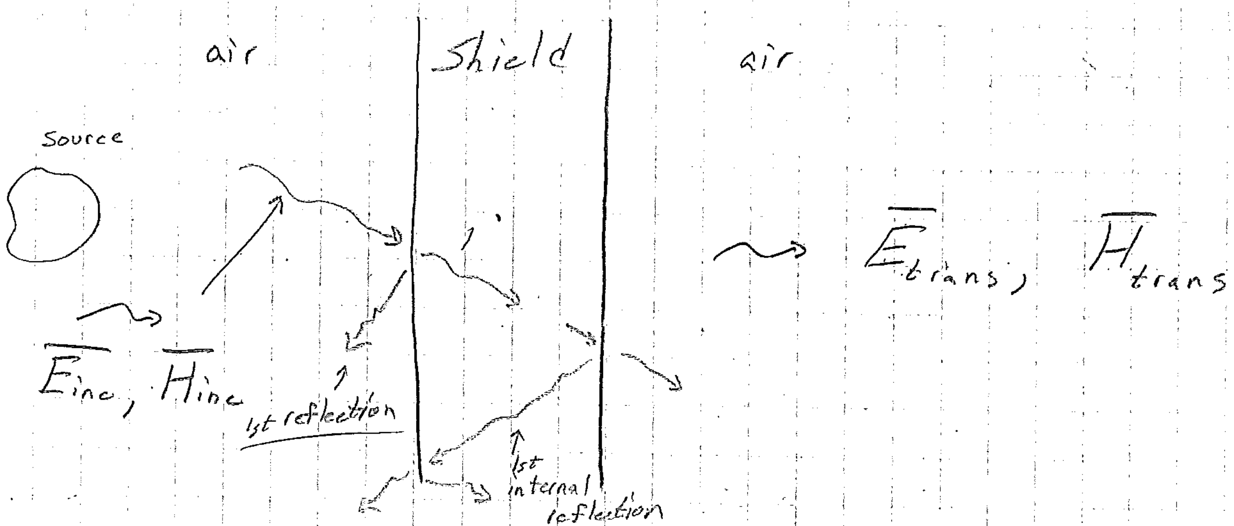
(Box)

Shielding

- use to protect our devices from external fields.

- or use to keep our noise emmissions from interfering w/ others.



shielding effectiveness (SE) =

$$20 \log \left| \frac{E_{inc}}{E_{trans}} \right| \text{ dB}$$

(electric field SE)

$$\text{or } 20 \log \left| \frac{H_{inc}}{H_{trans}} \right| \text{ dB.}$$

we will assume

$$SE = R + A + B$$

multiple reflection factor.

accounts $\forall$ the multiple reflection terms.

reflection loss (dB)

will account for the 1st initial reflection + the 1st internal reflection.

Absorption ~~Absorbtion~~ loss (dB)

accounts for the material loss for one pass through the shield.

Absorption loss:

The field of a plane wave propagating in the +z-dir. can be expressed as

$$E_x(z,t) = E_0 e^{-\alpha z} \cos(\omega t - \beta z)$$

$$\tilde{E}_x(z) = E_0 e^{-(\alpha + j\beta) z} = E_0 e^{-\gamma z}$$

where $\gamma = \alpha + j\beta$

$$= \sqrt{j\omega\mu(\sigma + j\omega\varepsilon)}$$

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

$$\nabla \times \hat{E} = -j\omega\mu \tilde{H}$$

$$\nabla \times \hat{H} = \hat{J} + j\omega\varepsilon \tilde{E}$$

$$\nabla \cdot \hat{D} = \rho_v$$

$$\nabla \cdot \tilde{B} = 0$$

perfect dielectric: $\sigma = 0$

$$\Rightarrow \alpha = 0$$

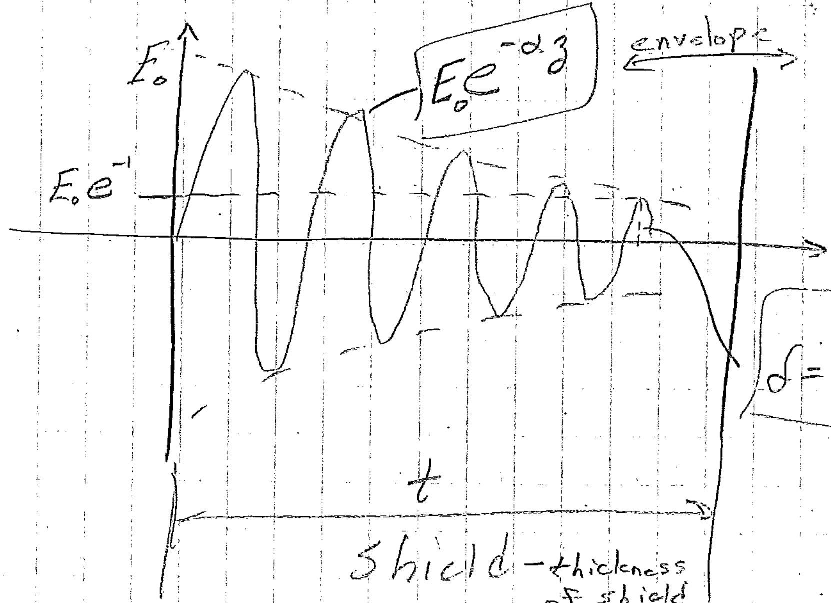
$$\beta = \omega\sqrt{\mu\varepsilon}.$$

good conductor $\left(\frac{\sigma}{\omega\varepsilon} >> 1\right)$

$$\gamma \to \underbrace{j\omega\sqrt{\mu\varepsilon}\sqrt{\frac{-j\sigma}{\omega\varepsilon}}}$$

$$= \cancel{\alpha}\sqrt{\mu\omega\sigma}\ \underbrace{\angle 45^\circ}_{\frac{1}{\sqrt{2}}(1+j)}$$

$$\boxed{\gamma \to \sqrt{\pi f \mu\sigma}\,(1+j)} \quad \therefore \boxed{\beta = \alpha = \sqrt{\pi f \mu \sigma}}$$



$$\boxed{E_0 e^{-\alpha z}} \xleftrightarrow{\text{envelope}} E_0 e^{-z/\delta}$$

skin depth

$$\boxed{\delta = \frac{1}{\alpha}} \xleftrightarrow{\text{good conductor}} \boxed{\frac{1}{\sqrt{\pi f \mu \sigma}}}$$

$$A = 20\log\left|\frac{E_0}{E_0 e^{-\alpha t}}\right| = 20\log\left|e^{t/\delta}\right| = \boxed{20\log e^{t/\delta}\ \text{dB}}$$

$$\Rightarrow \boxed{A = 8.69\left(\frac{t}{\delta}\right)\ dB}$$

$\approx$ 9dB of shielding for each skindepth of shielding.

or $\bar{A} = 8.69\, t\sqrt{\pi f \mu \sigma}$ t = meters

$\sigma = \sigma_{copper}\sigma_r$

$\mu = \mu_o \mu_r$

In meters

$$A = 131.5\, t\sqrt{f\mu_r\sigma_r}$$

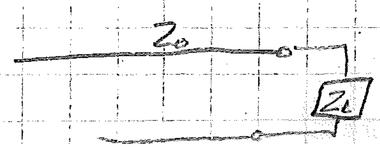
$$= 3.34\, t\sqrt{f\mu_r\sigma_r}$$

In inches

Reflection loss depends on

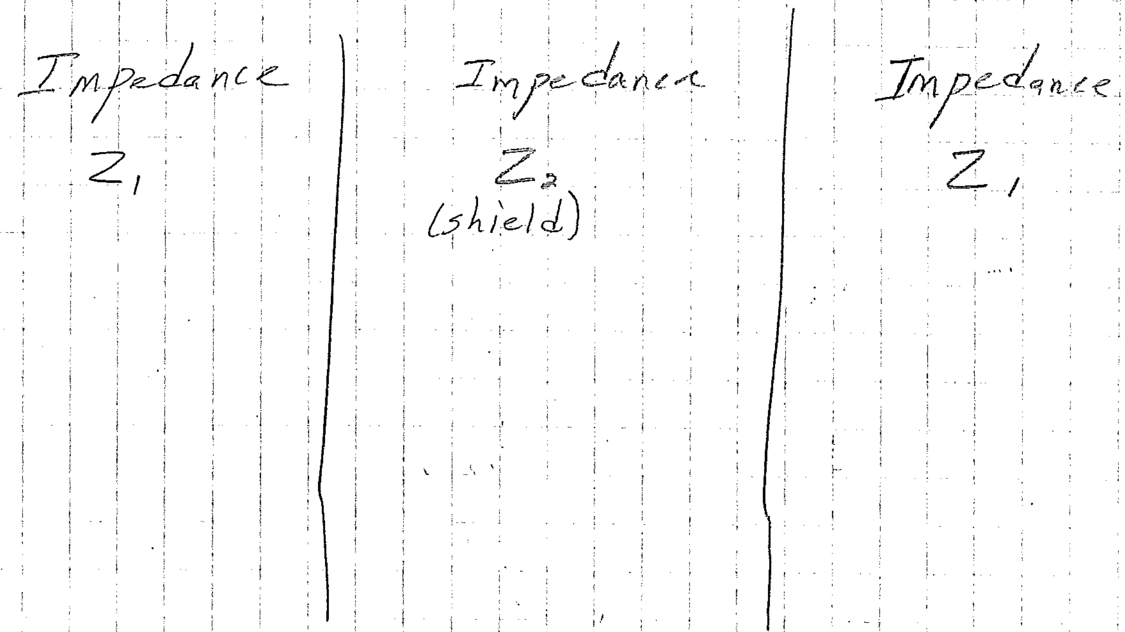
- distance from the sources
- possibly type of field created by source (i.e. mainly electric or magnetic etc.)

From T-line Theory



$$\Gamma_L = \frac{Z_L - Z_o}{Z_L + Z_o}$$

First assume we are far from the source - looks like a plane wave:



10/27 Review

1) Components
- R, L, C, conductors, beads

2) Analog Grounding
- single / multipt / hybrid
- minimize gnd loop

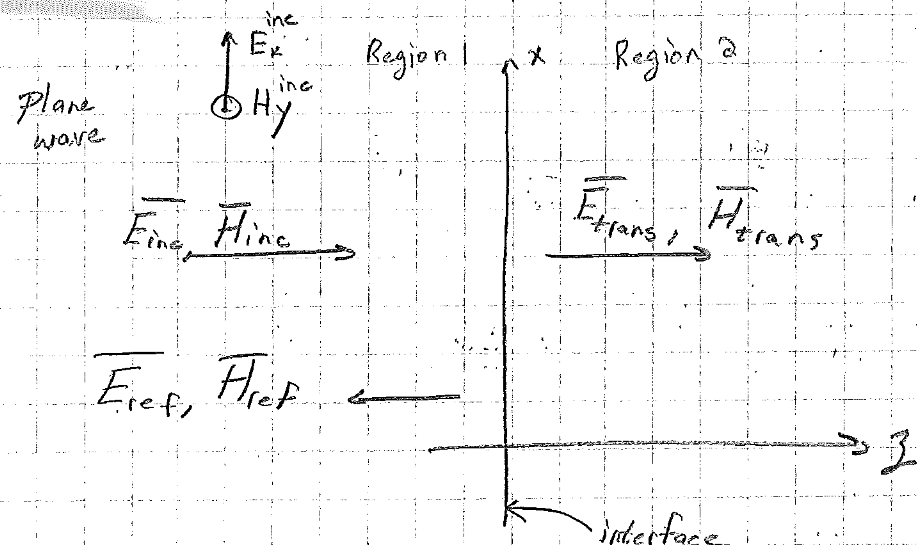
3) Filter
- DM, CM } LP, HP, BP, BS

4) Shielding
- absorbtion loss.

He will provide Filter tables, Attn. charts eqns, Filter Transformations. - We can
8½ x 11

Lab Reports:

- group report
- reports due from lab 1/2 due on the week of lab 3/4



$$\bar{E}_{inc} = E_0 e^{-j\beta_1 z} \hat{a}_x$$

$$\bar{E}_{ref} = \Gamma E_0 e^{+j\beta_1 z} (\hat{a}_x)$$

reflection coef.

$$\bar{E}_{trans} = E_0 T \cdot e^{-j\beta_2 z} \hat{a}_x$$

Transmission coef.

We could show that $\Gamma = \dfrac{Z_2 - Z_1}{Z_2 + Z_1}$

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

N.P.

where Z_1 + Z_2 are the wave impedances in region 1 + 2, resp.

$$\overline{H}_{inc} = H_0 e^{-j\beta_1 z} a_y$$

$$\overline{H}_{ref} = -H_0 \Gamma e^{+j\beta_1 z} \hat{a}_y = -H_0 \left[\frac{\overset{Z_2 - Z_1}{\cancel{Z_1 - Z_2}}}{Z_1 + Z_2}\right] e^{j\beta_1 z} \hat{a}_y$$

$$\overline{H}_{trans} = \cancel{H_0 \left(\frac{2Z_1}{Z_2}\right) e^{-j\beta_2 z} \hat{a}_y}$$

$$= H_0 \left(\frac{2Z_1}{Z_1 + Z_2}\right) e^{-j\beta_2 z} \hat{a}_y$$

Reflection loss

These are different regions

Impedance Z_1	impedance Z_2	Impedance Z_1
Z_w - wave impedance	Z_s (intrinsic imp. of the shield)	
$E_0 \rightarrow$	$E_1 = E_0 \cdot \left(\frac{2Z_2}{Z_1 + Z_2}\right) \rightarrow$	$E_t = E_0 \left(\frac{2 \cdot Z_2}{Z_2 + Z_1}\right)\left(\frac{2Z_1}{Z_1 + Z_2}\right) \rightarrow$
$H_0 \rightarrow$	$H_1 = H_0 \left(\frac{2Z_1}{Z_1 + Z_2}\right) \rightarrow$	$H_t = H_0 \left(\frac{2Z_1}{Z_1 + Z_2}\right)\left(\frac{2Z_2}{Z_1 + Z_2}\right) \rightarrow$

reflection loss.

$$\Rightarrow R = 20 \log \left|\frac{E_{inc}}{E_{trans}}\right| \text{ dB}$$

electric field case.

$$\Rightarrow R = 20 \log \left|\frac{(Z_1 + Z_2)^2}{4Z_1 Z_2}\right| \text{ dB}$$

11/3

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

plane wave prop. in $+z$-dir.

$$\tilde{E}_x = E_o e^{-\gamma z}\,\hat{a}_x$$

mag. field will be

$$H_y = \frac{E_o}{\eta} e^{-\gamma z}$$

intrinsic imp. of the material

η = ratio of E to H for a plane wave.

from Maxwell's eqn. $\boxed{\eta = \frac{j\omega\mu}{\gamma} = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\varepsilon}}}$

$\therefore$ for the shield impedance we will use η for a good conductor.

$\therefore$ we can show that η for a good conductor

is $\sqrt{\frac{\omega\mu}{\sigma}}\ \angle 45^\circ = (1+j)\cdot\sqrt{\frac{\omega\mu}{2\sigma}}$

$\boxed{|Z_s| = \sqrt{\frac{\omega\mu}{\sigma}}}$ $\leftarrow$ what we will use for reflection loss for Z_s

If $Z_2 \ll Z_1$

then $$E_t \cong \frac{4Z_1Z_2}{Z_1^2} E_0 = \frac{4Z_2}{Z_1} E_0$$

& $$H_t \cong \frac{4Z_2}{Z_1} H_0$$

$$R \cong 20 \log \left| \frac{(Z_1+Z_2)^2}{4Z_1Z_2} \right| \cong 20 \log \left| \frac{Z_1}{4Z_2} \right|$$

Z_w

Z_s

And Also if $Z_2 \ll Z_1$

$$\Rightarrow E_1 = \frac{2Z_2}{Z_1} E_0 \quad \& \quad H_1 \approx 2H_0$$

IN $SE = R + A + B$ consider this term if have low freq. mag fields.

The wave impedance is also a ratio of E to H but is a more general concept which is not constrained to plane waves.

2 - special cases often used to approx. radiation from ckts. are

1) Small electric dipole
2) small loop of current.