

**Problem 7.18** Generate a plot for the skin depth  $\delta_s$  versus frequency for seawater for the range from 1 kHz to 10 GHz (use log-log scales). The constitutive parameters of seawater are  $\mu_r = 1$ ,  $\epsilon_r = 80$ , and  $\sigma = 4 \text{ S/m}$ .

**Solution:**

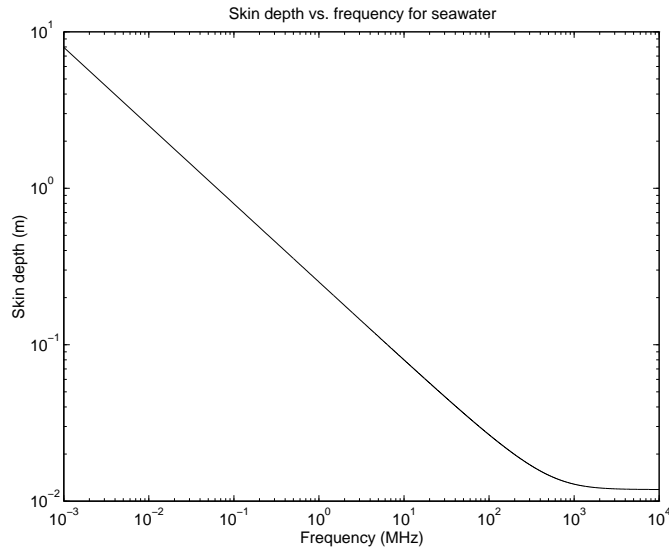
$$\delta_s = \frac{1}{\alpha} = \frac{1}{\omega} \left[ \frac{\mu \epsilon'}{2} \left[ \sqrt{1 + \left( \frac{\epsilon''}{\epsilon'} \right)^2} - 1 \right] \right]^{-1/2},$$

$$\omega = 2\pi f,$$

$$\mu \epsilon' = \mu_0 \epsilon_0 \epsilon_r = \frac{\epsilon_r}{c^2} = \frac{80}{(3 \times 10^8)^2},$$

$$\frac{\epsilon''}{\epsilon'} = \frac{\sigma}{\omega \epsilon} = \frac{\sigma}{\omega \epsilon_0 \epsilon_r} = \frac{4 \times 36\pi}{2\pi f \times 10^{-9} \times 80} = \frac{72}{80f} \times 10^9.$$

See Fig. P7.18 for plot of  $\delta_s$  versus frequency.



**Figure P7.18:** Skin depth versus frequency for seawater.