VALOVI 9.

2015/16

3. Ravni EM val se širi sredstvom $\mu_r = 2$

$\bar{E} = 2\sin(8\cdot10^8 t - 5z)\,\bar{a_y}$ V/m

Smjer u kojem se giba val, valnu duljinu λ, ε_r, $\bar{H}(t = 20\,ms,\ z = 12\,m)$

x val x
z E y
-y H z

a) $\beta = 5$

$\omega = 8\cdot10^8$

b) val se giba u smjeru $\bar{a_z}$

$\bar{E} \to \bar{a_y}$

$\bar{H} \to -\bar{a_x}$

$\bar{a_z}$
$\bar{a_y}$
$-\bar{a_x}$

z
x y
y z x

$$\lambda = \frac{2\pi}{\beta} = 1{,}257\ m$$

$$\beta = \omega\sqrt{\mu\varepsilon}$$

$$\mu_0\mu_r\varepsilon_0\varepsilon_r = \frac{\beta^2}{\omega^2}$$

$$\varepsilon_r = \frac{\beta^2}{\omega^2}\cdot\frac{1}{\mu_0\mu_r\varepsilon_0} = 1{,}755$$

$$\frac{E_0}{H_0} = \frac{\omega\mu}{\beta}$$

$$H_0 = \frac{E_0\beta}{\omega\mu}$$

c) $$\bar{H} = \frac{1}{\omega\mu}\,\bar{\beta}\times\bar{E}$$

$$|Z| = \frac{E_0}{H_0} = 120\pi\sqrt{\frac{\mu_r}{\varepsilon_r}}$$

$$H_0 = \frac{E_0}{|Z|} = \frac{E_0}{120\pi\sqrt{\frac{\mu_r}{\varepsilon_r}}} = 4{,}97\ mA/m$$

$$\bar{H} = 4{,}97\cdot10^{-3}\sin(8\cdot10^8 t - 5z)$$

$$\bar{H} = 4{,}89\ mA/m$$

$$\bar{H} = \frac{1}{\omega\mu}\,\bar{\beta}\times\bar{E} = \frac{1}{\omega\mu}\begin{vmatrix} \bar{a_x} & \bar{a_y} & \bar{a_z} \\ 0 & 0 & 5 \\ 0 & 2 & 0 \end{vmatrix} = -\frac{10}{\omega\mu}\,\bar{a_x}$$

9.1.

ZI 14/15 sinusni ravni val

$$\bar{E} = (\bar{a_x} - \bar{a_y}) \cos[2\cdot 10^8 t - 2(x+y)] \text{ V/m} \quad , \mu_r = 1$$

$$\bar{E} = E_m e^{-\alpha x} \cos(\omega t - \beta x)$$

a) vektor mag. polja

$$\bar{H} = \frac{1}{\mu\omega} \beta \times \bar{E} \quad , \omega = 2\cdot 10^8 \text{ rad/s}$$

$$\left.\begin{array}{l} \bar{\beta} = \beta_x \bar{a_x} + \beta_y \bar{a_y} + \beta_z \bar{a_z} \\ \bar{r} = x\bar{a_x} + y\bar{a_y} + z\bar{a_z} \end{array}\right\} \bar{\beta} = 2(\bar{a_x} + \bar{a_y})$$

$$|\beta| = \sqrt{8}$$

$$\bar{\beta} \times \bar{E} = 2(\bar{a_x} + \bar{a_y}) \times (\bar{a_x} - \bar{a_y}) \cos(2\cdot 10^8 t - 2(x+y))$$

$$= 2(-\bar{a_z} - \bar{a_z}) \cos(\;)$$

$$\bar{H} = \frac{1\cdot(-4)}{\mu_0 \omega} \cos(\;) \bar{a_z}$$

$$\bar{H} = \frac{-\bar{a_z}}{20\pi} \cos(\omega t - 2(x+y)) \text{ A/m}$$

b) Poyntingov vektor

$$\bar{N} = \bar{E} \times \bar{H} = (\bar{a_x} - \bar{a_y}) \cos(\;) \times (-\bar{a_z}) \frac{\cos(\;)}{20\pi}$$

$$\bar{N} = (\bar{a_y} + \bar{a_x}) \frac{1}{20\pi} \cos^2(\omega t - 2(x+y))$$

c) valna impedancija sredstva

$$|Z| = 120\pi \sqrt{\frac{\mu_r}{\varepsilon_r}} = \frac{40\pi}{\sqrt{2}}$$

d) $\varepsilon_r = ?$

$$c = \frac{c_0}{\sqrt{\mu_r \varepsilon_r}} \qquad \frac{\omega}{\beta} = \frac{c_0}{\sqrt{\varepsilon_r}} \qquad \varepsilon_r = \left(\frac{c_0 \beta}{\omega}\right)^2 = 18$$

$$\beta = \frac{\omega}{c} \Rightarrow c = \frac{\omega}{\beta}$$

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4. $\bar{E} = 100\, \bar{a}_z \cos(\omega t - x - 2y)$ [V/m] , $\varepsilon_r = 4$, $\mu_r = 1$

$\bar{H}$, $\omega = ?$ $\qquad E = 100 \cos(\omega t - x - 2y)$

$$\bar{\beta} = \beta_x \bar{a}_x + \beta_y \bar{a}_y + \beta_z \bar{a}_z = \bar{a}_x + 2\bar{a}_y \qquad |\beta| = \sqrt{5}$$

$$\beta = \frac{\omega}{c} \Rightarrow \omega = \beta \cdot c = \beta \cdot \frac{c_0}{\sqrt{\mu_r \varepsilon_r}} = 3{,}35 \cdot 10^8 \ s^{-1}$$

$$\bar{H} = \frac{1}{\mu\omega} \bar{\beta} \times \bar{E} = \frac{1}{\mu\omega} \begin{vmatrix} \bar{a}_x & \bar{a}_y & \bar{a}_z \\ 1 & 2 & 0 \\ 0 & 0 & E \end{vmatrix} = \frac{1}{\mu\omega} (2E\bar{a}_x - E\bar{a}_y)$$

$$\bar{H} = \frac{100}{\mu_r \mu_0 \omega} (2\bar{a}_x - \bar{a}_y) \cos(\omega t - x - 2y) = (0{,}475\, \bar{a}_x - 0{,}238\, \bar{a}_y) \cos(\omega t - x - 2y)$$

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Mag. polje ravnog EM vala se prostire u sredstvu bez gubitaka. Vektor el. polja?

3. $\bar{H} = (-\bar{a}_x + \bar{a}_y)\cos(\omega t - 0{,}1\pi(x+y+z))$ A/m $\quad \bar{H}_0 = (-\bar{a}_x + \bar{a}_y)e^{-j0{,}1\pi(x+y+z)}$

$\mu = \mu_0$ $\quad \bar{\beta}\cdot\bar{r} = 0.1\pi(x+y+z)$ $\quad \bar{r} = x\bar{a}_x + y\bar{a}_y + z\bar{a}_z$

$\omega = 10^7\ s^{-1}$ $\quad \bar{\beta} = 0.1\pi(\bar{a}_x + \bar{a}_y + \bar{a}_z)$

$\beta_x = \beta_y = \beta_z = 0.1\pi$

$\bar{E} = ?$ srednja snaga kroz kvadrat stranice $a = 0{,}1$ m čija je površina okomita na pravac prostiranja vala

$\bar{\beta} = 0.1\pi(\bar{a}_x + \bar{a}_y + \bar{a}_z)$

$\bar{H}_0 = (-\bar{a}_x + \bar{a}_y)$ $\quad \bar{H}_0 = \frac{\bar{\beta}\times\bar{E}_0}{\omega\mu} = \begin{vmatrix} \bar{a}_x & \bar{a}_y & \bar{a}_z \\ \beta_x & \beta_y & \beta_z \\ E_x & E_y & E_z \end{vmatrix}$

$\bar{H}_0 = \frac{1}{\omega\mu}(\bar{\beta}\times\bar{E}_0)$

$\bar{H}_0 = \frac{1}{\omega\mu}\left(\bar{a}_x(\beta_y E_z - \beta_z E_y) - \bar{a}_y(\beta_x \bar{E}_z - \beta_z \bar{E}_x)\right)$ $\quad \bar{H}_0 = (-\bar{a}_x + \bar{a}_y)$

① $\frac{1}{\omega\mu}(\beta_y E_z - \beta_z E_y) = -1$ $\quad$ ② $-\frac{1}{\omega\mu}(\beta_x E_z - \beta_z E_x) = 1$

$\beta_x = \beta_y = \beta_z$

$\beta_x E_z - \beta_x E_y = -\omega\mu$ $\quad \beta_x \bar{E}_z - \beta_x E_x = -\omega\mu$

$E_z - E_y = -\frac{\omega\mu}{\beta_x} \rightarrow$ $\quad \leftarrow E_z - E_x = -\frac{\omega\mu}{\beta_x}$

$E_z - E_y = E_z - E_x$

$E_y = E_x$

$\boxed{\bar{E}_0\cdot\bar{\beta} = 0}$ $\Rightarrow$ jer moraju biti okomiti

$E_x\beta_x + E_y\beta_y + E_z\beta_z = 0$

③ $E_x + E_y + E_z = 0$

①② → ③

$E_z + \frac{\omega\mu}{\beta_x} + E_z + \frac{\omega\mu}{\beta_x} + E_z = 0$

$E_z = -\frac{2}{3}\frac{\omega\mu}{\beta_x}$

$E_z = -26{,}67$ V/m

$E_y = E_z + \frac{\omega\mu}{\beta_x} = -\frac{2}{3}\frac{\omega\mu}{\beta_x} + \frac{\omega\mu}{\beta_x}$

$E_y = \frac{1}{3}\frac{\omega\mu}{\beta_x} = \frac{10^7\cdot 4\cancel{\pi}\cdot 10^{-7}}{3\cdot 0.1\cancel{\pi}} = 13.33\ V/m = E_x$

$\bar{E}_0 = 13{,}33\bar{a}_x + 13{,}33\bar{a}_y - 26{,}67\bar{a}_z$, $\quad \bar{E} = \bar{E}_0\cos(\omega t - 0.1\pi(x+y+z))$ V/m

$\bar{H}_0^* = (-\bar{a}_x + \bar{a}_y)e^{j0.1\pi(x+y+z)}$, $\quad \bar{E}_0 = 13{,}33(\bar{a}_x + \bar{a}_y - 2\bar{a}_z)\cdot e^{-j0.1\pi(x+y+z)}$

$N_{sr} = \frac{1}{2}(\bar{E}\times\bar{H}^*) = \frac{1}{2}\begin{vmatrix} \bar{a}_x & \bar{a}_y & \bar{a}_z \\ 13.33 & 13.33 & -26.67 \\ -1 & 1 & 0 \end{vmatrix} = \frac{1}{2}(26.67\bar{a}_x + 26.67\bar{a}_y + 26.67\bar{a}_z)$

$dS = a^2 = 0.1^2$

$\bar{n} = \bar{a}_x + \bar{a}_y + \bar{a}_z$

$P_{sr} = \int \bar{N}_{sr}\cdot\bar{n}\,dS = 13.33\cdot 3\cdot 0{,}1^2 = 0.4$ W

P.4) RAVNI VAL

4) $\mu_r = 1$
$\varepsilon_r = 2$

$\bar{H} = \bar{a}_y \, 10 \cos(\omega t - 3x)$ A/m

β, v [m/s], $E\,[t = 10\,ns,\ x = 0.4\,m] = ?$; smjer širenja vala

$\beta = 3$

smjer širenja vala $\parallel \bar{a}_x$

$$v = \pm \frac{\omega}{\beta} = \frac{\frac{\beta}{\sqrt{\mu\varepsilon}}}{\beta} = \frac{1}{\sqrt{\mu\varepsilon}} = c$$

$$\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{\omega\sqrt{\mu\varepsilon}}$$

$$\beta = \omega\sqrt{\mu\varepsilon}$$

$$\omega = \frac{\beta}{\sqrt{\mu\varepsilon}}$$

$v = \pm 2{,}12 \cdot 10^8$ m/s

$$Z = \sqrt{\frac{\mu}{\varepsilon}} = 120\pi\sqrt{\frac{\mu_r}{\varepsilon_r}} = 266{,}57$$

$$\frac{E}{H} = Z =$$

$$E_0 = Z \cdot H = 2665.7$$

$$E = 2665.7\,\bar{a}_z \cos(\omega t - 3x)$$
$$= 2665.7\,\bar{a}_z \cos\left(10 \cdot 10^{-9} \cdot \frac{3}{\sqrt{2\mu_0\varepsilon_0}} - 3 \cdot 0.4\right)$$
$$= 2654{,}9\ \bar{a}_z\ \text{V/m}$$
$$= 2{,}65\ \text{kV/m}$$

2011)

4) SINUSNO PROMJENJIV VAL

$\varepsilon_r = 6,\ \mu_r = 1,\ K = 0{,}5\ S/m$

$f = 150\ MHz \qquad \omega = 2\pi f$

$E_0 = 200\ V/m$

$\frac{K}{\omega\varepsilon} = \frac{0.5}{2\pi \cdot 150 \cdot 10^6 \cdot 6 \cdot \varepsilon_0} = 9{,}99$

$\frac{E(x=0)}{E(x=2\lambda)} = ? \qquad Z = ? \qquad N_{sr}(x = 0.8d)$

$c = \frac{c_0}{\sqrt{\mu_r \varepsilon_r}} = \frac{3 \cdot 10^8}{\sqrt{6}} = 1{,}22 \cdot 10^8$

a) $\alpha = \frac{\sqrt{2}\, c}{\omega}\left(\sqrt{1+\left(\frac{K}{\omega\varepsilon}\right)^2} - 1\right)^{-\frac{1}{2}} = \frac{\sqrt{2}}{\omega} \cdot \frac{\sqrt{6}}{6} c_0 \left(\sqrt{1+9{,}99^2} - 1\right)^{-\frac{1}{2}} = 0{,}061$

$\alpha = 16{,}39$

$\beta = \frac{\omega}{\sqrt{2}\, c} \cdot \sqrt{\sqrt{1+\left(\frac{K}{\omega\varepsilon}\right)^2} + 1} = 18{,}15$

$\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{18{,}15} = 0{,}35$

$2\lambda\alpha = \frac{4\pi}{\beta} \cdot \alpha = 2\pi \cdot \frac{\alpha}{\beta}$

0,903
0,903

b) $\frac{E(x=0)}{E(x=2\lambda)} = ? = \frac{\cancel{E_0}\, e^0 \cos\omega t}{\cancel{E_0}\, e^{-2\lambda\alpha} \cos(\omega t - \beta \cdot 2\lambda)} = \frac{\cos\omega t}{e^{-4\pi\frac{\alpha}{\beta}} \cos(\omega t - \cancel{\beta} \cdot \frac{4\pi}{\cancel{\beta}})}$

$E = E_0\, e^{-\alpha x} \cos(\omega t - \beta x)$

$= \frac{\cancel{\cos\omega t}}{e^{-4\pi\frac{\alpha}{\beta}}\, \cancel{\cos\omega t}} = e^{4\pi\frac{\alpha}{\beta}}$

$\frac{\alpha}{\beta} = 0{,}903$

c) $Z = \frac{\omega\mu}{\sqrt{\alpha^2+\beta^2}}\, e^{j\,\mathrm{arctg}\frac{\alpha}{\beta}} = \frac{2\pi f \cdot \mu_0}{\sqrt{\alpha^2+\beta^2}}\, e^{j\overbrace{\mathrm{arctg}\, 0{,}903}^{42^\circ}}$

$= 48{,}43\, e^{j42^\circ} = 48{,}43 \angle 42^\circ$

d) $x = 0.8d \qquad x = \frac{0.8}{\alpha}$

$x = 0{,}0488$

$N_{sr} = \frac{1}{2} \frac{E_0^2}{|Z|} e^{-2\alpha x} \cos\varphi = \frac{1}{2} \cdot \frac{200^2}{48{,}43}\, e^{-2 \cdot \cancel{\alpha} \cdot \frac{0{,}8}{\cancel{\alpha}} = -1{,}6} \cos 42^\circ$

$= 61{,}9$

oll) RAVNI VAL

2) $E(x,y,z,t) = E_0(x,y) \cdot e^{j(1.5\cdot10^8 t - kz)}$

$B(x,y,z,t) = B_0(x,y) \cdot e^{j(1.5\cdot10^8 t - k\cdot z)}$

E_0, B_0 su vektori u xy ravnini
k je konstanta

a) $k = ?$
b) $\lambda = ?$

Odredite konstantu k tako da su zadovoljene Maxwellove jednadžbe

a) $\nabla \times \bar{E} = -\frac{\partial B}{\partial t}$

$$\begin{vmatrix} \bar{a}_x & \bar{a}_y & \bar{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ E_x & E_y & E_z \end{vmatrix} = \bar{a}_x\left(\frac{\partial E_z}{\partial y} - \frac{\partial E_y}{\partial z}\right) + \bar{a}_y\left(\frac{\partial E_x}{\partial z} - \frac{\partial E_z}{\partial x}\right) + \bar{a}_z\left(\frac{\partial E_y}{\partial x} - \frac{\partial E_x}{\partial y}\right)$$

uzimamo samo $\bar{a}_x$ smjer

$$\frac{\partial E_y}{\partial z} = \frac{\partial B}{\partial t}$$

$$E_0(-jk)\cdot e^{j(1.5\cdot10^8 t - k\cdot z)} = \frac{dB}{dt}$$

$$B = \frac{-E_0 k e^{j(1.5\cdot10^8 t - kz)}}{1.5\cdot10^8} \qquad H = \frac{B}{\mu_0} \qquad B_0 = \frac{-E_0 k}{1.5\cdot10^8}$$

$$H_0 = \frac{-E_0\cdot k}{1.5\cdot10^8\mu_0}$$

$$\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{k} = \frac{2\pi}{0.5} = 4\pi$$

b) $\nabla \times H = \frac{\partial D}{\partial t}$

$$-\frac{\partial H}{\partial z} = \varepsilon\frac{\partial E}{\partial t}$$

$$\frac{E_0\cdot k}{1.5\cdot10^8\mu_0}(-kj)\cdot e^{j(1.5\cdot10^8 t - kz)} = \varepsilon E_0 \cdot 1.5\cdot10^8 j e^{j(1.5\cdot10^8 - kz)}$$

$$k^2 = \varepsilon\cdot\mu(1.5\cdot10^8)^2$$

$$k = 0.5$$

2011 PROMJENJIV VAL

3) $\mu_r = 1$

$$\bar{H} = \frac{e^{-200y}}{10} \cos(2\pi \cdot 10^{10} t - 350y)\, \bar{a}_x \; [A/m]$$

Valna imp. sredstva ?, $E(t = 2ms, y = 0.1m)$ [mV/m]

a) $\alpha = 200$

$\beta = 350$

$$Z = \frac{\omega \mu}{\sqrt{\alpha^2 + \beta^2}} e^{j \,\mathrm{arctg} \frac{\alpha}{\beta}} = \underbrace{\frac{2\pi \cdot 10^{10} \cdot \mu_0}{\sqrt{200^2 + 350^2}} e^{j \,\mathrm{arctg} \frac{200}{350}}}_{196\, e^{j30^\circ}}$$

$$Z = 196 \angle 30^\circ$$

b) $\nabla \times \bar{H} = \frac{\partial D}{\partial t}$

$$\nabla \times \bar{H} = \begin{vmatrix} a_x & a_y & a_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ H_x & 0 & 0 \end{vmatrix} = -\frac{1}{10} \bar{a}_z \frac{\partial}{\partial y}\left[e^{-200y} \cos(2\pi \cdot 10^{10} t - 350y) \right]$$

$$\frac{\partial D}{\partial t} = -\frac{1}{10} \bar{a}_z \left[-200 e^{-200y} \cos(2\pi \cdot 10^{10} - 350y) + 350 e^{-200y} \sin(2\pi \cdot 10^{10} t - 350y) \right]$$

$$D = \int \left[20 e^{-200y} \cos(2\pi \cdot 10^{10} t - 350y) - 35 e^{-200y} \sin(2\pi \cdot 10^{10} t - 350y) \right] dt$$

$$= -20\, e^{-200y}\, 2\pi \cdot 10^{10} \sin(2\pi \cdot 10^{10} t - 350y) - 35\, e^{-200y}\, 2\pi \cdot 10^{10} \cos(2\pi\, 10^{10} t - 350y)$$

$D(t = 2ms, y = 0.1m) = 1485.63 - 3712.98 = -2227.35$

$E = ?$

$$196\, e^{j30^\circ} = 196(\cos 30^\circ + j \sin 30^\circ)$$

$Z = \frac{E}{H}$ $E = Z \cdot H$

$$E = \mathrm{Re}\{Z\} \cdot H = 196 \cdot \cos(30^\circ) \cdot \frac{e^{-20}}{10} \cos(2 \cdot 180^\circ \cdot 10^{10} \cdot 2 \cdot 10^{-3} - 35)$$

≈ 28.6 uV/m

2012) RAVNI ~~PROMJENJIVI~~ VAL

8. $E = ?$

$|E(t=0, x=0.8\lambda)| = ?$

$E(x,t) = 12\sin(\omega t - \beta x)\,\bar a_y - 16\sin(\omega t - \beta x)\,\bar a_z$ [V/m]

→ val se širi u $\bar a_y$ i $-\bar a_z$ smjeru

$\beta = \frac{2\pi}{\lambda}$ $\qquad \beta \cdot x = \beta \cdot 0.8\lambda = \frac{2\pi}{\cancel{\lambda}} \cdot 0.8\cancel{\lambda} = 1.6\pi$

$x = 0.8\lambda$

$E(0.8\lambda, 0) = 12\sin(-1.6\pi)\,\bar a_y - 16\sin(-1.6\pi)\,\bar a_z$

$= 11.4126\,\bar a_y - 15.216\,\bar a_z$

$|E| = 19.0210$ V/m

PROMJENJIV VAL

9) $\mu_r = 1$

$\bar H = \frac{e^{-y}}{5}\cos(2\pi \cdot 10^8 t - 2y)\,\bar a_x$ [V/m] $\qquad \alpha = 1$

$\bar E = ?$ $\qquad t = 0.02\,\mu s$

$y = 0.2\,m$

→ nije ravni val jer je fazni kut valne imp. $\neq 0$

$\varphi = \mathrm{arctg}\,\frac{\alpha}{\beta} = \mathrm{arctg}\,\frac{1}{2} \neq 0$

$\nabla \times \bar H = \frac{\partial \bar D}{\partial t}$

$$\nabla \times \bar H = \begin{vmatrix} \bar a_x & \bar a_y & \bar a_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ H_x & 0 & 0 \end{vmatrix} = -\frac{1}{5}\,\bar a_z \frac{\partial}{\partial y}\left(e^{-y}\cos(2\pi \cdot 10^8 t - 2y)\right)$$

$$= -\frac{1}{5}\,\bar a_z\left[-e^{-y}\cos(2\pi \cdot 10^8 t - 2y) + 2e^{-y}\sin(2\pi \cdot 10^8 t - 2y)\right] = \frac{\partial D}{\partial t}$$

$$\bar E = \frac{1}{5\varepsilon_0}\,e^{-y}\,\bar a_z\left[\frac{1}{\omega}\sin(\omega t - 2y) + \frac{2}{\omega}\cos(\omega t - 2y)\right], \quad \omega = 2\pi \cdot 10^8$$

$E(t = 0.02\,\mu s,\ y = 0.2\,m) = 42.75\,\bar a_z$ [V/m]

2013. RAVNI VAL

5) $\mu_r = 2$

$\bar{E} = 5 \sin(1{,}5 \cdot 10^8 t - 5x)\, \bar{a}_y$ V/m $\qquad \bar{E} = E_2 e^{-\alpha x} \cos(\omega t - \beta x)$

Smjer, λ, ε_r, $\bar{H}(t = 35\ \text{ns}, x = 50\ \text{m})$, srednja vrijednost Poyntingova vektora

a) ako se el. polje giba u $\bar{a}_y$ smjeru, val se može gibati u $\bar{a}_z$ ili $\bar{a}_x$. Val se giba u $\bar{a}_x$ jer u izrazu $\bar{E}$ uz β stoji x. $\bar{H}$ je $\bar{a}_z$ smjera

$\vec{E}$ $\bar{a}_y$

$\bar{H}$ $\bar{a}_z$

val $\bar{a}_x$

2) $\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{5}$

3) $\beta = \frac{\omega}{c}$ $\qquad c = \frac{1}{\sqrt{\mu\varepsilon}}$ $\qquad \frac{\omega}{\beta} = \frac{1}{\sqrt{\mu_r \mu_0 \varepsilon_0 \varepsilon_r}}$

$\varepsilon_r = \frac{\beta^2}{\omega^2 \mu_r \mu_0 \varepsilon_0} = 49{,}93$

4) $Z_0 = 120\pi \sqrt{\frac{\mu_r}{\varepsilon_r}} = 75{,}45$

$H_{zm} = \frac{E_{zm}}{|Z| = Z_0}$ $\qquad \bar{H} = H_{zm} \overbrace{\sin(1{,}5 \cdot 10^8 t - 5x)}^{-0{,}766}\, \bar{a}_z$

$H_{zm} = 0{,}066$ $\qquad \bar{H} = -56{,}5\ \bar{a}_z$

5) $\bar{N} = \bar{E} \times \bar{H} = E_y \cdot H_z\ \bar{a}_x = \frac{5 \cdot 5}{2\sqrt{\frac{\mu}{\varepsilon}}}\ \bar{a}_x = 0{,}1659\ \bar{a}_x\ [\text{W/m}^2]$ $\qquad \sin^2 = \frac{1}{2}$

$N_{sr} = \bar{a}_r \frac{E_m^2}{2|Z|}$

pr. 9.3.2

$\bar{E} \cdot \bar{B} = 0$ $\qquad \bar{a}_x \cdot \bar{a}_y$ $\qquad (-\bar{a}_x + \bar{a}_y)(\bar{a}_x + \bar{a}_y + \bar{a}_z)$

$\bar{a}_y$ $\qquad -\bar{a}_x + \bar{a}_y$

VALOVI RAVNI VAL

2014. 1) vakuum $\lambda_v = 2\pi$ m

dielekt $\lambda_d = \frac{\lambda_v}{2}$

$$\frac{E_{2m}}{H_{2m}} = \sqrt{3} \cdot \frac{E_{1m}}{H_{1m}}$$

$\varepsilon_r, \mu_r, \omega$, fazna konst = ?

vakuum

$\lambda_v = 2\pi$ m

$\lambda_v = \frac{2\pi}{\beta_v}$

$\beta_v = 1$

$c = c_0$

$\omega = \beta_v \cdot c_0 = 3 \cdot 10^8$ m/s

$$Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} \sqrt{\frac{\mu_r}{\varepsilon_r}} = 120\pi \sqrt{\frac{\mu_r}{\varepsilon_r}}$$

$|Z| = \frac{E_{2m}}{H_{2m}}$

$\sqrt{3}\,|Z_v| = |Z_d|$

$\sqrt{3}\,|Z_v| = |Z_v| \cdot |Z_d|$

$\sqrt{3} = \sqrt{\frac{\mu_r}{\varepsilon_r}}$

$\mu_r = 3\varepsilon_r$

dielektrik

$\lambda_d = \pi$ m

$\beta_v = 2$

$\omega_v = \omega_d$

$\beta_v c_v = \beta_d c$

$\beta_v c_0 = \beta_d c$

$c = \frac{c_0}{2}$ $\frac{c_0}{c} = 2$

$c = \frac{c_0}{\sqrt{\mu_r \varepsilon_r}}$

$\frac{c_0}{c} = \sqrt{\mu_r \varepsilon_r}$

$2 = \sqrt{3 \cdot \varepsilon_r \cdot \varepsilon_r}$

$2 = \sqrt{3}\,\varepsilon_r$

$\varepsilon_r = \frac{2\sqrt{3}}{3}$

$\mu_r = 2\sqrt{3}$ $\omega = c_0$

fazna konstanta:

$\omega t \pm \beta x = $ konst

$c_0 t \pm 2x = $ konst

pr. 9.1.4.