7.19.the wavelength of a uniform linear polarization plane wave in the air is 60m, $\vec{E} = \vec{e}_x \cos(\omega t)\ v/m$ at the place where it is 1 meters below sea level as the wave enters into the sea along the z axis and propagates down vertically. Find the instantaneous $\vec{E}$ and $\vec{H}$,the phase velocity and the wavelength at any point below the sea level. For the sea water, $\sigma = 4s/m$ and $\varepsilon_r = 80, \mu_r = 1$.

Solution:

$$\frac{\sigma}{\omega\varepsilon} = 180 \gg 1$$

So the sea is a good conductor.

$$\alpha = \beta \approx \sqrt{\frac{1}{2}\omega\mu\sigma} = \sqrt{\frac{1}{2}\omega\mu_r\mu_0} = 8.9 rad/m\ ;$$

$$\vec{V}_p = \frac{\omega}{\beta}\vec{e}_z \approx 3.35\times10^6\vec{e}_z\ m/s\ ;$$

$$\lambda = \frac{2\pi}{\beta} \approx 0.71m\ ;$$

For : $\vec{E} = \vec{e}_x E_0 e^{-\alpha z}\cos(\omega t - \beta z + \varphi_0)$,

when z=1 : $\vec{E} = \vec{e}_x E_0 e^{-\alpha z}\cos(\omega t - \beta + \varphi_0) = \vec{e}_x \cos\omega t$;

$$E_0 = e^{\alpha}\ v/m;$$

so : $\varphi_0 = \beta\ rad;$

$$\eta_c = \sqrt{\frac{\omega\mu}{\sigma}}e^{j\frac{\pi}{4}} = \pi e^{j\frac{\pi}{4}}(\Omega);$$

$$\vec{H} = \frac{1}{\eta_c}\vec{e}_k \times \vec{E} = \vec{e}_z 2.32\times10^3 e^{j(\pi\times10^7 t - 8.9z + 8.1)};$$

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$$\vec{E} = \vec{e}_x 7.3\times10^3 e^{j(\pi\times10^7 t - 8.9z + 8.9)};$$

7.20 The conductivity of sea water is σ=4s/m and ε_r=8, faind the attenuation constant, wavelength and wave impedance of the electromagnetic wave in the sea with frequencies of 10kHz, 1MHz, 10MHz and 1GHz.

Solution:

(1) $w = 2\pi f\ \frac{\sigma}{w\varepsilon} = \frac{4}{2\pi f\varepsilon} >> 1$

$$\alpha = \sqrt{\pi f \mu \sigma} = 0.126\pi$$

$$\lambda = \frac{2\pi}{\beta} = 15.87m$$

$$\eta = \sqrt{\frac{\mu}{\varepsilon_r}} = 0.032\pi(1+\mathrm{j})\Omega$$

(2) $\frac{\sigma}{w\varepsilon} = \frac{4}{2\pi f \varepsilon} >> 1$

$$\alpha = \sqrt{\pi f \mu \sigma} = 0.126\pi$$

$$\lambda = \frac{2\pi}{\beta} = 1.587m$$

$$\eta = \sqrt{\frac{\mu}{\varepsilon_r}} = 0.316\pi(1+\mathrm{j})\Omega$$

(3) $\frac{\sigma}{w\varepsilon} = \frac{4}{2\pi f \varepsilon} >> 1$

$$\alpha = \sqrt{\pi f \mu \sigma} = 4\pi$$

$$\lambda = \frac{2\pi}{\beta} = 0.5m$$

$$\beta = \sqrt{\frac{\mu}{\varepsilon_r}} = \pi(1+\mathrm{j})\Omega$$

(4) $\frac{\sigma}{w\varepsilon} \approx 1$

$$a = w\sqrt{\frac{\mu\varepsilon}{2}[\sqrt{1+(\frac{\sigma}{\omega\varepsilon})^2} - 1]}$$

$$=2\pi\mathrm{f}\sqrt{\frac{\mu\varepsilon}{2}[\sqrt{1+(\frac{\sigma}{\omega\varepsilon})^2} - 1]} = 24.65\pi$$

$$\beta = w\sqrt{\frac{\mu\varepsilon}{2}[\sqrt{1+(\frac{\sigma}{\omega\varepsilon})^2} - 1]} = 12.8\pi rad/m$$

$$\lambda = \frac{2\pi}{\beta} = 0.03m$$

$$\eta = \sqrt{\frac{\mu}{\varepsilon}}(1-\mathrm{j}\frac{\sigma}{w\varepsilon})^{-0.5} = \frac{42}{\sqrt{1-0.39j}}\Omega$$