5.14 A resonant six-turn loop of *closely spaced turns* is operating at **80** MHz. The radius of the loop is $\lambda/30$, and the loop is connected to a 50-ohm transmission line. The radius of the wire is $\lambda/300$, its conductivity is $\sigma = 5.7 \times 10^7$ S/m, and the spacing between the turns is $\lambda/100$. Determine the

(a) directivity of the antenna (in dB)

(b) radiation efficiency taking into account the proximity effects of the turns

(c) reflection efficiency (d) gain of the antenna (in dB)

- Note: "resonant" means you assume $X_A = 0$. Assume antenna is 'small'.

a) $C_{single} = 2\pi a = \frac{2\pi\lambda}{30} = 0.20944\lambda$ ← borderline

For a 'small' antenna, per (5-31)

$D_{max} = D_0 = 3/2 = 10\log_{10} 3/2 = 1.7609$ dBi

b) For radiation efficiency, we need R_r & R_L.

From (5-24), $R_{r,1\text{-turn}} = \eta\left(\frac{\pi}{6}\right)(k^2a^2) = \eta\left(\frac{\pi}{6}\right)(ka)^4$

$= 376.7303\left(\pi/6\right)\left[\frac{2\pi}{\lambda}\frac{\lambda}{30}\right]^4$

$= 0.379545309\,\Omega$

From (5-24a) $R_r = N^2 R_{r,1\text{-turn}} = 6^2(0.3795453)$

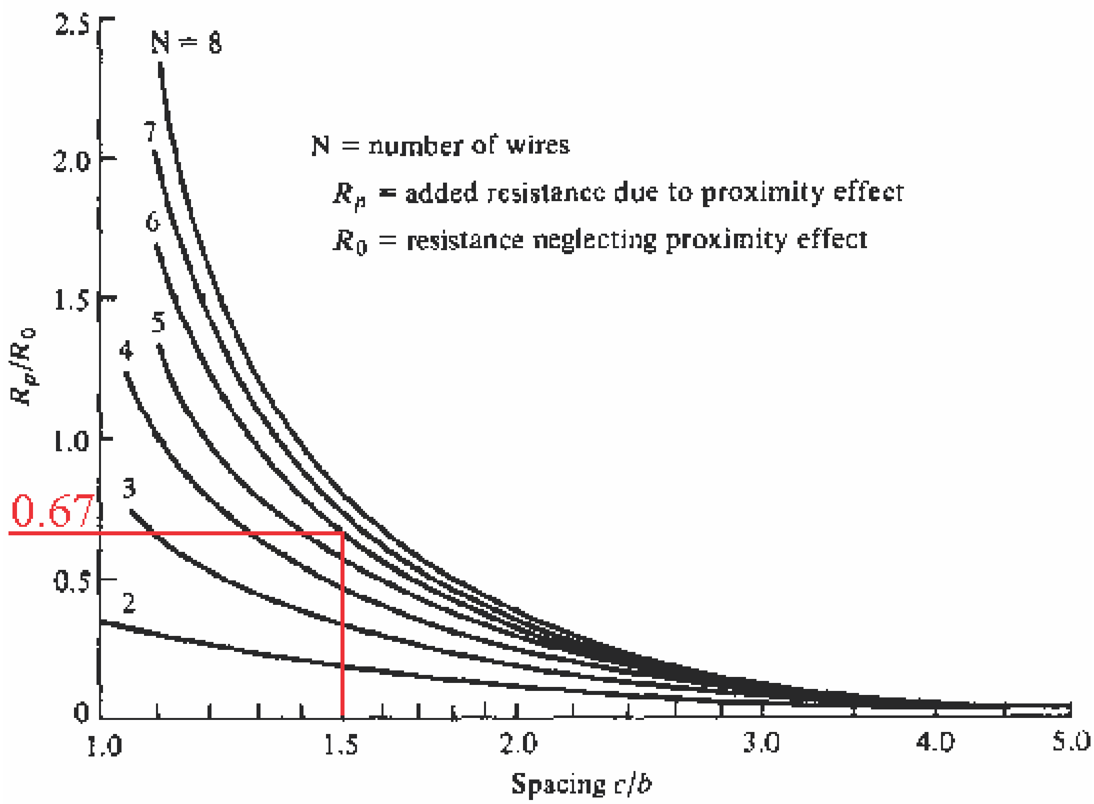
$R_r = 13.66363\,\Omega$

From (5-25), $R_L = R_{ohmic} = \frac{Na}{b} R_s\left(\frac{R_p}{R_0} + 1\right)$

where $R_s = \sqrt{\frac{\omega\mu_0}{2\sigma}}$

The ratio $\frac{R_p}{R_0}$ can be found using Fig 5-3 on next page knowing $N = 6$ and

$\frac{2c}{2b} = \frac{\text{turn spacing}}{\text{wire diameter}} = \frac{\lambda/100}{2\,\lambda/300} = 1.5$ to be 0.67.



(b) Ohmic resistance due to proximity (after G. N. Smith)

Figure 5.3 *N*-turn circular loop and ohmic resistance due to proximity effect. (SOURCE: G. S. Smith, "Radiation Efficiency of Electrically Small Multiturn Loop Antennas," *IEEE Trans. Antennas Propagat.*, Vol. AP-20, No. 5, pp. 656-657, Sept. 1972© (1972) IEEE).

b) cont. $R_L = \frac{6(\lambda/30)}{\lambda/300}\sqrt{\frac{2\pi(80\times10^6)4\pi\times10^{-7}}{2\,(5.7\times10^7)}}\,(0.67+1) = \underline{0.23586\ \Omega}$

Per (2-90), $e_{cd} = \frac{R_r}{R_r+R_L} = \frac{13.66363}{13.66363+0.23586} = \underline{\underline{0.983 \text{ or } 98.3\%}}$

c) $Z_A = R_A + jX_A$ ($X_A \to 0$ (resonant)) $= R_r + R_L = 13.89949\ \Omega$

$\Gamma = \frac{Z_A - Z_0}{Z_A + Z_0} = \frac{13.89949-50}{13.89949+50} = -0.56496$

Per (2-45), $e_r = 1-|\Gamma|^2 = 1-(0.56496)^2 = \underline{\underline{0.6808 \text{ or } 68.08\%}}$

d) Per (2-49a), $G_0 = e_{cd} D_0 = 0.983(3/2) = \underline{\underline{1.4745 = 1.686\text{ dBi}}}$

Per (2-49c), the absolute gain $G_{abs} = e_r e_{cd} D_0 = \underline{\underline{1.0039 = 0.0169\text{ dBi}}}$