 10^7$ S/m
See App. F p. 687

For Cu at 3 GHz

$$R_s = 0.014\ \Omega/\square$$

$$\alpha_c = \frac{0.014}{4\pi \times 50}\left(\frac{1}{1}+\frac{1}{2.3}\right) \times 10^3 \times 8.686$$

$$= 0.278 \text{ dB/m} \quad \approx \sqrt{f_{MHz}}$$

<u>For a Teflon filled line</u> $\alpha_d \neq 0$; $a = 1$ mm ; $b = 3.326$ mm

$$\alpha_c = \frac{0.014}{4\pi \times 50}\left(\frac{1}{1}+\frac{1}{3.326}\right) \times 10^3 \times 8.686 \text{ dB/m}$$

$$= 0.252 \text{ dB/m}$$

$$\alpha_d = \frac{1}{2}\omega\epsilon''\eta \times 8.686$$

$$= \pi \times 3 \times 10^9 \times (73.67 \times 10^{-16}) \times 50 \times 8.686$$

$$= 0.032 \text{ dB/m} \approx \sqrt{f_{MHz}}$$

; $\tan\delta = \frac{\epsilon''}{\epsilon'} = 0.0004$ at 10 GHz (See p. 687, App. G)

$\epsilon' = 2.08$ App. E

$\epsilon'' = 4 \times 10^{-4} \times 2.08 \times 8.854 \times 10^{-12}$ F/m

$= 73.67 \times 10^{-16}$

$$\alpha_{total} = 0.252 + 0.032 = 0.284 \text{ dB/m}$$

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in dB: $\log_{10} e^{-2\alpha x} \Rightarrow -2\alpha \times 10\log_{10} e = -(8.686)(\alpha x)$

pp.128/129 (Eq. 3.159) $\lambda_c \approx \pi(a+b)$ ← average circumference $\frac{2\pi a + 2\pi b}{2}$

$$f_c \simeq \frac{c_\epsilon}{\lambda_c} = \frac{c_\epsilon}{\pi(a+b)}$$

For air-filled coax. $$f_c = \frac{3\times10^8}{\pi(1+2.3)\times10^{-3}} = 31.83 \text{ GHz}$$

For Teflon-filled coax. $$f_c = \frac{3\times10^8/\sqrt{2.08}}{\pi(1+3.326)\times10^{-3}} = 15.31 \text{ GHz}$$

p. 156 Power capacity of a coax line (air-filled line) $E_\rho = \frac{V_0}{\rho \ln b/a}$

$$E_{max} = E_\rho\Big|_{\rho=a} = \frac{V_0}{a\ln(b/a)} \simeq 30{,}000 \text{ V/cm} = 3\times10^6 \text{ V/m} \text{ for dry air}$$

$$V_{max} = 3\times10^6\, a \ln(b/a) \quad \text{peak to peak} \Rightarrow 3\times10^6 \times (1\times10^{-3}) \ln 2.3$$

$$\Rightarrow 2499 \text{ Volts}$$

$$P_{max} = \frac{V_{max}^2}{2 Z_0} = \frac{(2499)^2}{2\times50} = 62.44 \text{ KW}$$