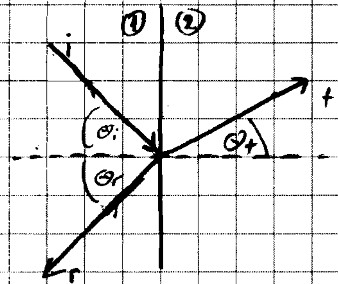
KOSI UPAD

SNELLOV ZAKON REFLEKSIJE:



$$\theta_i = \theta_r$$

$$\frac{\sin \theta_i}{\sin \theta_t} = \sqrt{\frac{\mu_{r2} \cdot \varepsilon_{r2}}{\mu_{r1} \cdot \varepsilon_{r1}}}$$

KUT TOTALNE REFLEKSIJE (KRITIČNI KUT) - samo za val koji upada iz gušćeg u rjeđe sr.

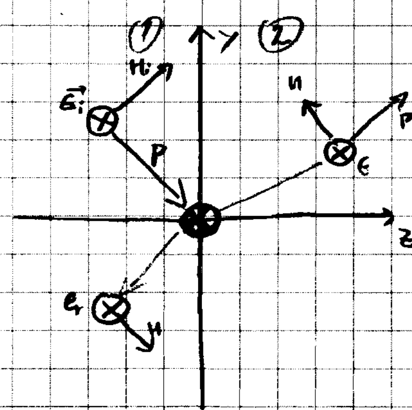
$$\theta_c = \arcsin \sqrt{\frac{\mu_2 \varepsilon_2}{\mu_1 \varepsilon_1}}$$

KUT TOTALNOG PRIJENOSA (BREWSTEROV KUT) - samo za paralelnu polarizaciju $\vec{E}$

- za $\mu_{r1} = \mu_{r2}$

$$\theta_B = \mathrm{arc\,tg} \sqrt{\frac{\varepsilon_{r2}}{\varepsilon_{r1}}}$$

- ako je $\vec{E}$ okomit na ravninu incidencije → okomita polar.
- ako vektor $\vec{E}$ leži u ravnini incidencije → vertikalna polar.



x-y - granica sred.
y-z - ravnina incidencije

$$\Gamma_r = \frac{E^r}{E^i} = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$

ZA ⊥ polar.

$$Z_1 = \frac{\eta_1}{\cos\theta_i} = \eta_0 \sqrt{\frac{\mu_{r1}}{\varepsilon_{r1}}} \cdot \frac{1}{\cos\theta_i}$$

$$Z_2 = \frac{\eta_2}{\cos\theta_t}$$

ZA HORIZONTALNU polar.

$$Z_1 = \eta_1 \cos\theta_i$$

$$Z_2 = \eta_2 \cos\theta_t$$

Z1

Ravni okomito pol. harmonički val $f = 600\ \text{MHz}$ upada pod kutem $38°$ iz $\varepsilon_{r1} = 6.32$ na $\varepsilon_{r2} = 2.7$. Rezultirajuće polje E jakosti na granici iznosi $E_2 = 45\ \text{mV/m}$. Kolika je snaga upadnog vala i kolika je vršna vrijednost jakosti reflektiranog vala. Koliki je kut totalne refleksije?

$$\Theta_t = \arcsin\left(\sin\Theta_i \cdot \sqrt{\frac{\varepsilon_{r1}}{\varepsilon_{r2}}}\right) = 70.38°$$

$$E_0' = E_2\left(1 + \frac{Z_1}{Z_2}\right) = E_2\left(1 + \frac{\frac{\eta_0}{\sqrt{\varepsilon_{r1}}\cdot\cos\Theta_i}}{\frac{\eta_0}{\sqrt{\varepsilon_{r2}}\cdot\cos\Theta_t}}\right) = 0.02877\ \text{V/m}$$

$$E_0'' = E_2\left(1 - \frac{Z_1}{Z_2}\right) = 0.01623\ \text{V/m}$$

$$P_i = \frac{|E_0'|^2}{2\eta_1} = 2.76\ \mu\text{W/m}^2$$

• pazi da je η_1 ne Z_1 !

$$\Theta_c = \arcsin\sqrt{\frac{\varepsilon_{r2}}{\varepsilon_{r1}}} = 40.82°$$

Z2

Val upada iz dielektrika u slobodni prostor. Ako je $\Theta_i = \Theta_c = 20°$ odredite relativnu dielektričnu konstantu

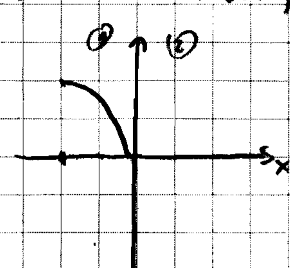
$$\sin\Theta_c = \sqrt{\frac{\varepsilon_{r2}}{\varepsilon_{r1}}}$$

$$\varepsilon_{r1} = \frac{1}{\sin\Theta_c^2} = \frac{1}{0.34202^2} = 8.5486$$

Z3

Ravni okomito pol. har. val $f = 80\ \text{MHz}$ upada iz zraka na površinu aluminija $\sigma = 3.6\cdot10^{7}\ \text{S/m}$ pod kutem $\Theta_i = 65°$. U trenutku $t = 0$ jakost polja na granici iznosi $E(t=0) = 17\ \text{mV/m}$. Maksimum polja nalazi se $35\ \text{cm}$ od površine.

Koliki su gubici u aluminiju



$$E' = E_0'\cos(\omega t + k_x x + \psi)$$

$$\cos(-k_x\cdot 0.35 + \psi) = 1$$

$$-k_x\cdot 0.35 + \psi = 0$$

$$\psi = 0.35\,k_x$$

$$k_x = \frac{2\pi}{\lambda} = \frac{2\pi f}{c} = \frac{\omega}{c} = 1.675$$

$$\psi = 0.35\cdot 1.675 = 0.58\ \text{rad}$$

$E_R' = E_R \cos(\omega \cdot 0 + k_x \cdot 0 + \varphi)$ ... u $t=0$ na granici sredstava

$E_R' = 20.41$ mV/m

• gušenje na jednoličnom sloju se prenosi u aluminij

$\Gamma_t = \frac{2Z_2}{Z_1 + Z_2}$

$$\underbrace{y = \sqrt{\frac{\omega \mu_0}{2\sigma}}}_{\alpha} (1+j)$$

$y_{al} = 2.96 \cdot 10^{-7}(1+j)$

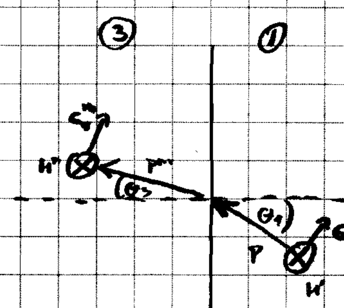
$\Gamma_t = 9.4 \cdot 10^{-3} \angle 45°$

$P_t = \frac{|\Gamma_t| |E_R'|^2}{Re\{Z_2\}} = 6.2\ \mu W/m^2$

Z4

Paralelno pol. ravni. har. val $f = 575$ MHz upada iz zraka pod kutem $42°$ na ravninu dielektrika $\varepsilon_r = 8.45$. Koliki se dio upadne snage prenosi u dielektrik? Kolika mora biti debljina i konstanta sloja koji ćemo ubaciti između dielektrika tako da uništimo reflektirani val

a) $\frac{P'''}{P'} = \frac{|E_e'''|^2 / 2Z_3}{|E_e'|^2 / 2Z_1} = \frac{|\Gamma_t \cdot E_e'|^2 Z_1}{|E_e'|^2 \cdot Z_3} = \frac{\Gamma_t^2 Z_1}{Z_3}$



$\sin\Theta_3 = \sqrt{\frac{\varepsilon_{r1}}{\varepsilon_{r3}}} \cdot \sin\Theta_1 \Rightarrow \Theta_3 = 13.33°$

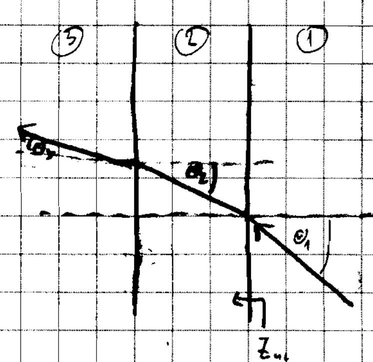
$\Gamma_t = \frac{2\sin(2\Theta_3)}{2\sin(2\Theta_1) + \sin(2\Theta_3)} = 0.62$

$Z_1 = y_0 \cos\Theta_1 = 279.8\ \Omega$

$Z_3 = y_3 \cos\Theta_3 = 126.29\ \Omega$

$\frac{P'''}{P'} = \underline{0.957}$

b) $\Theta_B = \operatorname{arctg} \frac{\sqrt{\varepsilon_r}}{\varepsilon_1} = 71°$



• reflektirani val će biti uništen ako je ulazna imp. na granici ploče i diel. jednaka kar. imp. sredstva 1

$Z_{ul} = Z_2 \frac{Z_3 + jZ_2 \operatorname{tg}(\beta_z d)}{Z_2 + jZ_3 \operatorname{tg}(\beta_z d)}$ $\beta d = \frac{\pi}{2}$ $(d = \frac{\lambda}{4})$

$Z_{ul} = \frac{Z_2^2}{Z_3}$ $Z_{ul} = Z_1 \Rightarrow Z_2^2 = Z_1 Z_3$

$\frac{\cos^2\Theta_2}{\sqrt{\varepsilon_r}^2} = \frac{\cos\Theta_1 \cdot \cos\Theta_3}{\sqrt{\varepsilon_{r1} \cdot \varepsilon_{r3}}}$

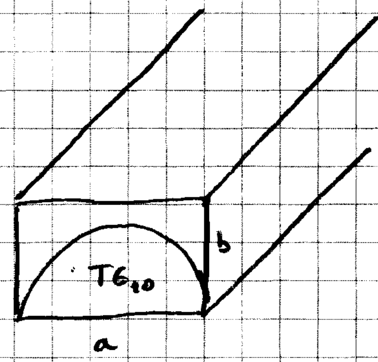
ČEKAJ WEB

$\varepsilon_{r2} = \sqrt{\varepsilon_{r1} \cdot \varepsilon_{r3}}$

VALOVODI

λ u smjeru širenja

$$\lambda_p = \frac{\lambda/\sqrt{\varepsilon_r}}{\sqrt{1-\left(\frac{\lambda}{\sqrt{\varepsilon_r}\,\lambda_c}\right)^2}} \qquad \lambda_c = 2a$$



$$v_p = \frac{c}{\sqrt{1-\left(\frac{\lambda}{\sqrt{\varepsilon_r}\,\lambda_c}\right)^2}}$$

$$v_g = c\cdot\sqrt{1-\left(\frac{\lambda}{\sqrt{\varepsilon_r}\,\lambda_c}\right)^2}$$

$$v_p \cdot v_g = c^2$$

TE
$$Z_0 = \frac{\frac{Z_0}{\sqrt{\varepsilon_r}}}{\sqrt{1-\left(\frac{\lambda}{\sqrt{\varepsilon_r}\,\lambda_c}\right)^2}}$$

TM
$$Z_0 = \frac{\eta_0}{\sqrt{\varepsilon_r}}\sqrt{1-\left(\frac{\lambda}{\sqrt{\varepsilon_r}\,\lambda_c}\right)^2}$$

• za frekvencije ispod cut-offa ($d < \frac{\lambda}{2}$)
em se reflektira (totalna refleksija na ulazu)

$$\lambda_c = \frac{2ab}{\sqrt{(mb)^2+(na)^2}} \qquad \begin{bmatrix} TE_{mn} \\ TM_{mn} \end{bmatrix}$$

Z5

$a = 6$
$b = 2.5$
$\varepsilon_r = 2.8$

Odrediti sve modove valovoda pa moguće širenje za $f = 6.5\,GHz$

Odrediti valnu impedanciju i valnu duljinu u smjeru širenja za dominantni mod. (TE_{10})

poluval po dužoj stranici

TE_{11} : TM_{11} imaju isti cut-off

TE_{11}, TM_{11}	$\lambda_c = 4.62$
TE_{02}	2.5
TE_{20}	6
TE_{21}, TM_{21}	3.84
TE_{40}	3
TE_{50}	2.4

$TE_{10} \Rightarrow 12$ cm
$TE_{01} \Rightarrow 5$ cm

sve λ manje od ove mogu se širiti

LANNACHER

Datum: 19.12.2008 Blatt Nr.: PEM-31

Z6

Odredimo veličine stranica pravokutnog valovoda kojem su:

TE_{11} $f_c = 5.44$ GHz $\Rightarrow$ $\lambda_c = 5.51$ cm

TM_{21} $f_c = 7.81$ GHz $\Rightarrow$ $\lambda_c = 3.84$ cm

$a, b = ?$

$a = 5$ cm
$b = 3$ cm

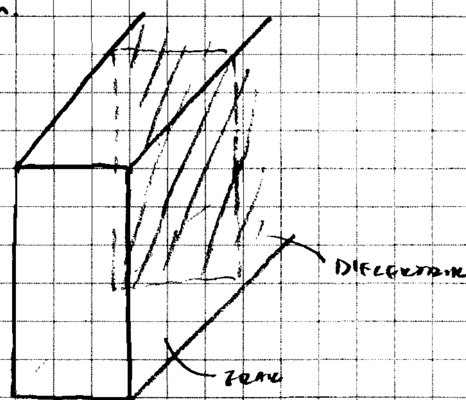
Z7

$a = 3.4$ cm
$b = 5.1$ cm

Ispunjen je djelomično zrakom djelomično dielektrikom $\varepsilon_r = 1.3$

Ako na taj valovod šaljemo val frekvencije $f = 3.75$ GHz,

odredite OSV u zraku.



$$\lambda = \frac{c}{f} = 8 \text{ cm}$$

$$\lambda_\varepsilon = \frac{c}{\sqrt{\varepsilon_r}\, f} = 7.02 \text{ cm}$$

• Dominantni mod TE_{01}

$$\lambda_c = 2 \cdot 5.1 = 10.2 \text{ cm}$$

$$Z_{01} = \frac{376.7}{\sqrt{1-\left(\frac{8}{10.2}\right)^2}} = 607\ \Omega$$

$$Z_{02} = \frac{376.7}{\sqrt{1.3}\sqrt{1-\left(\frac{8}{\sqrt{1.3}\cdot 10.2}\right)^2}} = 455\ \Omega$$

$$\Gamma_R = \frac{Z_{02}-Z_{01}}{Z_{02}+Z_{01}} = -0.143$$

$$OSV = \frac{1+|\Gamma|}{1-|\Gamma|} = 1.33$$