Report.
(3기p)
Cheng.

문 7-8. 다음의 주파수 (a) 1 MHz (b) 1GHz 에서

구리 (σ_{cu} = 5.80 x10^{7} S/m) 와

황동 (σ_{br} = 1.59 x 10^{7} S/m) 의

특성임피던스, 감쇄상수 (Np/m, dB/m) , 표피두께를 구하고 비교.

$5.8 \times 10^7 \, S/m$

구리 (Cu) 에서 Skin depth "δ", 감쇄상수 "α" Np/m, 특성임피던스 η_m.

< 1 MHz >

* Skin depth.

$$\delta = 1/\alpha = 1 \Big/ \sqrt{\pi f \mu \sigma}$$

$\mu = \mu_0 \mu_r$ $(\mu_r = 1)$ $= \mu_0 = 4\pi \times 10^{-7}$

$$= 1 \Big/ \sqrt{\pi \times 10^6 \, Hz \times 4\pi \times 10^{-7} \times 5.8 \times 10^7}$$

$$= 6.6085 \times 10^{-5}$$

$$\doteqdot \underline{6.61 \times 10^{-5}} \; m$$

* α 감쇄상수 [Np/m]

dB/m ? 못구하겠음?

$$\alpha = 1/\delta = 1 \Big/ 6.61 \times 10^{-5}$$

$$= 1.5132 \times 10^4$$

$$\doteqdot \underline{1.51 \times 10^4 \; Np/m}$$

η_c . η_m

* 특성 임피던스. [Ω] $\eta_c = (1+j)\sqrt{\dfrac{\pi \mu f}{\sigma}} = (1+j)\dfrac{1}{\sigma\delta}$

$$= (1+j) \frac{1}{5.8 \times 10^7 \times 6.61 \times 10^{-5}}$$

$$= (1+j)\, 2.60897 \times 10^{-4} \; [\Omega]$$

$$\doteqdot \underline{(1+j)\, 2.61 \times 10^{-4} \; \Omega}$$

+ α 감쇠 상수 에서 dB/m 표현.

$$1 \text{ Neper} = 8.686 \text{ dB}$$

$$\alpha = 8.686 \times 1.51 \times 10^4 \text{ Np/m}$$

$$= 1.31 \times 10^5 \text{ dB/m}$$

구리 (cu)

< 1 GHz >

* Skin depth $\delta = 1/\alpha = 1/\sqrt{\pi f \mu \sigma}$

$= 1/\sqrt{\pi \times 10^9 Hz \times 4\pi \times 10^{-7} \times 5.8 \times 10^7}$

$= 2.0898 \times 10^{-6}$

$\doteqdot 2.09 \times 10^{-6}$ m

1 Nepor = 8.686 dB

* 감쇄상수 $\alpha = 1/\delta = 1/2.09 \times 10^{-6}$

$\doteqdot 4.79 \times 10^5$ Np/m

dB/m $\Rightarrow$ $8.686 \times 4.79 \times 10^5 \doteqdot 4.16 \times 10^6$ dB/m

* 특성 임피던스 $\eta_m = (1+j)\frac{1}{\sigma \cdot \delta}$

$= (1+j)\left(\frac{1}{5.8 \times 10^7 \times 2.09 \times 10^{-6}}\right)$

$= (1+j)\, 8.25 \times 10^{-3}$ Ω

황동 ($\sigma_{br} = 1.59 \times 10^{7}$ ℧/m) 에서 " δ, α, η_c "

< 1 MHz >

$$\ast\ \delta = 1/\alpha = 1/\sqrt{\pi \mu f \sigma}$$

$$= 1/\sqrt{\pi \times 4\pi \times \cancel{10^{-7}} \times 10^{6}\,\text{Hz} \times 1.59 \times \cancel{10^{7}}}$$

$$= 1/\sqrt{6.36 \times \pi^2 \times 10^{6}}$$

$$\doteqdot 1.26 \times 10^{-4}\ m$$

$$\alpha = 1/\delta \doteqdot 7.92 \times 10^{3}\ Np/m$$

$$\rightarrow 8.686 \times \alpha(Np/m) \doteqdot 6.88 \times 10^{5}\ dB/m$$

$$\eta_c = (1+j) \cdot \frac{1}{\sigma \cdot \delta}$$

$$= (1+j) \cdot \frac{1}{1.59 \times 10^{7} \times 1.26 \times 10^{-4}}$$

$$\doteqdot (1+j) \cdot 4.98 \times 10^{-4}\ [\Omega]$$

황동 ($\sigma_{br} = 1.59 \times 10^{7}$ S/m)

< 1 GHz >

* $\delta = 1/\sqrt{\pi \mu f \sigma}$

$= 1/\sqrt{6.36 \times \pi^{2} \times 10^{9}}$

$\fallingdotseq 3.99 \times 10^{-6}$ m

* $\alpha = 1/\delta \fallingdotseq 2.51 \times 10^{5}$ Np/m

$\rightarrow$ 8.686 dB/Np $\times$ 2.51×10^{5} Np/m $=$ 2.18×10^{6} dB/m

* $\eta_c = (1+j)\dfrac{1}{\sigma \cdot \delta}$

$= (1+j) \cdot \left(1/1.59 \times 10^{7} \times 3.99 \times 10^{-6} \right)$

$= (1+j)\ 1.58 \times 10^{-2}\ \Omega$

문 7-9. 100 MHz 에서

흑연의 표피두께는 0.16 mm 라고 할 때,

(a) 흑연의 도전율과

(b) 1 GHz의 파가 흑연 내를 전파할 때 그 전계강도가
30 dB 만큼 줄어드는 거리를 계산하라.

b) 1GHz → 흑연, −30dB 감소. 거리는 ?

$$\alpha = \sqrt{\pi f \mu \sigma}$$

f: 1GHz = 10^9Hz, μ: $4\pi \times 10^{-7}$, σ: 9.9×10^4 S/m

$$= \sqrt{\pi \times 10^9 \times 4\pi \times 10^{-7} \times 9.9 \times 10^4}$$

$$= \sqrt{4\pi^2 \times 9.9 \times 10^6}$$

$$\fallingdotseq 1.98 \times 10^4 \ Np/m$$

$$20 \cdot \log_{10} e^{-\alpha z} = -30 \ dB$$ 이므로

$$\cancel{-}\alpha z \log e = \cancel{-}\frac{3}{2}$$ 를 정리하면

$$z = 1.5 / \alpha \log e = \frac{1.5}{1.98 \times 10^4 \times \log e}$$

$$= 1.744 \times 10^{-4} \ m$$

$$= 0.174 \ mm$$

a) 흑연의 도전율. "$\sigma_{흑}$"

$$\delta = 1/\sqrt{\pi \mu f \sigma}$$

$\downarrow$ 변형

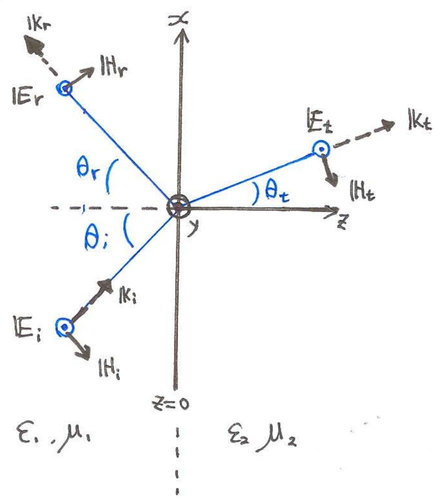
$$\sigma = \frac{1}{\pi f \mu \delta^2}$$

$$= \frac{1}{\pi \times 100 \times \cancel{10^6}\,\mathrm{Hz} \times 4\pi \times \cancel{10^{-7}} \times (0.16 \times 10^{-3})^2}$$

$$= \frac{1}{40\pi^2 \times (0.16 \times 10^{-3})^2}$$

$$\fallingdotseq 9.90 \times 10^4 \ \mathrm{S/m}$$

Cheng 373p. 문 7-21)



<그림 7-14>

그림 7-14 에 보인 바와 같이, 수직 편파된 평면파가

$$\begin{cases} \epsilon_1 = \epsilon_0, \quad \epsilon_2 = 2.25\,\epsilon_0 \\ \mu_1 = \mu_2 = \mu_0 \end{cases}$$

인 경계평면으로

경사각을 가지고 입사하였다.

"$E_{io} = 20\ V/m$, $f = 100\ MHz$, $\theta_i = 30°$" 라고

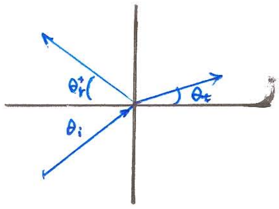
가정하고,

a) 반사 및 투과 계수를 구하라.

b) $\mathbf{E}_t(x, z; t)$ 와 $\mathbf{H}_t(x, z; t)$ 에 대한 순시식을 써라.

면파.

a) 반사, 투과계수.



$$\theta_r = \theta_i$$

$$\frac{\sin\theta_t}{\sin\theta_i} = \frac{n_1}{n_2} = \frac{\eta_2}{\eta_1} = \sqrt{\frac{\varepsilon_1}{\varepsilon_2}}$$

$(\mu_1 = \mu_2)$

$$\sin\theta_t = \sqrt{\frac{\varepsilon_1}{\varepsilon_2}} \cdot \sin\theta_i$$

$$= \sqrt{\frac{1}{2.25}} \cdot \sin\theta_i = \frac{2}{3}\sin\theta_i \qquad (\theta_i = 30^\circ)$$

$$= \frac{2}{3}\sin 30^\circ = \frac{1}{3}$$

$$\therefore \ \sin\theta_t = \frac{1}{3} \qquad (\theta_t \doteqdot 19.47^\circ)$$

$$\cos\theta_t = \cos(19.47^\circ) = 0.9428$$

$$\frac{\eta_2}{\eta_1} = \sqrt{\varepsilon_1/\varepsilon_2}$$

$\downarrow$ 이용.

$$\left(* \ \eta_0 \doteqdot 377\,\Omega \ \rightarrow \ \eta_1 = \eta_0 \right)$$

$$\therefore \frac{\eta_2}{377} = \frac{2}{3} \ \rightarrow \ \eta_2 = 251.33\,\Omega$$

$$\therefore \eta_2 = 251.33\,\Omega$$

수직 편파 반사계수

$$\Gamma_{\perp} = E_{ro}/E_{io}$$

$$= \frac{\eta_2 \cos\theta_i - \eta_1 \cos\theta_t}{\eta_2 \cos\theta_i + \eta_1 \cos\theta_t}$$

$$= \frac{251.33 \times \cos 30^\circ - 377\,(0.9428)}{251.33 \times \cos 30^\circ + 377\,(0.9428)}$$

$$= -0.240$$

수직편파 투과계수

$$\tau_{\perp} = \frac{E_{to}}{E_{io}} = 1 + \Gamma_{\perp}$$

$$= 1 - 0.24 = 0.76$$

* $\mathbb{E}_t(x.y ; t)$ 순시식

(Cheng 7-141 식)

$$\mathbb{E}_t(x.z) = E_{t0}\, e^{-j\beta_2 (x \sin\theta_t + z\cos\theta_t)} \cdot \bar{y}$$

이용.

* $\tau_\perp = 0.760 \xrightarrow{\text{이용}} \tau_\perp = E_{t0}/E_{i0}$

$\Rightarrow E_{t0} = 20 \times 0.76$

$= 15.2$

* $\sin\theta_t = 0.333$, $\cos\theta_t = 0.943$

* $\beta_2 = \omega\sqrt{\mu_2\varepsilon_2} = \omega\sqrt{\mu_0\varepsilon_0}\cdot\sqrt{\varepsilon_r} = \cancel{2\pi\cdot 10^8 Hz}\cdot\cancel{\frac{1}{3\times10^8}} \times \cancel{\frac{3}{2}}$

$= \pi$

$$\mathbb{E}_t(x.z) = 15.2\, e^{-j\pi(0.333x + 0.943z)} \cdot \bar{y}$$

$$= 15.2\, e^{-j(1.047x + 2.9619z)} \cdot \bar{y}$$

↓ Real Part 순시값.

$$\mathbb{E}_t(x.y ; t) = \underline{15.2 \cos\left(2\pi\times10^8 t - (1.047x + 2.962z)\right)\cdot\bar{y}}$$

[V/m]

(cheng 7-142)

$$\mathbb{H}_t(x.z) = \frac{E_{t0}}{\eta_2}\left(-\cos\theta_t\cdot\bar{x} + \sin\theta_t\cdot\bar{z}\right)e^{-j\beta_2(\sim)}$$

$$\left\{\begin{array}{l} * \; E_{t0} = 15.2 \\ \quad \eta_2 = 251.33 \\ \\ * \left(\begin{array}{l} \cos\theta_t = 0.9428 \\ \sin\theta_t = 0.3333 \end{array}\right. \\ \\ * \; \beta_2 = \pi \end{array}\right.$$

$$\therefore \mathbb{H}_t(x.z) = \frac{15.2}{251.33}\left(-0.943\,\bar{x} + 0.333\,\bar{z}\right)e^{-j(1.049x + 2.962z)}$$

$$\downarrow$$

$$\underline{\mathbb{H}_t(x.z:t) = 0.06\left(-0.943\,\bar{x} + 0.333\,\bar{z}\right)e^{-j(1.049x + 2.962z)}} \;//$$

[V/m]

TM mode : E mode 유도 하기!

* $e_z \neq 0$ 이고, $h_z = 0$ 일 때,

* 식 5-5 변형 →

(식 5-5")

$$\left.\begin{array}{l} \left.\begin{array}{l} e_x = \dfrac{-j}{k_c^2} \cdot \beta \dfrac{\partial e_z}{\partial x} \\[2ex] e_y = {}^{-j}/_{k_c^2} \cdot \beta \dfrac{\partial e_z}{\partial y} \end{array}\right) \\[6ex] \left.\begin{array}{l} h_x = \dfrac{j}{k_c^2} \; \omega\varepsilon \dfrac{\partial e_z}{\partial y} \\[2ex] h_y = \dfrac{-j}{k_c^2} \; \omega\varepsilon \dfrac{\partial e_z}{\partial x} \end{array}\right) \end{array}\right\}$$

where, $k_c^2 = k^2 - \beta^2$

$e_z(x.y)$는 $\underbrace{\text{holmholtz's Eq}}$ (2-6) 을 만족해야함.

$$\nabla^2 \mathbb{E} + k^2 \mathbb{E} = 0$$

$$\underbrace{\frac{\partial^2 e_z}{\partial x^2} + \frac{\partial^2 e_z}{\partial y^2} = -k_c^2 e_z}$$ (5-36 변형식)

where, $e_z(x.y) = X(x)\,Y(y)$

↓

$$X''Y + XY'' = -k_c^2 XY$$

양변을 XY로 나눈다.

$$\underbrace{\frac{X''}{X}}_{-k_x^2} + \underbrace{\frac{Y''}{Y}}_{-k_y^2} = -k_c^2$$

$(\because k_x^2 + k_y^2 = -k_c^2)$

x 방향 파수 y 방향 파수

$$\frac{1}{X}\cdot\frac{d^2X}{dx^2} = -k_x^2 \text{ 의 해.}$$

$$\frac{d^2X}{dx^2} + k_x^2 \cdot X = 0$$

미.방.

$$X = A\cdot e^{jk_xx} + B e^{-jk_xx}$$

삼각함수

$$= A\cos k_x x + B\sin k_x x$$

같은 방법으로 Y를 풀면,

$$Y = C\cos k_y y + D\sin k_y y$$

$$e_z(x.y) = X(x)\,Y(y)$$

$$= (A\cos k_x x + B\cos k_x x)(C\cos k_y y + D\cos k_y y)$$

*

Ⓐ

(식 5-5") 에 의해, $h_x \propto \frac{\partial e_z}{\partial y}$ 이므로,

$$\frac{\partial e_z}{\partial y} = \frac{\partial}{\partial y}\left\{(A\cos k_x x + B\sin k_y y)\cdot(C\cdot\cos k_y y + D\sin k_y y)\right\}$$

$$= \underbrace{(A\cos k_x x + B\sin k_x x)}_{*}(-k_y\cdot C\cdot\sin k_y + k_y\cdot D\cos k_y y)$$

($x=0$, a) 일때,

① $x=0$, $A\cdot\cos k_x\cdot 0 = 0$ $\therefore A=0$

② $x=a$ $B\cdot\sin \underbrace{k_x\cdot a}_{m\pi.} = 0$ $(m = 1.2.3\cdots)$

$$k_x = \frac{m\pi}{a}$$

정리하면, $A=0$, $k_x = \frac{m\pi}{a}$

B (식 5-5") 에 의해, $h_y \propto \frac{\partial e_z}{\partial x}$ 이므로,

$$\frac{\partial e_z}{\partial x} = \frac{\partial}{\partial x}(A\cos k_x x + B\sin k_x x)\cdot(C\cos k_y y + D\sin k_y y)$$

x에 미분.

$$= (-k_x\cdot A\cdot\sin k_x x + k_x\cdot B\cdot\cos k_x x)\cdot(C\cos k_y y + D\sin k_y y)$$

① $y=0$ 일때

$$C\cdot\cos k_y\cdot 0 = 0$$

$$\therefore\ C=0$$

② $y=b$ 일때,

$$D\cdot\sin(k_y b) = 0$$

$n\pi$ $(k_y\cdot b = n\pi \quad (n=1.2.3\cdots))$

정리하면, $C=0,\ k_y = \frac{n\pi}{b}$

$\therefore$

$$e_z(x.y)\,e^{-j\beta z}$$

$$= E_{mn}\sin\frac{m\pi x}{a}\sin\frac{n\pi y}{b}\,e^{-j\beta z}$$

(E_{mn}은 B, D의 진폭상수)

$$= E(x.y.z)$$

< 5-40 식 유도. >

$e_z \equiv E_z(x,y)$

$$* \; e_z(x,y,z) = E_{mn} \sin\frac{m\pi x}{a} \sin\frac{n\pi y}{b} e^{-j\beta z}$$

(식 5-5)을 $e_z \neq 0$, $h_z = 0$ 조건에 맞추어 변형.

↓

(5-5″)

$$e_x = \frac{-j}{k_c^2} \beta \frac{\partial e_z}{\partial x} \quad / \quad e_y = \frac{-j}{k_c^2} \beta \frac{\partial e_z}{\partial y}$$

$$h_x = \frac{j}{k_c^2} \omega\varepsilon \frac{\partial e_z}{\partial y} \quad / \quad h_y = \frac{-j}{k_c^2} \cdot \omega\varepsilon \frac{\partial e_z}{\partial x}$$

이용하여 각 식을 유도.

$$e_x = \frac{-j}{k_c^2} \beta \frac{\partial}{\partial x} \left(E_{mn} \sin\frac{m\pi x}{a} \sin\frac{n\pi y}{b} e^{-j\beta z} \right)$$

x 편미분.

$$= \frac{-j}{k_c^2} \cdot \beta \cdot E_{mn} \cdot \frac{m\pi}{a} \cdot \cos\frac{m\pi x}{a} \cdot \sin\frac{n\pi y}{b} e^{-j\beta z}$$

$$= \frac{-j\beta m\pi}{a \cdot k_c^2} \cdot E_{mn} \cdot \cos\frac{m\pi x}{a} \sin\frac{n\pi y}{b} e^{-j\beta z}$$

(5-40 a)

같은 방법으로.

$$e_y = \frac{-j}{k_c^2} \beta \cdot \frac{\partial}{\partial y} \left(E_{mn} \sin\frac{m\pi x}{a} \sin\frac{n\pi y}{b} e^{-j\beta z} \right)$$

y 편미분.

$$= \frac{-j\beta n\pi}{b \cdot k_c^2} \cdot E_{mn} \sin\frac{m\pi x}{a} \cos\frac{n\pi y}{b} e^{-j\beta z}$$

(5-40b)

$$h_x = \frac{j}{k_c^2}\,\omega\varepsilon\,\frac{\partial e_z}{\partial y}$$

$$= \frac{j}{k_c^2}\,\omega\varepsilon\,\frac{\partial}{\partial y}\left(E_{mn}\,\sin\frac{m\pi x}{a}\,\sin\frac{n\pi y}{b}\cdot e^{-j\beta z}\right)$$

y 편미분.

$$= \frac{j\omega\varepsilon\, n\pi}{b\cdot k_c^2}\cdot E_{mn}\cdot\sin\frac{m\pi x}{a}\,\cos\frac{n\pi y}{b}\cdot e^{-j\beta z}$$

(5-40c)

$$h_y = \frac{-j}{k_c^2}\cdot\omega\varepsilon\cdot\frac{\partial e_z}{\partial x}$$

$$= \frac{-j}{k_c^2}\,\omega\varepsilon\,\frac{\partial}{\partial x}\left(E_{mn}\cdot\sin\frac{m\pi x}{a}\cdot\sin\frac{n\pi y}{b}\cdot e^{-j\beta z}\right)$$

x 편미분.

$$= \frac{-j\omega\varepsilon\, m\pi}{a\cdot k_c^2}\cdot E_{mn}\cdot\cos\frac{m\pi x}{a}\,\sin\frac{n\pi y}{b}\,e^{-j\beta z}$$

(5-40d)