Loss in waveguide:

Marcuvitz gives for TE_{10} in rectangular guide, the loss constant due to walls of finite conductivity σ:

$$\alpha_r = \frac{R}{\mathcal{J} b} \cdot \frac{1 + \frac{2b}{a}\left(\frac{\lambda}{2a}\right)^2}{\sqrt{1 - \left(\frac{\lambda}{2a}\right)^2}}$$

This can be simplified, because

$$\mathcal{J} \equiv \sqrt{\frac{\mu}{\epsilon}} = 377\ \Omega \text{ in air}$$

$$R = \pi \mathcal{J} \frac{\delta}{\lambda}$$

$$\delta = \sqrt{\frac{2}{\omega \mu \sigma}} \quad \text{(skin depth)}$$

Using $\lambda = \frac{c}{f}$, $c = \frac{1}{\sqrt{\mu\epsilon}}$, $\omega = 2\pi f$

$$R = \pi \mathcal{J} f \sqrt{\mu\epsilon} \sqrt{\frac{1}{\pi f \mu \sigma}}$$

$$= \mathcal{J} \frac{\pi f \sqrt{\mu\epsilon}}{\sqrt{\pi f \mu \sigma}}$$

$$= \mathcal{J} \sqrt{\frac{\pi f \epsilon}{\sigma}} = \mathcal{J} \sqrt{\frac{\omega \epsilon}{2\sigma}}$$

Also, $2a = \lambda_c$, and typically $b = \frac{a}{2}$

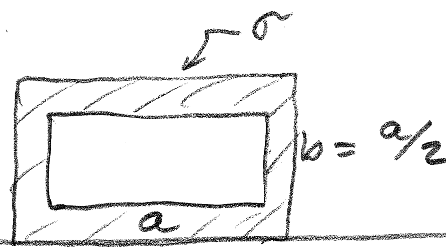
$$\therefore \quad \boxed{\alpha_r = \frac{\sqrt{\frac{\omega\epsilon}{2\sigma}}}{b} \left[\frac{1 + \left(\frac{\lambda}{\lambda_c}\right)^2}{\sqrt{1 - \left(\frac{\lambda}{\lambda_c}\right)^2}}\right]}$$

In circular wg of radius a,

$$\alpha_c = \frac{\sqrt{\frac{\omega \epsilon}{2\sigma}}}{a} \left[\frac{1.189 + \left(\frac{\lambda}{\lambda_c}\right)^2}{\sqrt{1 - \left(\frac{\lambda}{\lambda_c}\right)^2}} \right]$$

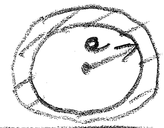
Since $\frac{f_c}{f} = \frac{\lambda}{\lambda_c}$,

For rectangular guide TE_{10} mode



$$\alpha_r = \frac{\sqrt{\frac{\pi \epsilon}{\sigma}} \sqrt{f}}{b} \left[\frac{1 + \left(\frac{f_c}{f}\right)^2}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}} \right]$$

For Circular wg, TE_{11} mode:



$$\alpha_c = \frac{\sqrt{\frac{\pi \epsilon}{\sigma}} \sqrt{f}}{a} \left[\frac{1.189 + \left(\frac{f_c}{f}\right)^2}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}} \right]$$

$\epsilon_0 = 8.854 \times 10^{-12}$ F/m

$\sigma_{cu} \simeq 5.8 \times 10^{7}$ $\frac{Mho}{m}$, $\sigma_{AL} \simeq 1.8 \times 10^{7}$ $\frac{Mho}{m}$

$$\Rightarrow \sqrt{\frac{\pi \epsilon_0}{\sigma_{cu}}} \simeq 0.69 \times 10^{-9} \left(\sec^{\frac{1}{2}}\right)$$

$$\sqrt{\frac{\pi \epsilon_0}{\sigma_{AL}}} \simeq 1.24 \times 10^{-9} \left(\sec^{\frac{1}{2}}\right)$$

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The loss L_o for waveguide of length L is;

$$L_o = e^{-\alpha L}$$

in dB,

$$L_o = 20 \log_{10}(e^{-\alpha L}) \quad (dB)$$

or

$$\boxed{L_o = -8.686\, \alpha L \quad (dB)}$$