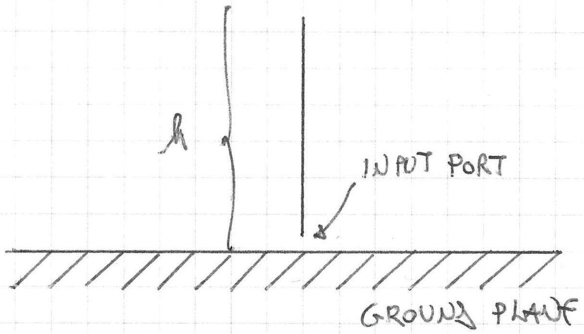
PROBLEM P6

WE CONSIDER A WHIP ANTENNA MOUNTED ON A GROUND PLANE: IT IS A MONOPOLE

THE WIRE (WHIP) HAS A RADIUS $a = 1{,}5$ mm AND IT IS MADE OF STAINLESS STEEL WHOSE CONDUCTIVITY IS $\sigma = 2 \times 10^6 \, \Omega^{-1} m^{-1}$



THE WHIP LENGTH IS $h = 0{,}8$ m AND THE WORKING FREQUENCY IS $f = 1$ MHz

1) BY ASSUMING A UNIFORM CURRENT FIND THE INPUT IMPEDANCE

UNDER THE PREVIOUS HYPOTHESIS THE ANTENNA IS EQUIVALENT TO "HALF IDEAL DIPOLE"

RADIATION RESISTANCE $R_R = \frac{1}{2} 80\pi^2 \left(\frac{2h}{\lambda}\right)^2 = 160\pi^2 \left(\frac{h}{\lambda}\right)^2$

$\lambda = \frac{c}{f} = \frac{3\,10^8}{10^6} = 300$ (THE WAVELENGTH IS MUCH LARGER THAN h)

$$R_R = 160\pi^2 \left(\frac{0{,}8}{300}\right)^2 = 0{,}0112 \, \Omega = 11{,}2 \, m\Omega$$

DISSIPATION (OR OHMIC) RESISTANCE $R_d = \frac{h}{2\pi a \delta} \frac{1}{\sigma}$

WHERE δ IS THE SKIN DEPTH $\delta = \frac{1}{\sqrt{\pi \mu f \sigma}} = 3{,}56\,10^{-4}\, m = 0{,}356$ mm

$$R_d = \frac{0{,}8}{2\pi \; 1{,}5\,10^{-3} \; 3{,}56\,10^{-4}} \cdot \frac{1}{2\,10^6} = 0{,}1192 \, \Omega = 119{,}2 \, m\Omega$$

THE REACTIVE PART OF INPUT IMPEDANCE IS $X_A = \frac{1}{2}\left\{ - \frac{120}{\pi \frac{2h}{\lambda}} \left[\ln\left(\frac{2h}{2a}\right) - 1 \right] \right\}$

$$X_A = -\frac{30}{\pi \frac{h}{\lambda}}\left[\ln\left(\frac{h}{a}\right)-1\right] = -18905\ \Omega$$

THE TOTAL INPUT IMPEDANCE IS $Z_A = R_R + R_d + jX_A = 0,1309 - j\,18905\ \Omega$

IT IS DIFFICULT TO IMPEDANCE MATCH THIS ANTENNA DUE TO THE SMALL INPUT RESISTANCE AND TO THE VERY LARGE CAPACITIVE REACTANCE. MOREOVER, THE RADIATION EFFICIENCY IS VERY SMALL $e_R = \frac{R_R}{R_R + R_d} = \frac{0,0112}{0,0112 + 0,1192} = 0,0859 \simeq 8,6\%$

2) BY ASSUMING A LINEARLY VARYING CURRENT DISTRIBUTION, FIND THE INPUT IMPEDANCE

WE OBSERVE THAT THE ANTENNA IS EQUIVALENT TO "HALF SHORT DIPOLE" (HAVING A TRIANGULAR CURRENT DISTRIBUTION

RADIATION RESISTANCE $R_R = \frac{1}{2}\,20\pi^2\left(\frac{2h}{\lambda}\right)^2 = 40\pi^2\left(\frac{h}{\lambda}\right)^2 = 0,0028\ \Omega = 2,8\ m\Omega$

DISSIPATION RESISTANCE $R_d = \frac{1}{2}\,\frac{1}{3}\,\frac{2h}{2\pi a\delta}\,\frac{1}{\sigma} = \frac{1}{3}\,\frac{h}{2\pi a\delta}\,\frac{1}{\sigma} = 0,0397\ \Omega$
$\stackrel{!}{=} 39,7\ m\Omega$

THE REACTIVE PART OF INPUT IMPEDANCE IS $X_A = -\frac{30}{\pi \frac{h}{\lambda}}\left[\ln\left(\frac{h}{a}\right)-1\right]$

$X_A = -18905\ \Omega$

THE TOTAL INPUT IMPEDANCE IS $Z_A = R_R + R_d + jX_A = 0,0425 - j\,18905\ \Omega$

AND THE RADIATION EFFICIENCY IS $e_R = \frac{R_R}{R_R + R_d} = \frac{0,0028}{0,0028 + 0,0397} = 0,0659 \simeq 6,6\%$