CURIOSIDAD:

ELECTRODINÁMICA: TENSOR DE FARADAY
ORDEN 2, COVARIANTE

$$\longrightarrow \vec{E} = E_i(x_1, x_2, x_3, t)\,\hat{x}^i$$

$$F = F_{\alpha\beta} = \begin{bmatrix} 0 & E_1/c & E_2/c & E_3/c \\ -E_1/c & 0 & -B_3 & B_2 \\ -E_2/c & B_3 & 0 & -B_1 \\ -E_3/c & -B_2 & B_1 & 0 \end{bmatrix}$$

OBJETO DE ESTUDIO DE LA ELECTRODINÁMICA

$\Rightarrow$ NO VAMOS A ANALIZAR NADA CON ESTE FORMALISMO FÍSICO.

REPASAMOS EC. MAXWELL

1) $\nabla \wedge \vec{E} = -\dfrac{\partial \vec{B}}{\partial t} - \vec{M}$

2) $\nabla \wedge \vec{H} = \dfrac{\partial \vec{D}}{\partial t} + \vec{J}$

3) $\nabla \cdot \vec{D} = \rho$

4) $\nabla \cdot B = 0$

5) UNA EC. CONSTITUTIVA DEL MATERIAL

$$\vec{D} = \varepsilon_0 \vec{E} + \vec{P}(\vec{E})$$

MKS

$$\left\{\begin{array}{l} E : V/m \\ H : A/m \end{array}\right\} \text{CAMPOS}$$

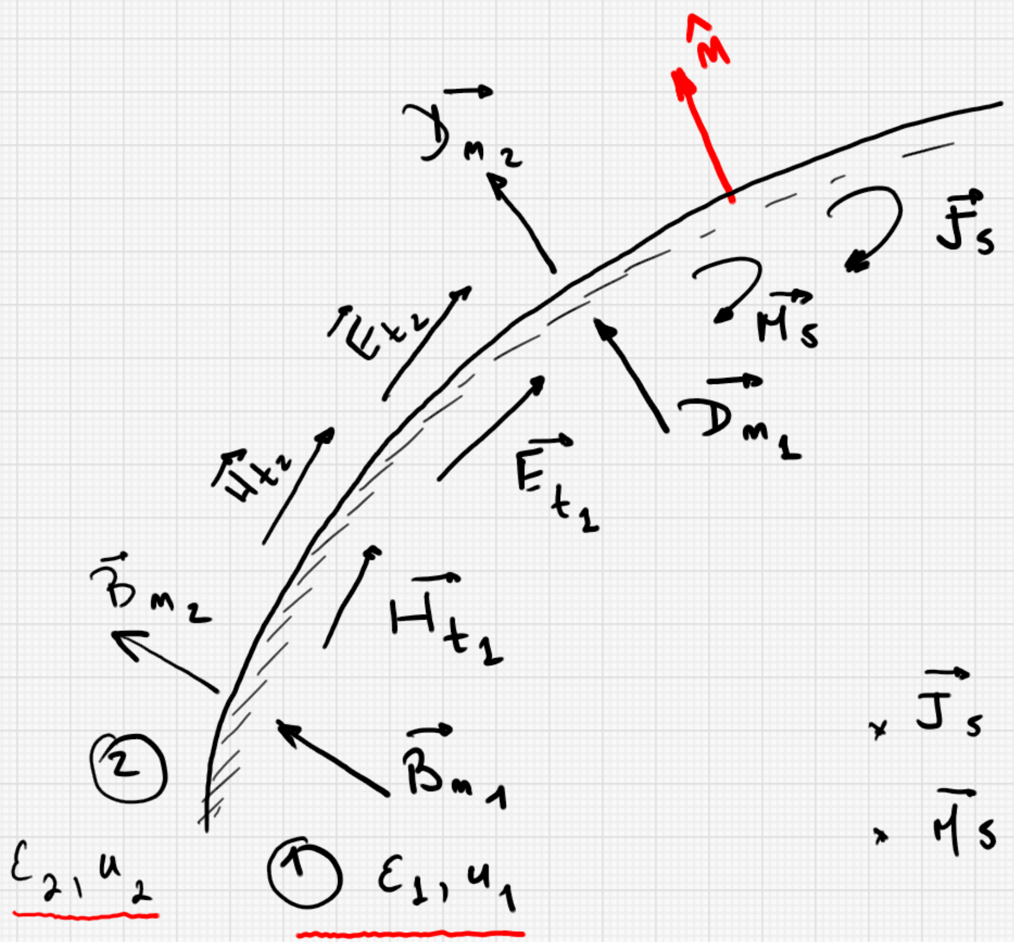
$$\left\{\begin{array}{l} D : C/m^2 \\ B : Wb/m^2 \end{array}\right\} \text{FLUJOS ó DENSIDAD}$$

$$\left\{\begin{array}{l} M : V/m^2 \\ J : A/m^2 \\ \rho : C/m^3 \end{array}\right\} \text{SOURCES}$$

OBJETIVOS DE ESTA CLASE: <u>ENTENDER LO SIGUIENTE</u>

1. $\{\varepsilon_r, \tan\delta\}$, PÉRDIDAS, Q
2. $\delta_s \longrightarrow e^{-1}$ "SKIN" DEL MATERIAL
3. REPASO DE ONDAS PLANAS Y CONDICIONES DE BORDE DE CAMPOS
4. ALGUNAS HIPÓTESIS DE TRABAJO PARA EL RESTO DEL CURSO (RÉGIMEN ESTACIONARIO)

CONDICIONES DE CONTORNO:



$$
\left\{
\begin{array}{ll}
1) & \hat{m} \cdot (\vec{D}_2 - \vec{D}_1) = \sigma_s \\
2) & \hat{m} \cdot (\vec{B}_2 - \vec{B}_1) = 0 \\
3) & \hat{m} \wedge (\vec{H}_2 - \vec{H}_1) = \vec{J}_s \\
4) & (\vec{E}_2 - \vec{E}_1) \wedge \hat{m} = \vec{M}_s
\end{array}
\right\}
$$

- $\vec{J}_s$: CORRIENTE SUPERFICIE
- $\vec{M}_s$: CORRIENTE MAGNETIZACIÓN SUPERFICIAL

VAMOS A TRABAJAR CON :

(H)

1. NO HAY DEPENDENCIA ARBITRARIA CON EL TIEMPO

   $\Rightarrow$ ESTUDIO RÉGIMEN <u>ARMÓNICO</u>

2. STEADY-STATE (CONDICIONES ESTABLECIDAS)

PERMITE REPRESENTACIÓN FASORIAL

$$\vec{E}(x_1, x_2, x_3, t) = Re\left\{ \vec{E}(x_1, x_2, x_3)\, e^{j\omega t} \right\}$$

OJO ¿QUE PASA CON LOS TRANSITORIOS ?

MATERIAL DIELÉCTRICO

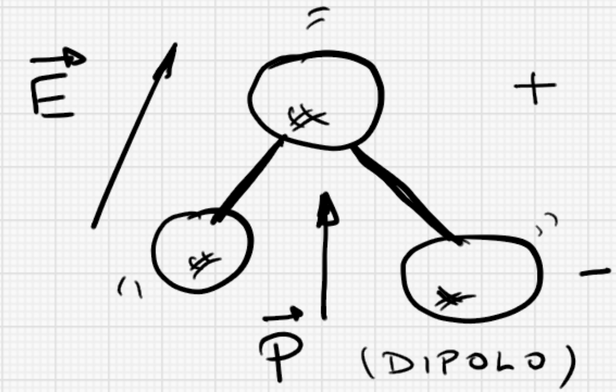
$$\vec{D} = \varepsilon_0 \vec{E} + \vec{P}(\vec{E})$$

$\varepsilon_0 \rightarrow 8{,}85 \times 10^{-12}\ F/m$

SI MEDIO LÍNEAL

$$\underbrace{\vec{P} = \varepsilon_0 \chi_0 \vec{E}}$$

$$\vec{D} = \varepsilon \vec{E}$$



COMO ESTAMOS CON REPRESENTACION FASORIAL LO CORRECTO ES USAR $\underline{\varepsilon = \varepsilon' - j\varepsilon''}$

(LO GENERAL ES $P_i = \varepsilon_0 \chi_{ij} E_j$ CONV. Eins.)

- $\varepsilon = \varepsilon' - j\varepsilon''$

$\hookrightarrow$ TOMA SENTIDO EN EL BALANCE DE POTENCIA

- $P_{ot} = \left\langle \frac{1}{2} \frac{\partial}{\partial t} (\vec{D} \cdot \vec{E}) \right\rangle$

$\hookrightarrow \mathrm{Re}\{\cdot\} + \mathrm{Im}\{\cdot\}$

ε'' PÉRDIDA, NO SE PUEDE USAR COMO ACTIVA (LO DISIPA EL MATERIAL)

VOLVEMOS A MAXWELL:

OBJETIVO: MAXWELL $\longrightarrow$ PASAR A ALGO QUE SE LEA EN HOJAS DE DATOS Y FABRICANTES DEN INFORMACIÓN

$$\nabla \wedge \bar{H} = j\omega\vec{D} + \vec{J}$$

$$= j\omega\varepsilon\vec{E} + \sigma\vec{E}$$

ÁLGEBRA

$$= (j\omega\varepsilon' + \underbrace{\omega\varepsilon''}_{\text{DIELECTRIC CLAMPING}} + \sigma)\vec{E}$$

$$= j\omega\varepsilon'\Big(1 + \underbrace{\frac{\omega\varepsilon'' + \sigma}{j\omega\varepsilon'}}_{\longrightarrow\ -j\tan\delta}\Big)\vec{E}$$

$$\vec{J} = \sigma \cdot \vec{E}$$

$$\varepsilon = \varepsilon' - j\varepsilon''$$

$$\frac{\partial}{\partial t} \longmapsto j\omega$$

COMO RESUMEN DE LAS CUENTAS:

$$\left\{\begin{aligned}
\varepsilon &= \varepsilon' - j\varepsilon'' \\
\varepsilon' &= \varepsilon_r \varepsilon_0 \\
\tan\delta &= \frac{\sigma + \omega\varepsilon''}{\omega\varepsilon'} \\
\varepsilon &= \varepsilon_0 \varepsilon_r (1 - \tan\delta)
\end{aligned}\right.$$

$\{\varepsilon_r, \tan\delta\}$ APARECE EN HOJAS DE DATOS

$\tan\delta$ = DF (DISSIPATION FACTOR)

* MEDIOS HOMOGENEOS, LA ÚNICA HIPÓTESIS ES LA EXISTENCIA DE INTERFACES DEL CONTINUO.

$$\frac{1}{Q} = \tan\delta = DF$$ DISSIPATION FACTOR

LOSS

DF : MEASURE OF LOSS-RATE OF ENERGY OF AN OSCILLATION IN A DISSIPATIVE SYSTEM

Q : QUALITY FACTOR (DURABILITY OF OSC.)

(LO VAMOS A VER MAS VINCULADO A C, L, R)

REPASO DE ONDAS PLANAS

MAXWELL FORMA FASORIAL

1) $\nabla \wedge \vec{E} = -j\omega\mu\vec{H}$

2) $\nabla \wedge \vec{H} = j\omega\varepsilon\vec{E}$

3) $\vec{B} = \mu\vec{H}$

$\Big\downarrow$ EC. ONDA

$$\nabla^2\vec{E} + \omega^2\mu\varepsilon\vec{E} = 0$$

$$K^2 = \omega^2\varepsilon\mu$$

$\Rightarrow$ CUENTO: MARCONI VS. MAXWELL

RECORDAMOS

$\varepsilon = \varepsilon' - j\varepsilon''$

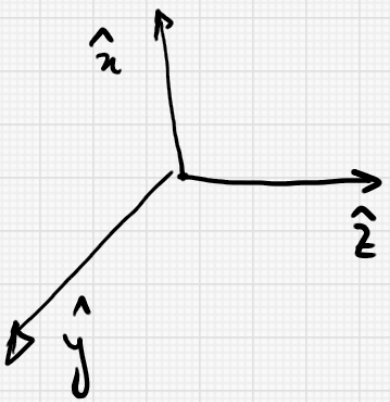
$\varepsilon' = \varepsilon_r\varepsilon_0$

$\varepsilon = \varepsilon_0\varepsilon_r(1 - j\tan\delta)$

$\tan\delta \triangleq \dfrac{\omega\varepsilon'' + \sigma}{\omega\varepsilon'}$

EC ONDA NO DISIPATIVA

$$\nabla^2 E + k^2 E = 0$$



$$\vec{E}_x(z) = E_x(z)\,\hat{x}$$

RECORDAMOS

$$\varepsilon = \varepsilon' - j\varepsilon''$$

$$\varepsilon' = \varepsilon_r \varepsilon_0$$

$$\varepsilon = \varepsilon_0 \varepsilon_r (1 - j \tan\delta)$$

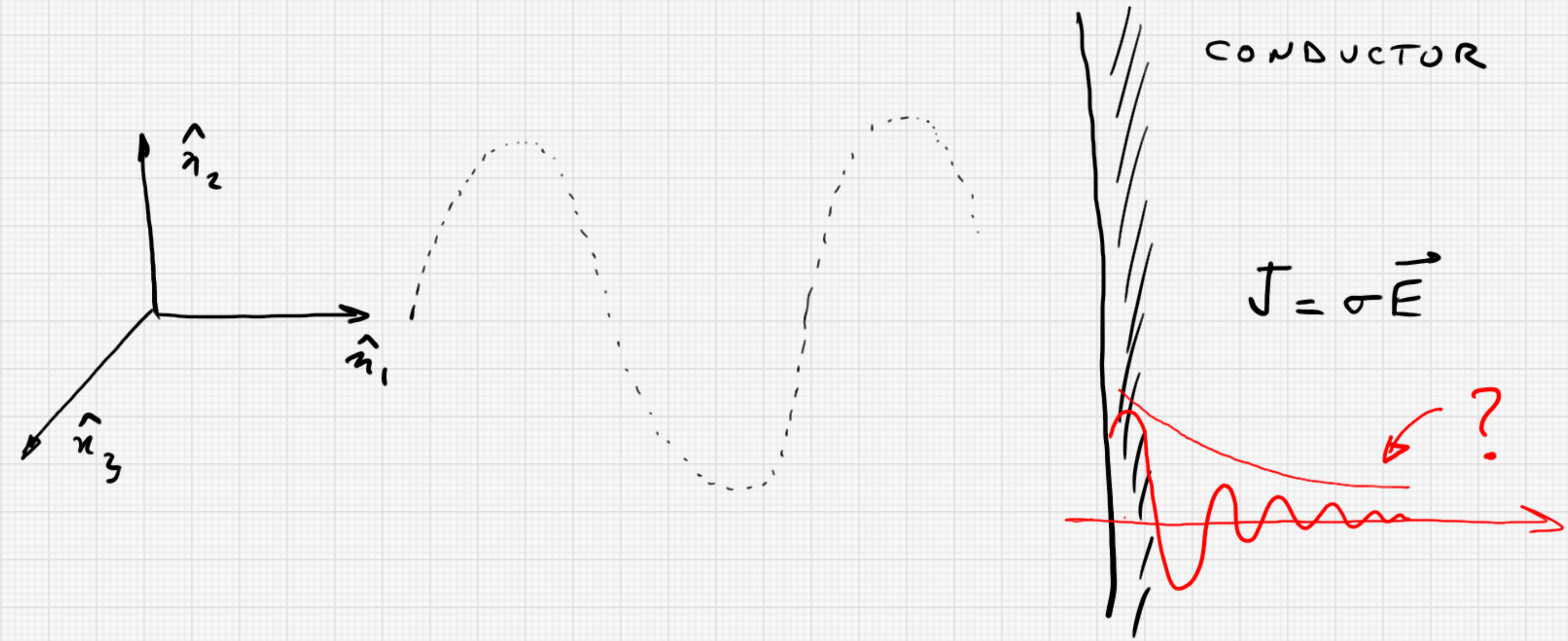
$$\tan\delta = \frac{\omega\varepsilon'' + \sigma}{\omega\varepsilon'}$$

$$\Rightarrow \frac{\partial^2 E_x}{\partial z^2} + k^2 E_x = 0 \Rightarrow E_x(z) = E^+ e^{-jkz} + E^- e^{jkz}$$

CONDICIÓN BORDE

$$\left\{ \begin{array}{l} v_p = \omega/k = \dfrac{1}{\sqrt{\mu\varepsilon}} \\ \lambda = \dfrac{2\pi}{k} \end{array} \right.$$

ó $E(z,t) = \left[E^+ \cos(\omega t - kz) + E^- \cos(\omega t + kz)\right]\hat{x}$



$$\vec{E} = R_e \left\{ E_0 e^{jKx_1} e^{j\omega t} \hat{x}_3 \right\} = E_0 \cos(Kx_1 + \omega t)\, \hat{x}_3$$

MAXWELL EN CONDUCTORES

$$\begin{cases} \nabla \wedge \vec{E} = -j\omega\mu\vec{H} \\ \nabla \wedge \vec{H} = j\omega\varepsilon\vec{E} + \sigma\vec{E} \end{cases}$$

$\rightarrow$ NOS QUEDA $\nabla^2 E + \underbrace{\omega^2\mu\varepsilon\left(1 - j\frac{\sigma}{\omega\varepsilon}\right)}_{-\gamma^2} E = 0$

$$\gamma = \alpha + j\beta = j\omega\sqrt{\mu\varepsilon}\sqrt{1 - j\frac{\sigma}{\omega\varepsilon}} \Rightarrow \vec{E} = ?$$

$\longrightarrow$

$$\nabla^2 \underline{E} - \gamma^2 \underline{E} = 0 \qquad \text{con} \qquad \gamma = \alpha + j\beta$$

$$= j\omega\sqrt{\mu\varepsilon}\sqrt{1 - j\frac{\sigma}{\omega\varepsilon}}$$

(CUALQUIER EJE COMPATIBLE)

$$\Rightarrow \vec{E} = \left(E^+ e^{-\gamma z} + E^- e^{\gamma z}\right)\hat{x}$$

PERO $e^{-\gamma z} = e^{-\alpha z}\, e^{-j\beta z}$

¡¡ ATENUACIÓN !!

$$\Rightarrow \vec{E} = \left[E^+ e^{\alpha z}\cos(\omega t - \beta z) + E^- e^{-\alpha z}\cos(\omega t + \beta z)\right]\hat{x}$$

$\rightarrow \infty \Rightarrow E^+ = 0$

$$\Rightarrow \quad e^{-\alpha z}\Big|_{z=\delta_s} = e^{-1}$$

$\uparrow$ SKIN

$$\gamma = \alpha + j\beta = (1+j)\sqrt{\frac{\omega\mu\sigma}{2}}$$

$\Lsh$ $\sigma \gg \omega\varepsilon$ (BUEN CONDUCTOR)

$$\delta_s = \frac{1}{\alpha} = \sqrt{\frac{2}{\omega\mu\sigma}}$$

$\delta_s \downarrow \;,\; \omega \uparrow$

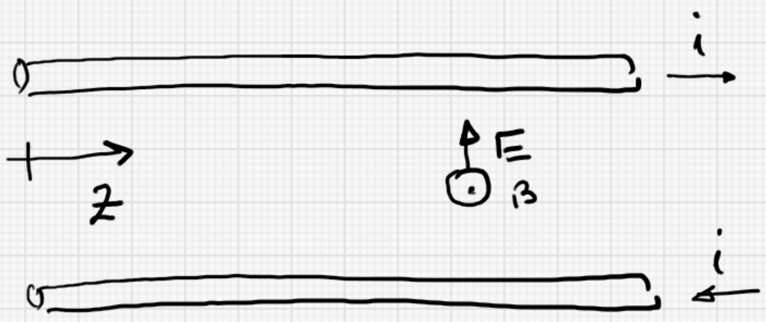
$\delta_s \downarrow \;,\; \sigma \uparrow$

DATOS

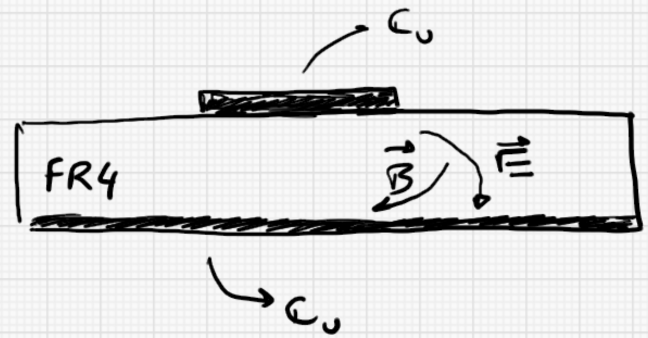
$$\left\{ \begin{array}{ll} Al & \delta_s = 0{,}8\,\mu m \\ Cu & \delta_s = 0{,}66\,\mu m \\ Au & \delta_s = 0{,}8\,\mu m \end{array} \right\} \text{@ } 500\,MHz$$

LÍNEAS DE TRANSMISIÓN

LINEA



LINEA MICROSTRIP

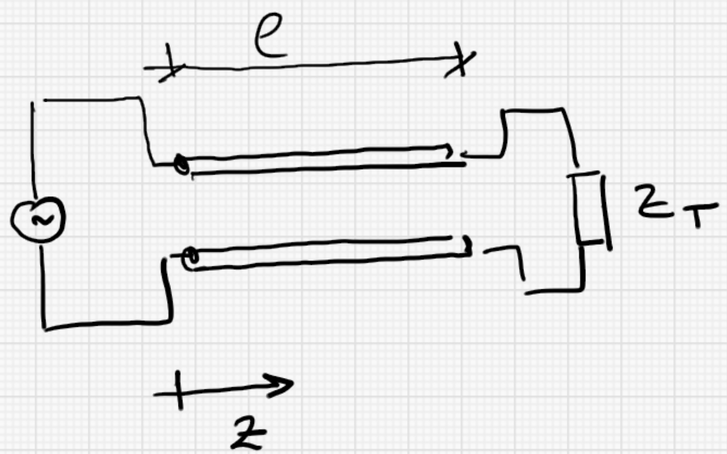


⇒ SE CARACTERIZAN POR

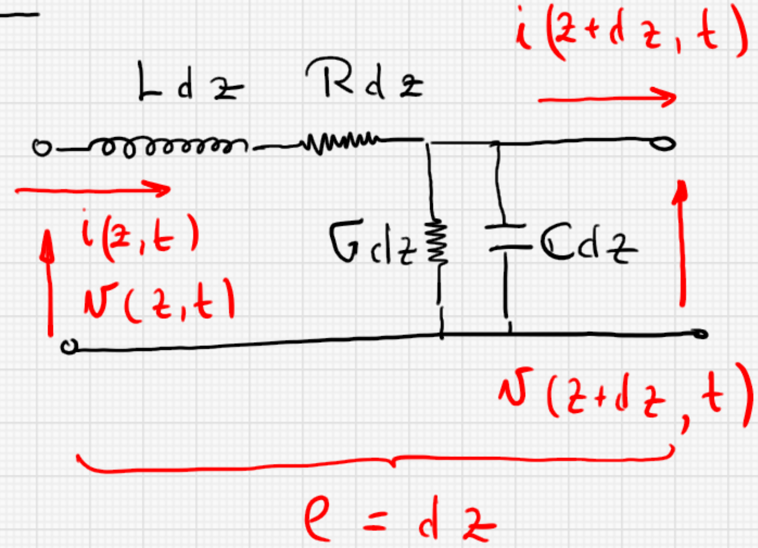
1) PARÁMETROS DISTRIBUIDOS

2) MODO DE PROPAGACION **TEM**

MODELO DE LINEA DE "DOS HILOS"



MODELO



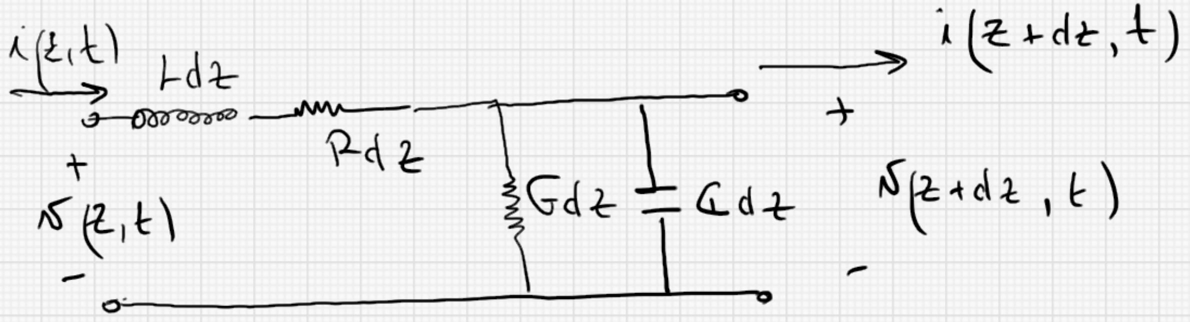
R [Ω/m] PERDIDA EN LA LÍNEA

C [F/m] ENERGÍA DEL CAMPO ELÉCTRICO

L [Hy/m] " " " MAGNÉTICO

G [℧/m] PERDIDA EN EL MEDIO POR PROPAGACIÓN DEL CAMPO

→ @ f



$\Rightarrow$ SE OBTIENE :

$$\begin{cases} -\dfrac{\partial v}{\partial z} = R i + L \dfrac{\partial i}{\partial t} \\[2ex] -\dfrac{\partial i}{\partial z} = G v + C \dfrac{\partial v}{\partial t} \end{cases}$$

$\Rightarrow$ COMO $v(z,t) = \mathrm{Re}\{ V(z) e^{j\omega t} \}$

PASAMOS A FASORES

$$\Rightarrow \begin{cases} \dfrac{dV(z)}{dz} = -(R + j\omega L)\, I(z) \\[2ex] \dfrac{dI(z)}{dz} = -(G + Cj\omega)\, V(z) \end{cases}$$

$$\frac{dV(z)}{dz} = -(R + j\omega L)\, I(z)$$

$$\frac{dI(z)}{dz} = -(G + Cj\omega)\, V(z)$$

DESACOPLO

$$\begin{cases} \dfrac{d^2V}{dz^2} - \overbrace{(R + j\omega L)(G + Cj\omega)}^{\gamma^2}\, V = 0 \\[2ex] \dfrac{d^2I}{dz^2} - (R + j\omega L)(G + Cj\omega)\, I = 0 \end{cases}$$

SOLUCIONES:
$$\begin{cases} V(z) = V_1 e^{-\gamma z} + V_2 e^{\gamma z} \\ I(z) = I_1 e^{-\gamma z} + I_2 e^{\gamma z} \end{cases}$$

$$\begin{cases} V(z) = V_1 e^{-\gamma z} + V_2 e^{\gamma z} \\ I(z) = I_1 e^{-\gamma z} + I_2 e^{\gamma z} \end{cases}$$

$$\gamma^2 = (R + j\omega L)(G + j\omega C)$$

$$\boxed{\gamma = \alpha + j\beta}$$

$$\begin{cases} v(z,t) = V_1 e^{-\alpha z} \operatorname{Re}\{ e^{j(\omega t - \beta z)} \} + V_2 e^{\alpha z} \operatorname{Re}\{ e^{j(\omega t + \beta z)} \} \\ i(z,t) = I_1 e^{-\alpha z} \operatorname{Re}\{ e^{j(\omega t - \beta z)} \} + I_2 e^{\alpha z} \operatorname{Re}\{ e^{j(\omega t + \beta z)} \} \end{cases}$$

$$v_p = \frac{\omega}{\beta} \quad , \quad \lambda = \frac{2\pi}{\beta}$$

$$[\alpha] = dB/m \quad , \quad [\beta] = rad/m$$

⇒ OBJETIVO : MANIPULAR LAS ECUACIONES PARA TENER POCOS PARAMETROS Y USARLAS DE MANERA "INGENIERIL"

DE LA EQ. TRANSMISIÓN: $\dfrac{d\,V(z)}{d\,z} = -(R + j\omega L)\, I$

$\Rightarrow$ SI SOLO ASUMIMOS ONDA PROGRESIVA TENEMOS QUE:

$$\cdot\, \gamma V_1 = -(R + j\omega L)\, I_1$$

$\Rightarrow$ SE PUEDE DEDUCIR $\dfrac{V_1}{I_1} = -\dfrac{V_2}{I_2} = \sqrt{\dfrac{R + j\omega L}{G + j\omega C}} = Z_0$

$$\Rightarrow \left\{ \begin{aligned} V(z) &= V_1\, e^{-\gamma z} + V_2\, e^{\gamma z} \\ I(z) &= \frac{V_1}{Z_0}\, e^{-\gamma z} - \frac{V_2}{Z_0}\, e^{\gamma z} \end{aligned} \right\}$$

con $\gamma^2 = (R + j\omega L)(G + j\omega C)$
$= \alpha + j\beta$

$$\Rightarrow \quad Z_0 = R_0 + jX_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

$$\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)} \quad , \quad \lambda = \frac{2\pi}{\beta} \quad , \quad \lambda = v_p \cdot f$$

$$\Rightarrow \quad (\alpha, \beta, Z_0) @ \omega \iff \underbrace{R, L, C, G}_{\text{DATOS DE LA ESTRUCTURA FÍSICA}}, \omega$$

$\Rightarrow$ SE CONSTRUYE PARA TRABAJAR A ω/ $\frac{\omega L}{R} >> 1$ Y $\frac{\omega C}{G} >> 1$

(LINEAS SIN PERDIDAS IDEALES $R = G = 0$) $\Rightarrow \alpha = 0$

EN ESTAS CONDICIONES $\dfrac{\omega L}{R} \gg 1$, $\dfrac{\omega C}{G} \gg 1$

$$\begin{cases} Z_0 = R_0 = \sqrt{L/C} \\ \alpha \approx 0 \\ \beta = \omega\sqrt{LC} \end{cases}$$

"LÍNEAS INDEPENDIENTES DE B_ω PARA UN ω_0 (CENTRAL) Y SIN PERDIDAS"

$$v_p = \frac{\omega}{\beta}$$

$$I = \frac{1}{Z_0}\left(V_1 e^{-\gamma z} - V_2 e^{\gamma z}\right)$$

$$\Rightarrow \quad Z(z) = \frac{V(z)}{I(z)} = Z_0 \frac{V_1 e^{-\gamma z} + V_2 e^{\gamma z}}{V_1 e^{-\gamma z} - V_2 e^{\gamma z}}$$

* ESPECIFICAMENTE $Z(z = \ell) = Z_T$

* COEFICIENTE DE REFLEXIÓN : $\rho_T = |\rho_T| e^{j\phi_T} = \dfrac{V_2 e^{\gamma \ell}}{V_1 e^{-\gamma \ell}} = \dfrac{V_2}{V_1} e^{2\gamma \ell}$

- $\rho_T = \dfrac{V_2 e^{2\gamma \ell}}{V_1}$

- $Z_T = Z_0 \dfrac{V_1 e^{-\gamma \ell} + V_2 e^{+\gamma \ell}}{V_1 e^{-\gamma \ell} - V_2 e^{+\gamma \ell}}$

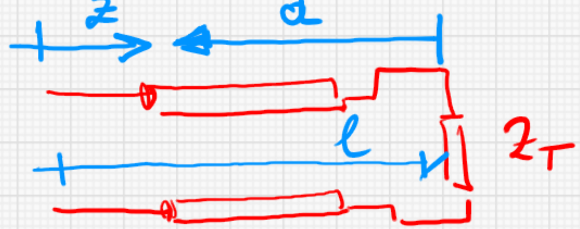
$\Rightarrow$ $\boxed{\dfrac{Z_T}{Z_0} = \dfrac{1+\rho_T}{1-\rho_T} \qquad \rho_T = \dfrac{Z_T/Z_0 - 1}{Z_T/Z_0 + 1}}$

- COMO GENERALIZAMOS:

$$Z(z) = Z_0 \frac{V_1 e^{-\gamma z} + V_2 e^{+\gamma z}}{V_1 e^{-\gamma z} - V_2 e^{+\gamma z}}$$

$$Z(z) = \frac{e^{\gamma(\ell - z)} + \rho_T e^{-\gamma(\ell - z)}}{e^{\gamma(\ell - z)} - \rho_T e^{-\gamma(\ell - z)}}$$

$$\rho_T e^{-2\gamma \ell} = \frac{V_2}{V_1}$$



ME QUEDA :

$$\frac{Z(d)}{Z_0} = \frac{1 + \rho_T e^{-2\gamma d}}{1 - \rho_T e^{-2\gamma d}} \qquad \rho_T = \frac{Z_T - Z_0}{Z_T + Z_0}$$

(EN TERMINAL)

$\Rightarrow$ CON BAJAS PERDIDAS :

$$\begin{cases} \alpha \approx 0 \\ \beta = \omega\sqrt{LC} \\ \frac{\omega L}{R} \gg 1 \quad y \quad \frac{\omega C}{G} \gg 1 \end{cases}$$

$$\Rightarrow \boxed{\frac{Z(d)}{Z_0} = \frac{Z_T/Z_0 + \tanh(j\beta d)}{1 + Z_T/Z_0 \tanh(j\beta d)}}$$

* TRANSFORMADORES

$$\frac{Z(d)}{Z_0} = \frac{Z_T/Z_0 + \tanh(j\beta d)}{1 + Z_T/Z_0 \, \underbrace{\tanh(j\beta d)}_{= j\tan(\beta d)}}$$

CASO 1:

$$\left.\begin{array}{l} \beta d = m\pi \\ \tan(m\pi) = 0 \end{array}\right| \Rightarrow \quad Z(d) = Z_T \ @ \ d = \frac{m\pi}{\beta} = \frac{m\pi}{2\pi/\lambda} = \frac{\lambda}{2} m$$

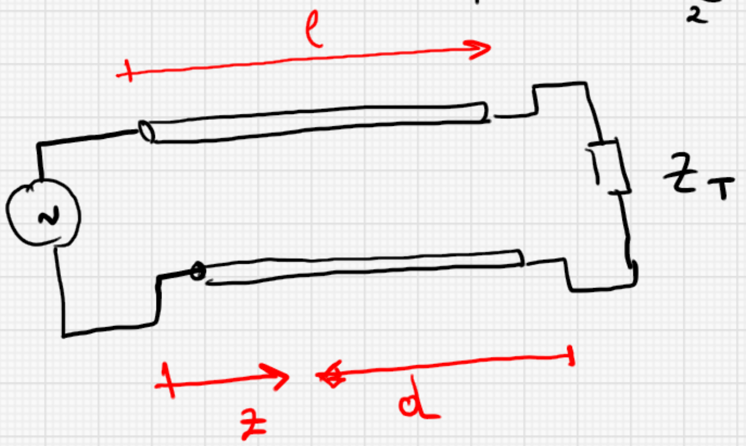
CASO 2:

$$\left.\begin{array}{l} \beta d = \frac{m\pi}{2} \\ \tan\left(\frac{m\pi}{2}\right) = \infty \end{array}\right| \Rightarrow \quad Z_0 = \sqrt{Z_T Z(d)} \ @ \ d = \frac{m\pi}{2\beta} = m\frac{\lambda}{4}$$

RESUMEN DE RELACIONES DE IMPEDANCIA :

$$Z(z) = Z_0 \frac{V_1 e^{-\gamma z} + V_2 e^{\gamma z}}{V_1 e^{-\gamma z} - V_2 e^{\gamma z}}$$

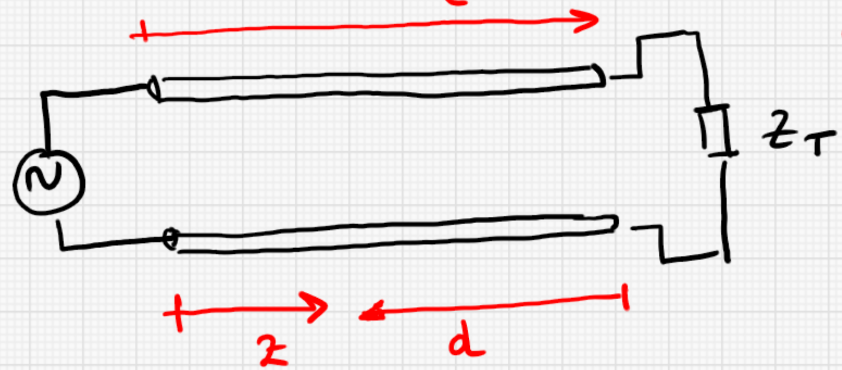
$$\left\{ \begin{array}{l} \gamma = \alpha + j\beta \\ Z(z = \ell) = Z_T \\ \alpha \approx 0 \\ \beta = \omega\sqrt{LC} = \frac{2\pi}{\lambda} \end{array} \right.$$



$$\Rightarrow \boxed{\frac{Z(d)}{Z_0} = \frac{Z_T/Z_0 + \tanh(\gamma d)}{1 + Z_T/Z_0 \tanh(\gamma d)} \quad , \quad \rho_T = \frac{Z_T/Z_0 - 1}{Z_T/Z_0 + 1}}$$

* COEFICIENTE DE REFLEXIÓN Y POTENCIA :

- RECORDAMOS :



$d = \ell - z$

$$V(z) = V_1 e^{-\gamma z} + V_2 e^{\gamma z} \Rightarrow \rho(z) = \frac{V_2 e^{\gamma z}}{V_1 e^{-\gamma z}} = \frac{V_2}{V_1} e^{2\gamma(\ell - d)}$$

$$\rho(d) = \underbrace{\frac{V_2}{V_1} e^{2\gamma \ell}}_{\rho_T} \cdot e^{-2\gamma d} = \boxed{\rho_T e^{-2\gamma d}}$$

$\gamma = \alpha + j\beta$

$\Rightarrow$ SE PUEDE ESCRIBIR :

$$\frac{Z(d)}{Z_0} = \frac{1 + \rho_T e^{-2\gamma d}}{1 - \rho_T e^{-2\gamma d}}$$

$$\rho_T = \frac{Z_T/Z_0 - 1}{Z_T/Z_0 + 1}$$

$$\begin{cases} V(z) = V_1 e^{-\gamma z} \left(1 + V_2/V_1 \, e^{2\gamma z} \right) \\ I(z) = \dfrac{V_1}{Z_0} e^{-\gamma z} \left(1 - V_2/V_1 \, e^{2\gamma z} \right) \end{cases}$$

POTENCIA

$$\Rightarrow P = \underbrace{V(z)\, I^*(z)}_{} \Rightarrow P_r = \left| \frac{V_1}{Z_0} \right|^2 R_0 \, e^{-2\alpha z} \left\{ 1 - |\rho(z)|^2 - \frac{2 X_0}{R_0} \, I_m[\rho(z)] \right\}$$

$$Z_0 = R_0 + j X_0$$

REAL

$$P_i = \left| \frac{V_1}{Z_0} \right|^2 X_0 \, e^{-2\alpha z} \left\{ 1 - |\rho(z)|^2 + \frac{2 R_0}{X_0} \, I_m[\rho(z)] \right\}$$

IMAGINARIA

A VECES $T_{(z)}$

$\Rightarrow \alpha \simeq 0$

$X_0 \simeq 0 \quad , \; Z_0 = R_0$

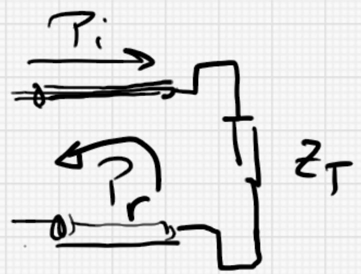
$$\langle P \rangle (z) = \underbrace{\frac{1}{2}\frac{|V_1|^2}{R_0}}\left(1 - |\rho(z)|^2\right)$$

SE PUEDE MOSTRAR QUE ES LA POTENCIA INCIDENTE EN UN PUNTO "z" CUALQUIERA

$$\Rightarrow P_{REF} = P_{ING}\left(1 - |\rho(z)|^2\right)$$

o EN "d"

$$\boxed{P_{REF} = P_{ING}\left(1 - |\rho(d)|^2\right)}$$



EN LA CARGA $P_{REF_T} = P_{ING_T}\left(1 - |\rho_T|^2\right)$

RECORDAR $\quad Z_0 = \sqrt{\dfrac{R + j\omega L}{G + j\omega C}} = R_0 + jX_0 = \sqrt{\dfrac{L}{C}} = R_0$

$\omega L \gg R$ @ ω DE TRABAJO

$\omega C \gg G$

* VAMOS A VER AHORA EL PARAMETRO <u>SWR</u> (ROE)

$ROE = \dfrac{|V(d)|_{MAX}}{|V(d)|_{min}}$ Y SE PUEDE PROBAR QUE $\boxed{ROE = \dfrac{1 + |\rho_T|}{1 - |\rho_T|}}$

* SALE DE USAR :

$$\begin{cases} |V(d)|_{MAX} = |V_1|\,(1 + |\rho|) \\ |V(d)|_{min} = |V_1|\,(1 - |\rho|) \end{cases}$$