PRIMIJENJENI ELEKTROMAGNETIZAM – FORMULE ZA ZAVRŠNI ISPIT

- MAXWELLOVE JEDNADŽBE:

$\oiint_S \mathbf{D} \cdot d\mathbf{S} = \iiint_V \rho \, dV$	$\nabla \cdot \boldsymbol{D} = \rho$	GAUSSOV ZAKON ZA ELEKTRIČNO POLJE
$\oiint_S \mathbf{B} \cdot d\mathbf{S} = 0$	$\nabla \cdot \boldsymbol{B} = 0$	GAUSSOV ZAKON ZA MAGNETSKU INDUKCIJU
$\oint_l \mathbf{E} \cdot d\mathbf{l} = -\frac{\partial}{\partial t} \int_S \mathbf{B} \cdot d\mathbf{S}$	$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}$	FARADAYEV ZAKON INDUKCIJE
$\oint_l \mathbf{H} \cdot d\mathbf{l} = \int_S \left(\boldsymbol{J}_C + \frac{\partial \boldsymbol{D}}{\partial t} \right) \cdot d\mathbf{S}$	$\nabla \times \boldsymbol{H} = \boldsymbol{J}_C + \frac{\partial \boldsymbol{D}}{\partial t}$	AMPEREOV KRUŽNI ZAKON PROTJECANJA (S MAXWELLOVIM DODATKOM)

$\boldsymbol{J}_C = \sigma \boldsymbol{E}$ → KONDUKCIJSKA STRUJA

$\boldsymbol{J}_D = \frac{\partial \boldsymbol{D}}{\partial t} \xrightarrow{uz\ sinusnu\ pobudu} \boldsymbol{J}_D = j\omega\varepsilon\boldsymbol{E}$ → POLARIZACIJSKA/POSMAČNA STRUJA

CT (Circuit Theory)	→	EM (ElectroMagnetism)
$I = G \cdot V \Rightarrow G = \frac{I}{V}$	→	$J = \sigma \cdot E \Rightarrow \sigma = \frac{J}{E}$
$Q = C \cdot V \Rightarrow C = \frac{Q}{V}$	→	$D = \varepsilon \cdot E \Rightarrow \varepsilon = \frac{D}{E}$
$\Psi = L \cdot I \Rightarrow L = \frac{\Psi}{I}$	→	$B = \mu \cdot H \Rightarrow \mu = \frac{B}{H}$

- ELEKTROMAGNETSKI VAL:

$\nabla^2 \boldsymbol{E} = \mu\varepsilon \frac{\partial^2 \boldsymbol{E}}{\partial t^2} \xrightarrow{uz\ sinusnu\ pobudu} \nabla^2 \boldsymbol{E} = -\omega^2 \mu\varepsilon \boldsymbol{E}$

$k = \omega\sqrt{\mu\varepsilon}$ → $\nabla^2 \boldsymbol{E} + k^2 \boldsymbol{E} = 0$

$\eta = \frac{E}{H} = \sqrt{\frac{\mu}{\varepsilon}}$ → INTRINZIČNA IMPEDANCIJA

$\eta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 376.6\Omega \approx 120\pi\Omega$ → INTRINZIČNA IMPEDANCIJA SLOBODNOG PROSTORA

$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ → BRZINA SVJETLOSTI U VAKUUMU

$\hat{\varepsilon} = \varepsilon' - j\varepsilon'' = \varepsilon - j\frac{\sigma}{\omega}$ → KOMPLEKSNA PERMITIVNOST (SREDSTVO S GUBITCIMA)

- <u>OKOMITI UPAD RAVNOG ELEKTROMAGNETSKOG VALA</u>:

$\Gamma_r = \Gamma = \frac{E''}{E'} = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}$ → KOEFICIJENT REFLEKSIJE

$1 + \Gamma = \Gamma_T = r_T = T = \frac{E'''}{E'} = \frac{2\eta_2}{\eta_1 + \eta_2}$ → KOEFICIJENT TRANSMISIJE

$P' = |\boldsymbol{P}| = |\boldsymbol{E} \times \boldsymbol{H}| = \frac{E_{ef}'^2}{\eta} = \frac{E'^2}{2\eta}$ → GUSTOĆA SNAGE

$P'' = \frac{E_{ef}''^2}{\eta} = \frac{\left(\Gamma E_{ef}''\right)^2}{\eta} = (\Gamma)^2 \frac{E_{ef}'^2}{\eta} = (\Gamma)^2 P'$

$P' - P'' = P'''$

$\eta_{IN} = \eta_2 \frac{\eta_3 + j\eta_2 \tan(kd)}{\eta_2 + j\eta_3 \tan(kd)}$

- <u>KOSI UPAD ELEKTROMAGNETSKOG VALA</u>:

$\boldsymbol{k} = k_x \boldsymbol{a_x} + k_y \boldsymbol{a_y} + k_z \boldsymbol{a_z}$, $k = \beta - j\alpha$

$k = |\boldsymbol{k}| = \omega\sqrt{\mu\varepsilon} = \frac{2\pi}{\lambda'}$, $\lambda' = \frac{\lambda}{\sqrt{\mu_r \varepsilon_r}}$

$\frac{\sin\alpha}{\cos\beta} = \sqrt{\frac{\varepsilon_{r2}}{\varepsilon_{r1}}}$ → SNELLOV ZAKON LOMA

- KOSI UPAD EM VALA ZA OKOMITU POLARIZACIJU (TE INCIDENCIJA):

$$\eta = \frac{E_\perp}{H_\perp} \quad \Rightarrow \quad Z_{n1,TE} = \frac{\eta_1}{\cos\theta_1}\,, \quad Z_{n2,TE} = \frac{\eta_2}{\cos\theta_2}$$

$$\Gamma_r = \frac{E'''}{H_t'''} = \frac{\eta_2\cos\theta_1 - \eta_1\cos\theta_2}{\eta_2\cos\theta_1 + \eta_1\cos\theta_2}$$

- KOSI UPAD EM VALA ZA PARELELNU POLARIZACIJU (TM INCIDENCIJA):

$$Z_{n1,TM} = \eta_1\cos\theta_1\,, \quad Z_{n2,TM} = \eta_2\cos\theta_2$$

$$\Gamma_r = \frac{\eta_2\cos\theta_2 - \eta_1\cos\theta_1}{\eta_2\cos\theta_2 + \eta_1\cos\theta_1}$$

$$\Gamma_r = 0 \quad \rightarrow \quad \sin\theta_1 = \sqrt{\frac{\varepsilon_{r2}}{\varepsilon_{r1} + \varepsilon_{r2}}} \quad \rightarrow \quad \text{BREWSTEROV KUT ili KUT POLARIZACIJE}$$

- VALOVODI:

$$\lambda_{c-m,n} = \frac{1}{\sqrt{\left(\frac{m}{2a}\right)^2 + \left(\frac{n}{2b}\right)^2}} \quad \rightarrow \quad \text{GRANIČNA VALNA DULJINA } TE_{m,n} \text{ ILI } TM_{m,n} \text{ MODA}$$

$$f_{c-m,n} = \frac{c}{2\sqrt{\mu_r\varepsilon_r}} \cdot \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} \quad \rightarrow \quad \text{GRANIČNA FREKVENCIJA}$$

$$k_{c-m,n} = \sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2} \quad \rightarrow \quad \text{GRANIČNI VALNI BROJ}$$

$$\beta = \frac{\omega\sqrt{\mu_r\varepsilon_r}}{c}\sqrt{1 - \left(\frac{f_c}{f}\right)^2} \quad \rightarrow \quad \text{FAKTOR PROPAGACIJE}$$

$$v_p = \frac{\omega}{k} = \frac{\frac{c}{\sqrt{\mu_r\varepsilon_r}}}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}} \quad \rightarrow \quad \text{FAZNA BRZINA}$$

$$v_g = \frac{\partial\omega}{\partial k} = \frac{c}{\sqrt{\mu_r\varepsilon_r}}\sqrt{1 - \left(\frac{f_c}{f}\right)^2} \quad \rightarrow \quad \text{GRUPNA BRZINA}$$

$$\lambda_p = \frac{\frac{c}{f\sqrt{\mu_r \varepsilon_r}}}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} \quad \rightarrow \quad \text{VALNA DULJINA U SMJERU ŠIRENJA}$$

$$P_{TEm,n} = \frac{\omega \varepsilon_0 \varepsilon_r \beta E_0^2 ab}{8k_c^2}, \qquad P_{TMm,n} = \frac{\omega \mu_0 \mu_r \beta H_0^2 ab}{8k_c^2} \qquad \rightarrow \text{ SREDNJA SNAGA}$$

$$Z_{TE} = \frac{\eta_0 \sqrt{\frac{\mu_r}{\varepsilon_r}}}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}, \qquad Z_{TM} = \eta_0 \sqrt{\frac{\mu_r}{\varepsilon_r}} \sqrt{1-\left(\frac{f_c}{f}\right)^2} \qquad \rightarrow \text{ VALNI OTPOR VALOVODA}$$

- <u>SVJETLOVODI</u>:

$$\theta_C = \sin^{-1} \sqrt{\frac{\varepsilon_{r2}}{\varepsilon_{r1}}}, \quad \varepsilon_{r1} > \varepsilon_{r2}$$

- <u>ELEKTROMAGNETSKI REZONATORI</u>:

$$Q = \frac{W_u}{W_d} = \frac{f_0}{\Delta f} \quad \rightarrow \quad \text{FAKTOR DOBROTE}$$

- <u>ANTENE</u>:

$$\boldsymbol{E} = -\nabla\varphi - \frac{\partial \boldsymbol{A}}{\partial t} \xrightarrow{uz\ sinusnu\ pobudu} \boldsymbol{E} = -\nabla\varphi - j\omega\boldsymbol{A}$$

$$\nabla^2 \boldsymbol{A} + k^2 \boldsymbol{A} = -\mu \boldsymbol{J}$$

$$P = |\boldsymbol{E} \times \boldsymbol{H}| = \frac{W}{4R^2\pi} \cdot D \ \ [W/m^2] \quad \rightarrow \quad \text{GUSTOĆA SNAGE}$$

$$D = \frac{P_{MAX}}{P_{izotropni\ radijator}} \quad \rightarrow \quad \text{USMJERENOST (DIRECTIVITY)}$$

$$G = k \cdot D \quad \rightarrow \quad \text{DOBITAK (GAIN)}$$

$$k = \frac{P_r}{P_i} = \frac{R_r}{R_r + R_D} \quad \rightarrow \quad \text{FAKTOR ISKORISTIVOSTI}$$