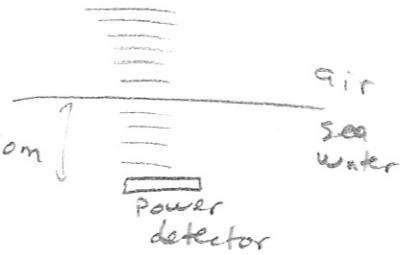
Example 1

A microwave beam is normally incident from air onto perfectly smooth sea water. If the incident beam has a power of 10W find the power at a depth of 5m for a frequency of $f = 1KHz$ and $f = 1MHz$.

use $\varepsilon_r = 81$, $\sigma = 4$ S/m



Find the transmission coefficient

$$\tau = \frac{2\eta_2}{\eta_2 + \eta_1} \qquad \Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}$$

$$\eta_1 = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 377$$

$$\eta_2 = \sqrt{\frac{\mu_0}{\varepsilon_2}}$$

$$\varepsilon_2 = \varepsilon_0 \varepsilon_r - j\frac{\sigma}{\omega}$$

$$= (8.854 \times 10^{-12})(81) - j\left(\frac{4}{2\pi \times 10^3}\right)$$

$$= 7.17 \times 10^{-10} - j\, 6.37 \times 10^{-4}$$

$$\eta_2 = \sqrt{\frac{4\pi \times 10^{-7}}{7.17 \times 10^{-10} - j\, 6.37 \times 10^{-4}}} = 0.0314 + j\, 0.0314$$

$$\tau = \frac{(2)(0.0314 + j\, 0.0314)}{377.0314 + j\, 0.0314}$$

$$\tau = 1.67 \times 10^{-4} + j\, 1.6675 \times 10^{-4}$$

Now work with power

$$T = |\tau|^2 = 5.56 \times 10^{-8}$$ power transmitted into water

loss of power from traveling through water

$$\vec{E} = \vec{E}_0 e^{-\gamma z}$$

$$\gamma = \sqrt{-\omega^2 \mu \varepsilon_c} = 0.1257 + j\, 0.1257$$

power loss $(e^{-\alpha z})^2 = e^{-2\alpha z}$

$$\exp[(-2)(0.1257)(5)] = 3.49 \times 10^{-6}$$

Power received $= (10W)(5.56 \times 10^{-8})(3.49 \times 10^{-6}) = 158$ nW

Now switch to 1MHz

$E_2 = 7.17 \times 10^{-10} - j\,6.37 \times 10^{-7}$

$\eta_2 = 0.99 + j\,0.99$

$\gamma = 0.0053 + j\,0.0052$

$T = 5.5 \times 10^{-5}$

$\gamma = 3.97 + j\,3.98$

Received power $= (10)(5.5 \times 10^{-5})\exp[-(2)(3.97)(5)] = 3.15 \times 10^{-21}$ W