EE 483/583 Antennas for Wireless Communications Quiz #9 (Spring 2024)

Name __KEY__

Instructions: Open book & notes. Place answers in indicated spaces & **show all** work for credit. $c = 2.9979 \times 10^8$ m/s.

Longing for entertainment in the student lounge, a loopy EE student makes a circular (3.75" diameter) antenna out of Kester solder (ε_0, μ_0, $\sigma = 6.4 \times 10^6$ S/m, 1 mm diameter). The antenna is located in free space using a stylish antenna mast mounted on a baseball hat (ME senior project). Due to abysmal taste (or possible brain damage), the student is listening to "93.9 The Mix". Determine if this loop antenna is electrically small, "smallish" w/ constant current, or large. Why? Find the free space wavenumber. Also, find the antenna circumference in terms of wavelengths C/λ, radiation resistance, loss resistance, and radiation efficiency (%).

solder/wire diameter $2b = 1$ mm $\Rightarrow$ wire radius $b = 0.5$ mm $= 0.0005$ m

loop diameter $2a = 3.75(0.0254) = 0.09525$ m $\Rightarrow$ loop radius $a = 47.625$ mm $= 0.047625$ m

Wavelength $\lambda = u/f = 2.9979\times10^8/93.9\times10^6 \Rightarrow \lambda = 3.19265$ m

Wavenumber $k = 2\pi/\lambda = 2\pi/3.19265 \Rightarrow$ **$k = 1.968015$ rad/m**

Loop circumference $C = 2\pi a = 2\pi\,(0.047625\text{ m}) \Rightarrow C = 0.299237$ m

$C/\lambda = ka = 0.299237\,/3.19265 =$ **0.093727** $< 0.1 \ll 1 \Rightarrow$ **electrically small loop**

Radiation resistance, per (5-24), $R_r = \eta(\pi/6)(ka)^4 = 376.7303\,(\pi/6)[0.093727]^4$

$\Rightarrow$ **$R_r = 0.015222\ \Omega = 15.222$ mΩ**

Loss resistance, per (2-90b),

$$R_L = \frac{\ell}{P}\sqrt{\frac{\omega\mu_0}{2\sigma}} = \frac{2\pi a}{2\pi b}\sqrt{\frac{\omega\mu_0}{2\sigma}} = \frac{a}{b}\sqrt{\frac{\omega\,\mu_0}{2\sigma}} = \frac{47.625}{0.5}\sqrt{\frac{2\pi(93.9\bullet10^6)\,4\pi\bullet10^{-7}}{2(6.4\bullet10^6)}}$$

$\Rightarrow$ **$R_L = 0.724916\ \Omega = 724.916$ mΩ**

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

$$e_{cd} = \left(\frac{R_r}{R_L + R_r}\right)100\% = \left(\frac{15.222}{724.916 + 15.222}\right)100\% \Rightarrow \textbf{$e_{cd} = 2.05669$ \%}$$

Loop is electrically: **small**, 'smallish' w/ constant current, or large. (Circle one)

Why? **$C/\lambda = ka = 0.093727 < 0.1 \ll 1$** $k =$ **1.968 rad/m** $C/\lambda =$ **0.093727**

rad. resistance = **$R_r = 15.222$ mΩ** loss resistance = **$R_L = 724.916$ mΩ** rad. eff. = **$e_{cd} = 2.06$ %**