☺ ☼ Friday, April 22, 2022 ☠ ♬

EE 483/583 Antennas for Wireless Communications Quiz #9 (Spring 2022)

Name KEY

Instructions: Open book & notes. Place answers in indicated spaces and **show all** work for credit.

Desperate for entertainment in the lab, a loopy EE student makes a circular (4" diameter) antenna out of solder (ε_0, μ_0, $\sigma = 6.6 \times 10^6$ S/m) that is 0.1" in diameter. The antenna is located in free space using a stylish antenna mast mounted on a baseball cap (ME senior design project). If the student is listening to KQRQ classic hits at 92.3 MHz, find the free space wavenumber. Then, determine if this loop antenna is electrically small or large. Why? Also, find the antenna circumference in terms of wavelengths C/λ, radiation resistance, loss resistance, and radiation efficiency (%).

solder/wire diameter $2b = 0.1(0.0254) = 0.00254$ m $\Rightarrow$ wire radius $b = 1.27$ mm

loop diameter $2a = 4(0.0254) = 0.1016$ m $\Rightarrow$ loop radius $a = 5.08$ cm $= 50.8$ mm

Wavelength $\lambda = u/f = 2.9979\times10^8/92.3\times10^6 \Rightarrow \lambda = 3.248$ m

Wavenumber $k = 2\pi/\lambda = 2\pi/3.248 \Rightarrow$ **$k = 1.93448$ rad/m**

Loop circumference $C = 2\pi a = 2\pi\,(0.0508\text{ m}) \Rightarrow C = 0.319186$ m

$C/\lambda = ka = 0.319186/3.248 =$ **0.098272** $< 0.1 << 1 \Rightarrow$ **electrically small loop**

Radiation resistance, per (5-24), $R_r = \eta(\pi/6)(ka)^4 = 376.7303\,(\pi/6)[0.098272]^4$

$\Rightarrow$ **$R_r = 0.018397\ \Omega = 18.397\ \text{m}\Omega$**

Loss resistance, per (2-90b),

$$R_L = \frac{l}{P}\sqrt{\frac{\omega\mu_0}{2\sigma}} = \frac{2\pi a}{2\pi b}\sqrt{\frac{\omega\mu_0}{2\sigma}} = \frac{a}{b}\sqrt{\frac{\omega\,\mu_0}{2\sigma}} = \frac{50.8}{1.27}\sqrt{\frac{2\pi(92.3\bullet10^6)4\pi\bullet10^{-7}}{2(6.6\bullet10^6)}}$$

$\Rightarrow$ **$R_L = 0.297214\ \Omega = 297.214\ \text{m}\Omega$**

Radiation efficiency (%), per (2-90)

$$e_{cd} = \left(\frac{R_r}{R_L + R_r}\right)100\% = \left(\frac{18.397}{297.214 + 18.397}\right)100\% \Rightarrow \textbf{$e_{cd} = 5.82895\ \%$}$$

Loop is electrically small or large (Circle one) Why? **$C/\lambda = ka = 0.09827 < 0.1 << 1$**

$k = 1.93448$ rad/m $C/\lambda =$ **$ka = 0.09827$** Radiation resistance = **$18.397\ \text{m}\Omega$**

Loss resistance = **$297.214\ \text{m}\Omega$** Radiation efficiency = **$5.83\ \%$**