5.16 Find the radiation efficiency (in percent) of an eight-turn circular-loop antenna operating at 30 MHz. The radius of each turn is a = 15 cm, the radius of the wire is b = 1 mm, and the spacing between turns is $2c$ = 3.6 mm. Assume the wire is copper ($\sigma = 5.7 \times 10^7$ S/m), and the antenna is radiating into free-space. Account for the *proximity effect*.

- As part of solution, find the loss and radiation resistances. Also, find the maximum gain (unitless and dBi).

$\lambda = c / f = 2.9979\times10^8 / 30\times10^6 = 9.993$ m

$a / \lambda = 0.15 / 9.993 = 0.015 = 1/66.6 \Rightarrow$ small loop

Per (5-24a), $R_r = \eta\left(\frac{\pi}{6}\right)\left(\frac{C}{\lambda}\right)^4 N^2 = 376.7303\left(\frac{\pi}{6}\right)\left(\frac{2\pi(0.15)}{9.993}\right)^4 8^2$

$\Rightarrow$ ***R_r* = 0.998873 Ω**.

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

$$R_s = \sqrt{\frac{\omega\mu_0}{2\sigma}} = \sqrt{\frac{2\pi(30\times10^6)4\pi\times10^{-7}}{2(5.7\times10^7)}} = 0.001441462\ \Omega.$$

From Figure 5.2 (next page), $R_p/R_0 = 0.5$.

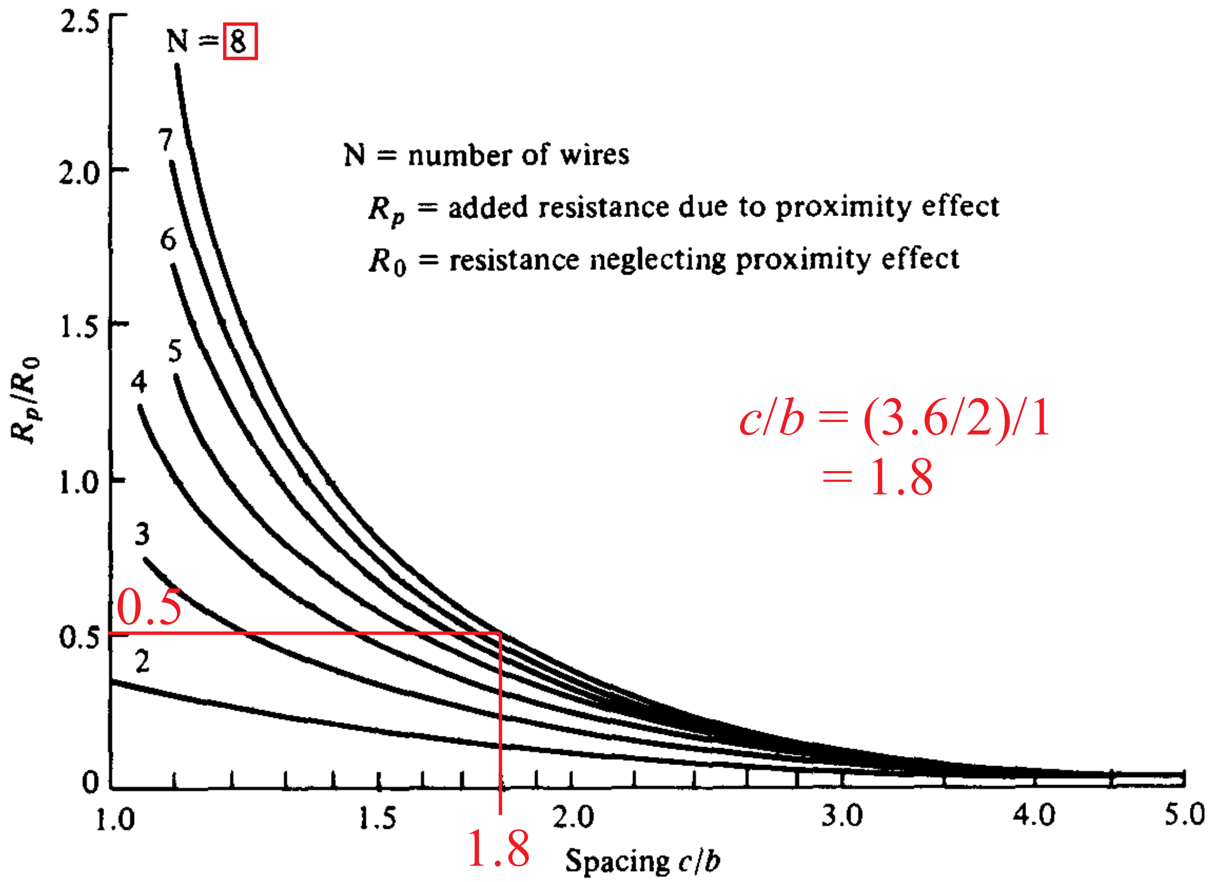
Now, $R_L = \frac{8(0.15)}{0.001} 0.001441462(0.5+1)$ $\Rightarrow$ ***R_L* = 2.59463 Ω**.

Per (2-90), $e_{cd} = R_r / (R_r + R_L) = 0.998873 / (0.998873+2.59463)$

$\Rightarrow$ ***e_cd* = 0.278 = 27.8%**

Since $a \ll \lambda$, per (5-31), the directivity is $D_0 = 3/2 = 1.5 = 1.7609$ dBi.

The gain, per (2-49a), is $G_0 = e_{cd} D_0 = 0.278\ (1.5)$ $\Rightarrow$ ***G_0* = 0.417 = -3.80 dBi**.



(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).