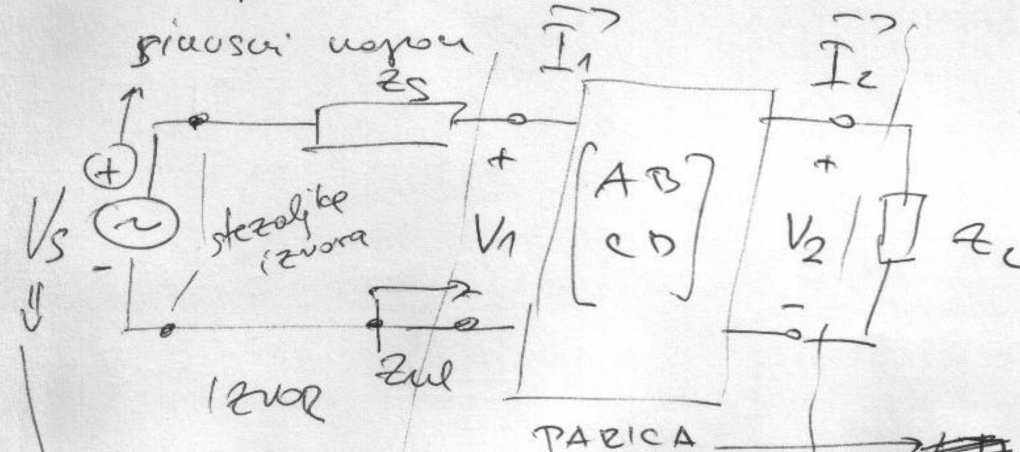
=> KAKO MODELIRATI PRIJENOSNU LINIJU?

(1)

↳ brzina EMV => prostiranje kroz žicu

↳ ovo je za žični prijenos, ne za bežični

– četveropol : 2 ulaza, 2 izlaza => odgovara parici



najjednost. oblik četveropola
⇓
dovoljno za paricu
⇓
CAT 3 do 30 MHz
CAT 5 do 150 MHz
⇓
nema dovoljno
⇓
VDSL do 30 MHz
⇓
naše parice tel. u zemlji su nešto lošije od CAT 3

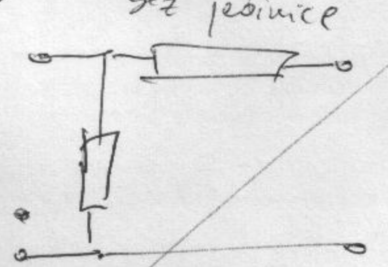
↓ razlika potencijala između točke "+" i "–"

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ I_1 \end{bmatrix}$$

A → bez jedinice; B → $[\Omega]$; C → $\frac{1}{\Omega}$ = Siemens; D → bez jedinice

=> moguće okrenuti (invertirati)
↳ treba znati matrični račun
↳ ispisati jednadžbe iz matrice

=>



=> napisati u matričnom obliku

=> obavezno pisati jedinice

=> prijenosna f-ja => odstupanje od materijala

$$H(f) = \frac{U_2(f)}{U_1(f)}$$

$$H(f) = \frac{V_2(f)}{V_1(f)}$$ => zaokruženi u knjizi Tf

$$= \frac{Z_L}{A Z_L + B}$$ => prijenosna f-ja, nema dimenziju

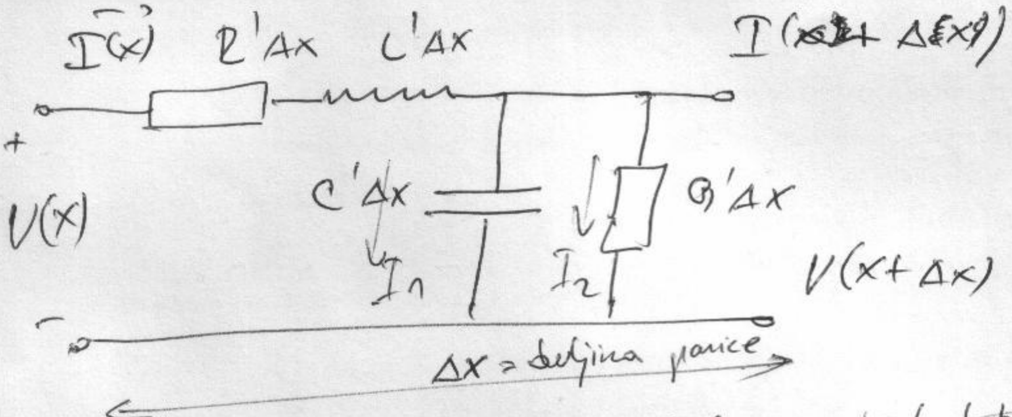
$$T(f) = \frac{V_2(f)}{V_s(f)} = \frac{\text{zaključni napon}}{\text{napon na izvoru}} = \frac{Z_1}{Z_1+Z_s} \cdot H(f)$$

↓

transfer f-ja

↳ nebitno, dodatno, objasnit će se ako će ~~trebati~~ na ispitu

$$Z_{ul}(f) = \frac{V_1(f)}{I_1(f)} = \frac{AZ_2+B}{CZ_2+D} \; [\Omega] \qquad (2)$$



el. shema parice

=> parica: 4 komponente: (otpor, induktivitet, kapacitet, ~~induktivitet~~ vodljivost)

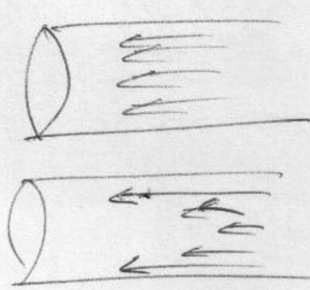
↓ raste s frekvenc.

↳ "skinefect"

$\phi = L \cdot I$

-> posljedica protjecanja struja i stvaranja mag. polja

pri višim frekv. struja počinje teći kroz izolator



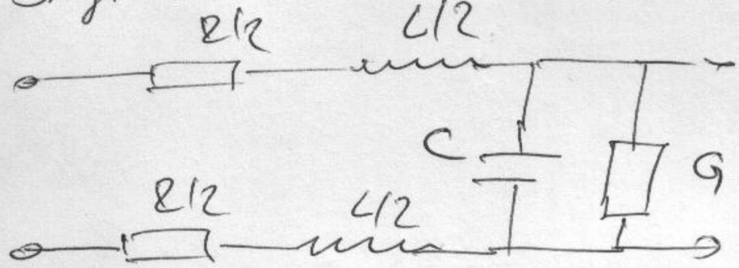
niže frekv.

više frekv.

↓

struja počinje teći uz krajeve, u sredini se smanjila struja

drugi način => pokazuje simetričnost



R'[Ω/km] L'[mH/km] G'[S/km] C[uF/km]

⇒ iznutra uglavnom RC krug, a malo L, G uglavnom 0

③

⇒ $V(x) = I(x) R' \Delta x + I(x) j\omega L' \Delta x + V(x+\Delta x)$

= { zbrajamo padove napona }

~~I(x)~~

$$V(x+\Delta x) - V(x) = -I(x)(R' + j\omega L')\Delta x$$

$$\frac{\Delta V(x)}{\Delta x} = -I(x)(R' + j\omega L')$$

$$\lim_{\Delta x \to 0} \frac{\Delta V(x)}{\Delta x} = \frac{dV(x)}{dx} = -(R' + j\omega L')I(x)$$

$$I(x) - I(x+\Delta x) = \underbrace{V(x+\Delta x) \cdot G'\Delta x}_{I_1} + \underbrace{\frac{V(x+\Delta x)}{\frac{1}{j\omega C'\Delta x}}}_{I_2}$$

$$I(x+\Delta x) - I(x) = -V(x+\Delta x)(G' + j\omega C')\Delta x$$

$$\frac{\Delta I(x)}{\Delta x} = -V(x+\Delta x)(G' + j\omega C')$$

$$\lim_{\Delta x \to 0} \frac{\Delta I(x)}{\Delta x} = \dots$$

$$\frac{d^2V(x)}{dx^2} = -(R' + j\omega L')\frac{dI(x)}{dx}$$

$$= \underbrace{-(R' + j\omega L')(G' + j\omega C')}_{\gamma^2} V(x)$$

$d^2V(x)$ $\gamma^2 V(x)$

(4)

$$\gamma = \sqrt{(R'+j\omega L')(G'+j\omega C')} \Rightarrow \text{bez dimenzije}$$

$$= \alpha + j\beta \quad , \quad \gamma(f),\ \alpha(f),\ \beta(f)$$

↳ za sad taj zapis zanemarujemo

α ↓ prigušenje $[\text{~~dB~~}/km]$, N_p => vezani

β ↓ fazna $[rad/km]$

$R' = G' = 0$ => linija bez gubitaka, $\alpha = 0$, $\beta \neq 0$

=> nema promjene amplitude napona

↳ za zadatke

A = gušenje snage $= \alpha \cdot l \ [N_p]$

$V_1(f)$ o—[$H(f)$]—o $V_2(f)$

$$A = \ln\left|\frac{V_1(f)}{V_2(f)}\right| [N_p] \qquad \left(\frac{1}{2}\ln\frac{P_1(f)}{P_2(f)}\right)$$

$$A[dB] = 8{,}686 \cdot \alpha\,[N_p/km] \cdot l$$

$$A = 20\log\left|\frac{V_1(f)}{V_2(f)}\right| = \frac{\ln\left|\frac{V_1(f)}{V_2(f)}\right|}{\ln 10}\cdot 20 \qquad \frac{20}{\ln 10} = 8{,}686$$

$$V(f) = |V(f)|\,e^{j\varphi(f)}$$

faza; ne utječe na snagu

=> paziti da se ne pobrkaju dB i N_p

=> 4-5 zadataka s a) - e)

=> čitko pisati i ne razdvajati rješenja

=> R, L, C, G => primarni parametri, zadani na početku (mjerenjem se ustanovljuju, ovise o f)

α, β, γ i Z_0 => sekundarni, proračunaju se iz R, L, C, G

Z_0 = valna impedancija = $\sqrt{\frac{R'+j\omega L'}{G+j\omega C'}}$ [Ω]

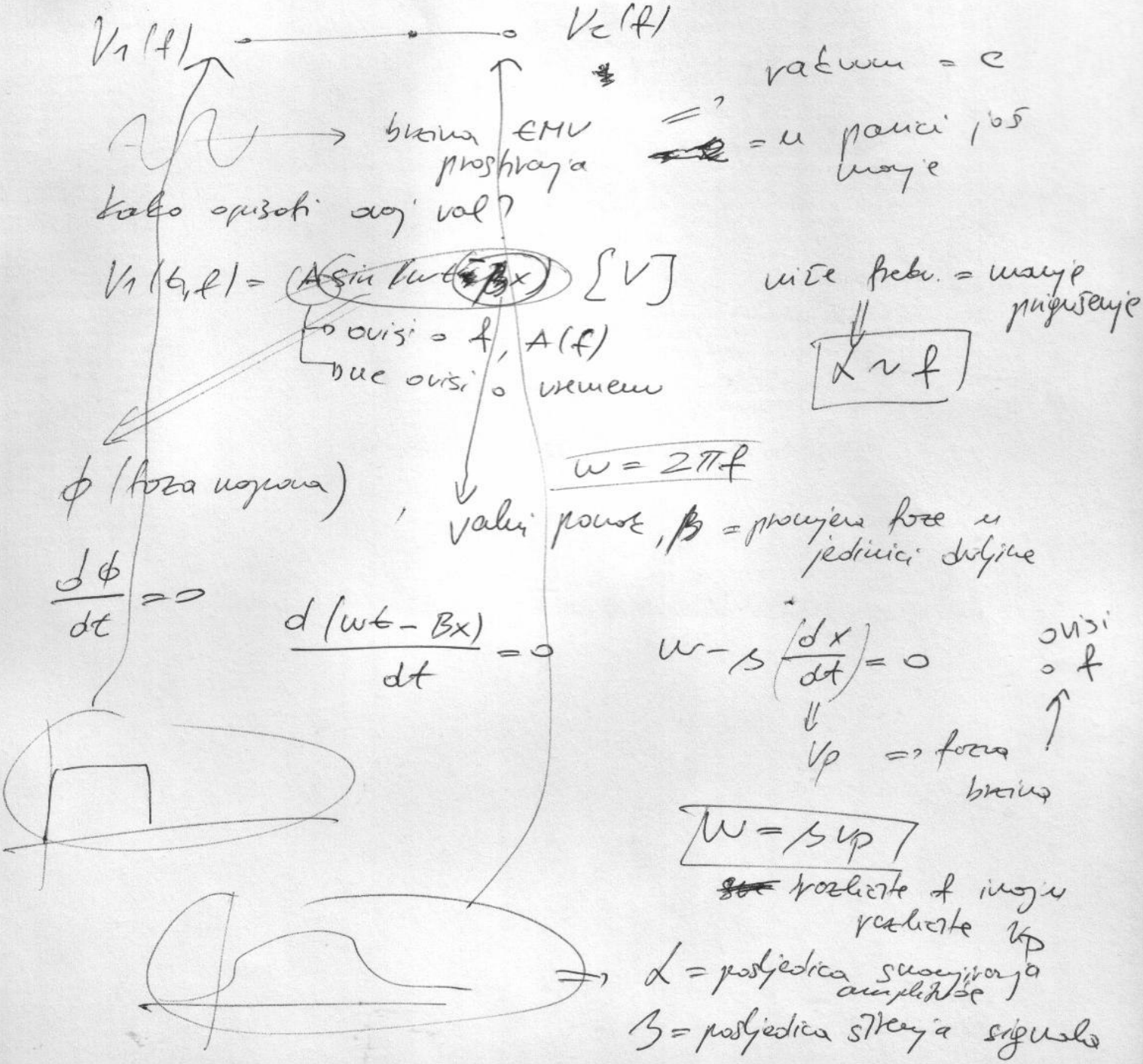
$= Z_r + j Z_i = |Z_0| e^{j\varphi_0}$

→ na višim frekv. (od 10 kHz) Z_0 je konst. = 100 – 120 Ω

l.b.g. ⇒ $\boxed{Z_0 = \sqrt{\frac{L'}{C'}}}$

⇓

Crnjo bez gubitaka



valna duljina = izmeđ. 2 točke u istoj fazi

(6)

$\beta \cdot \lambda = 2\pi$ ili (0) — $\sin(2\pi) = \sin(0)$

$$\boxed{\beta = \frac{2\pi}{\lambda}}$$ => u faznu brzinu => $V_p = \frac{\omega}{\beta}$

$$V_p = \frac{\omega}{\frac{2\pi}{\lambda}} = \frac{2\pi f}{\frac{2\pi}{\lambda}} = \boxed{\lambda f}$$

=> HENE - BARTOLIĆ : optika i valovi - pročitati

l.s.g => $\boxed{V_p = \frac{1}{\sqrt{L'C'}}}$ => nekada i > od c pa ima više mat. značenje

=> grupna brzina : kad imamo više bliskih frekvencija
↳ više nas zanima jer je uvijek < od c

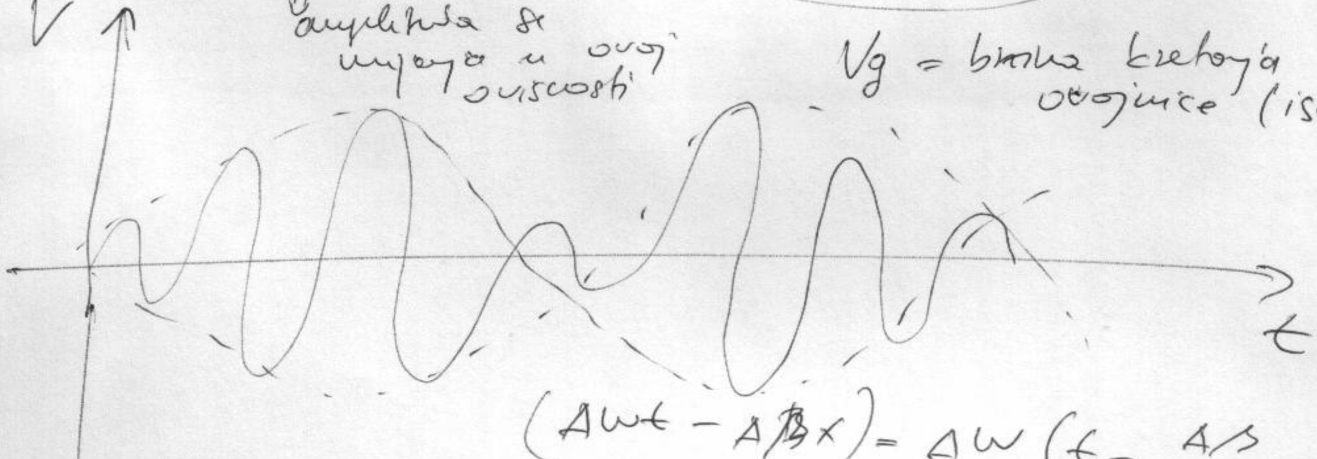
~~A cos~~

$$= A\cos\left[(\omega+\Delta\omega)t - (\beta+\Delta\beta)x\right] + A\cos\left((\omega-\Delta\omega)t - (\beta-\Delta\beta)x\right]$$

$$= 2A\cos\left[\Delta\omega t - \Delta\beta x\right]\cos(\omega t - \beta x)$$

⇓ amplituda se mijenja u ovoj ovisnosti

↗ visokofrekv. napon koji titra



V_g = brzina kretanja ovojnice (iscrtkano)

$$(\Delta\omega t - \Delta\beta x) = \Delta\omega\left(t - \frac{\Delta\beta}{\Delta\omega}x\right)$$

$$\boxed{V_g = \frac{d\omega}{d\beta}}$$ => grupno kašnjenje = $\boxed{\frac{1}{\tau_g}}$

$$t - \frac{x}{\frac{\Delta\omega}{\Delta\beta}} \quad \frac{\Delta\omega}{\Delta\beta} = V_g$$

$V_p = \frac{\omega}{\beta}$ [km/s] $\tau_p = \frac{1}{V_p}$ [s/km]

$V_g = \frac{d\omega}{d\beta}$ [km/s] $\tau_g = \frac{1}{V_g}$ [s/km]

$\frac{d\phi}{dt} = 1 - \frac{d\beta}{d\omega}\frac{dx}{dt} = 0$ $\frac{d\beta}{d\omega}\frac{dx}{dt} = 1$

$$\frac{dx}{dt} = \frac{d\omega}{d\beta} = V_g$$

=> τ_p i τ_g iznad 10 kHz

= 5 μs/km

$V_p = V_g$ = 200 000 km/s, ≈ 2/3 · c što je ok

optika = fizikalne komponente (složenije)

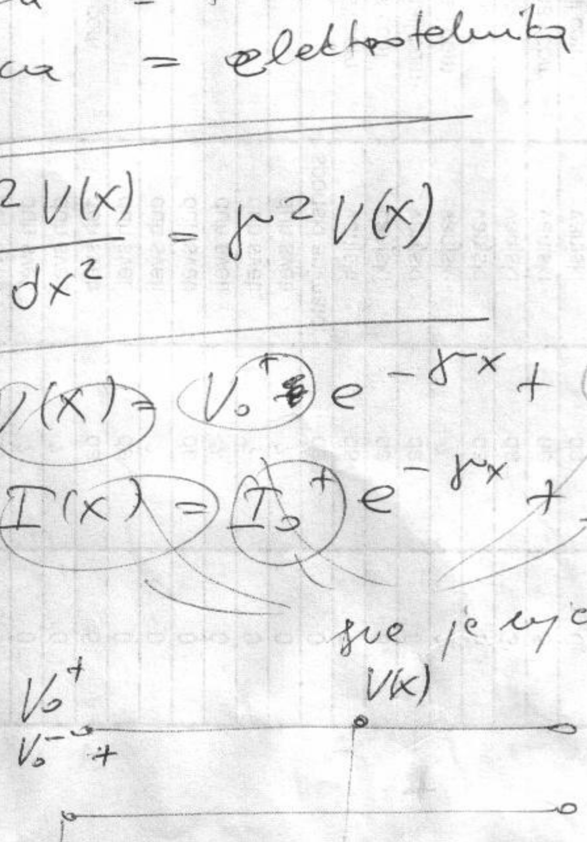
parica = elektrotehnika

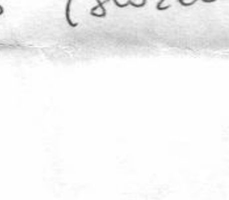
$$\frac{d^2 V(x)}{dx^2} = \gamma^2 V(x)$$

$V(x) = V_0^+ e^{-\gamma x} + V_0^- e^{\gamma x}$ $V(0) = V_0^+ + V_0^-$

$I(x) = I_0^+ e^{-\gamma x} + I_0^- e^{\gamma x}$

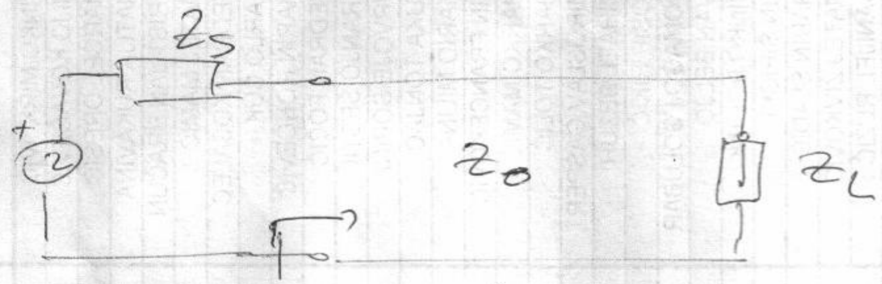
gdje je ovisno i f-ja frekvencije





$$Z_0 = \frac{V_0^+}{I_0^+} = -\frac{V_0^-}{I_0^-} = \sqrt{\frac{R'+j\omega L'}{G'+j\omega C'}} = \sqrt{\frac{Z}{Y}} = \sqrt{\frac{\text{impedancija}}{\text{admitancija}}}$$

=> ne brkati Z_0 i ulaznu impedanciju (Z_{ul})



$$Z_{ul} = \frac{V(x)}{I(x)} \neq \frac{V_0^+}{I_0^+}$$

→ s primarnim parametrima kabela = Z_0

$$\begin{bmatrix} V(0) \\ I(0) \end{bmatrix} = \begin{bmatrix} ch(\gamma d) & Z_0\, sh(\gamma d) \\ \frac{1}{Z_0} sh(\gamma d) & ch(\gamma d) \end{bmatrix} \begin{bmatrix} V(d) \\ I(d) \end{bmatrix}$$

ulazni — (Z_0, γ, d) — napon na kraju

$$H(f) = \frac{V(d,f)}{V(0,f)} = \frac{1}{ch(\gamma d) + \frac{Z_0}{Z_L} sh(\gamma d)}$$

dozvoljen 1 A4 obostrano s formulama

=> neće se računati kosinusi i sinusi => pogledati zadatke na webu

VAŽNO ZA ZADATKE !!!

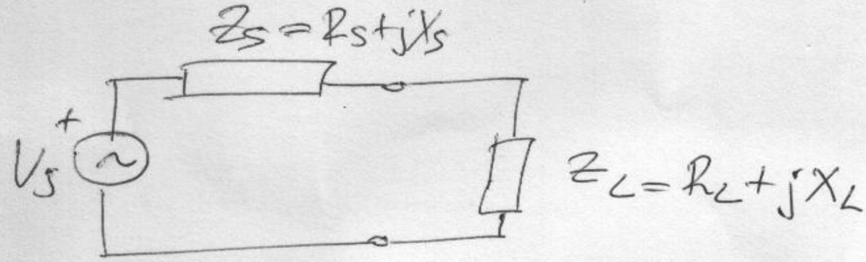
=> ne brkati s l.s.o.

$$Z_{ul} = Z_0 \frac{Z_L + Z_0\, th(\gamma d)}{Z_0 + Z_L\, th(\gamma d)}$$

a) $d \to \infty$
$th(\gamma d) \to 1$ => $Z_{ul} = Z_0$

b) $Z_L = Z_0$ => $Z_{ul} = Z_0$
⇓
idealno zaključena linija

PRIJENOS SNAGE S IZVORA ↓ na



max. prijenos kada

⇓

$X_S = -X_L$

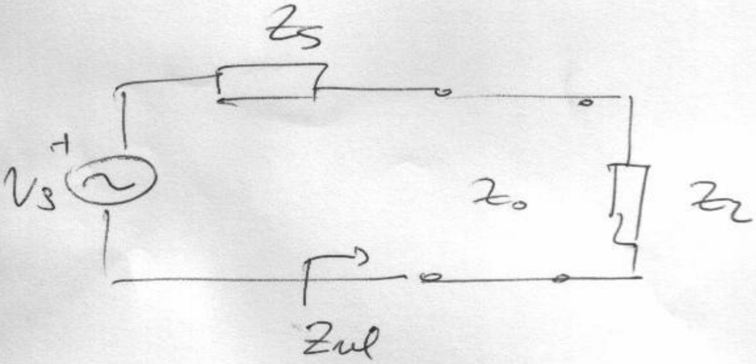
$Z_S = \overline{Z_L}$

$P(f) = \text{srednja} = \frac{1}{2} Re\{V \bar{I}\}$

$= \frac{1}{2} |I|^2 R_L = \frac{1}{2} \left|\frac{V}{Z}\right|^2 R_L$

$Z = \sqrt{R_L^2 + X_L^2}$

~~=> moramo se koncentrirati~~



$Z_S = \overline{Z_{ul}}$

⇓

za max prijenos snage

a) $d = \infty$

$Z_S = \overline{Z_0}$ → fiksno

↳ ovo prilagođavanje

ISPIT:
kada je max. prijenos s ponce na trošilo?

$Z_S = \overline{Z_0} = Z_L$

=> $d = \infty$

$$Z_{ul}' = Z_0 \frac{Z_S + Z_0 \, th(\gamma d)}{Z_0 + Z_S \, th(\gamma d)}$$

$$Z_{ul}' = Z_0$$

Koeficijent refleksije na opterećenju (brojim ponce)

$$\rho_L = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{V_0^- e^{+\gamma d}}{V_0^+ e^{-\gamma d}}$$ = omjer refl. kroz upadnog vala

$Z_L = Z_0 \Rightarrow \rho_L = 0$

$$\rho_S = \frac{V_0^-}{V_0^+} = \frac{Z_S - Z_0}{Z_S + Z_0}$$

Return loss $= RL = 10 \log \left(\frac{1}{|\rho|} \right)^2$ [dB]

- ρ manja → RL velik
- koliko refleksije smo izgubili ⇒ veći što više