$$\bar{E}(z) = \bar{a}\, E_0\, e^{-jkz}$$

$$\mu_0 \; \varepsilon_0$$

$$\bar{H}(z) = \bar{a}_z \times \bar{a}\, \frac{E_0}{\eta_0}\, e^{-jkz}$$

$$\eta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} \simeq 377\,\Omega$$

$$\nabla \times \bar{E} = -j\omega\mu_0 \bar{H}$$

$$\cancel{\nabla} \to \bar{a}_z \underbrace{\frac{\partial}{\partial z}}_{-jk}$$

$$\bar{H} = \frac{k}{\omega\mu_0}\, \bar{a}_z \times \bar{E}$$

$$\bar{S} = \frac{1}{2}\, \bar{E} \times \bar{H}^*$$

$$= \frac{1}{2}\, \bar{a}\, E_0\, e^{-jkz} \times \left(\bar{a}_z \times \bar{a}\, \frac{E_0}{\eta_0} e^{-jkz}\right)^*$$

$$= \frac{1}{2}\, \underbrace{\bar{a} \times (\bar{a}_z \times \bar{a})}_{\bar{a}_z \cdot 1 - \bar{a}\underbrace{(\bar{a}\cdot\bar{a}_z)}_{0}}\, E_0^2\, \frac{1}{\eta_0}\, \underbrace{e^{-jkz}\; e^{+jkz}}_{1}$$

$$E_0 E_0^* = |E_0|^2$$

$$\bar{S} = \frac{E_0^2}{2\eta_0}\, \bar{a}_z$$

$$E_0 = 10\, \frac{V}{m}$$

$$|\bar{S}| = \frac{100}{2 \cdot 377}\, \frac{V^2/m^2}{V/A} \simeq 0{,}13\, \frac{W}{m^2}$$

$$\mathcal{P}_{av} = \mathrm{Re}\{\bar{S}\}$$

ε, μ

$$\varepsilon = \varepsilon_r \varepsilon_0$$
$$\mu = \mu_r \mu_0$$

$$\nabla \times \bar{E} = -j\omega\mu_0 \bar{H}$$
$$\downarrow$$
$$-j\omega \underbrace{\mu \bar{H}}_{\bar{B}}$$

$$\nabla^2 \bar{E} + \omega^2 \mu_0 \varepsilon_0 \bar{E} = 0$$
$$\Downarrow$$
$$\nabla^2 \bar{E} + \underbrace{\omega^2 \mu \varepsilon}_{k^2} \bar{E} = 0$$

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

$$e^{-jkz} \qquad \cos(\omega t - kz)$$

phase velocity

$$v = \frac{\omega}{k} = \frac{\omega}{\omega\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_r\varepsilon_r}\sqrt{\mu_0\varepsilon_0}} = \frac{c}{\sqrt{\mu_r\varepsilon_r}} = u_p$$

$$\lambda = \frac{2\pi}{k} = \frac{2\pi}{\omega\sqrt{\mu\varepsilon}} = \frac{c}{f\sqrt{\mu_r\varepsilon_r}}$$

$$\sqrt{\mu_r\varepsilon_r} = n$$

(REFRACTIVE INDEX)

LOSSY MEDIUM:

ε

μ $\quad \sigma$

CONDUCTIVITY

Ohm's law: $\bar{J} = \sigma \bar{E}$

Ampère's law: $\nabla \times \bar{H} = \bar{J} + j\omega \underbrace{\varepsilon \bar{E}}_{\bar{D}}$

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

$= j\omega \underbrace{\left(\varepsilon + \frac{\sigma}{j\omega}\right)}_{\varepsilon_c} \bar{E}$

$\varepsilon_c = \varepsilon - j\frac{\sigma}{\omega}$

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

$$k_0^2 = \omega^2 \mu_0 \varepsilon_0$$

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

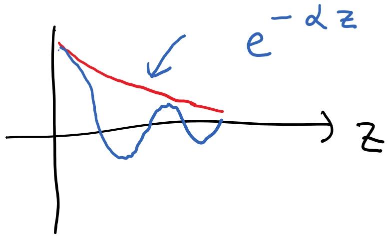
$$k_c^2 = \omega^2 \mu (\varepsilon' - j\varepsilon'')$$

(jk_c)

$\gamma = \alpha + j\beta$

$$e^{-jk_c z} = e^{-\gamma z} = e^{-\alpha z} \cdot e^{-j\beta z}$$

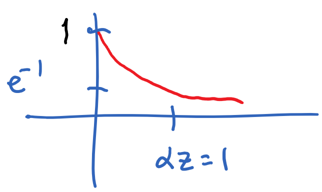
$$= e^{-j\left(Re\{k_c\} + j\, Im\{k_c\}\right) z} = e^{+\underbrace{Im\{k_c\}}_{-\alpha} z} \cdot e^{-j\underbrace{Re\{k_c\}}_{\beta} z}$$



$\alpha = -Im\{k_c\}$

$e^{-z/\delta}$ $\quad \delta = 1/\alpha$

PENETRATION DEPTH



DECIBEL

POWER MEASURED AGAINST A REFERENCE POWER P_0

$$\underbrace{10\, lg \frac{P}{P_0}}_{dB}$$

$P = 100 P_0$ — 20dB

$= 10^6 P_0$ 60 dB

$= P_0$ 0 dB

$lg = \log_{10}$

$ln = \log_e$

$= 10\ P_0$ 60 dB

dB

$= P_0$ 0 dB

$= 0.001\, P_0$ -30 dB

$$P \sim S \sim E^2$$

$$\Rightarrow \quad 10 \lg \frac{E^2}{E_0^2} = 20 \lg \frac{E}{E_0}$$

VERY LOSSY MEDIUM

$$\varepsilon' - j\underbrace{\frac{\sigma}{\omega}}_{\gg \varepsilon'}$$

$$k_c \cong \omega\sqrt{\mu\left(-j\frac{\sigma}{\omega}\right)}$$

$$\doteq \frac{\omega\sqrt{\mu\sigma}}{\sqrt{\omega}}\underbrace{\sqrt{-j}}_{\frac{1-j}{\sqrt{2}}}$$

$$k_c = (1-j)\underbrace{\sqrt{\frac{\omega\mu\sigma}{2}}}_{\sqrt{\pi f\mu\sigma}}$$

$$\alpha = \sqrt{\pi f\mu\sigma}$$

$$\delta = \frac{1}{\sqrt{\pi f\mu\sigma}}$$