Loop Antennas

EE-4382/5306 - Antenna Engineering

Outline

- Introduction
- Small Circular Loop
- Circular Loop of Constant current

Constantine A. Balanis, *Antenna Theory: Analysis and Design* 4th Ed., Wiley, 2016.
Stutzman, Thiele, *Antenna Theory and Design* 3rd Ed., Wiley, 2012.

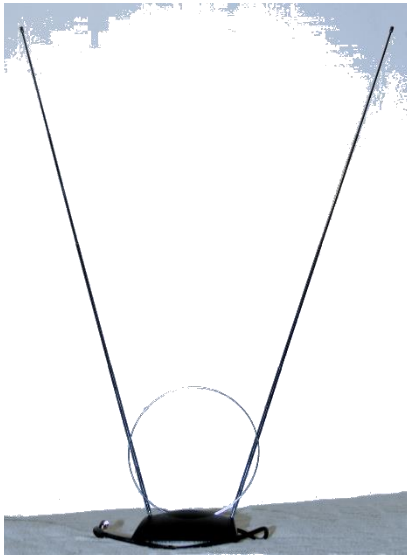
Introduction

Loop Antennas - Introduction

Loop antennas are also simple, cheap, and very versatile.

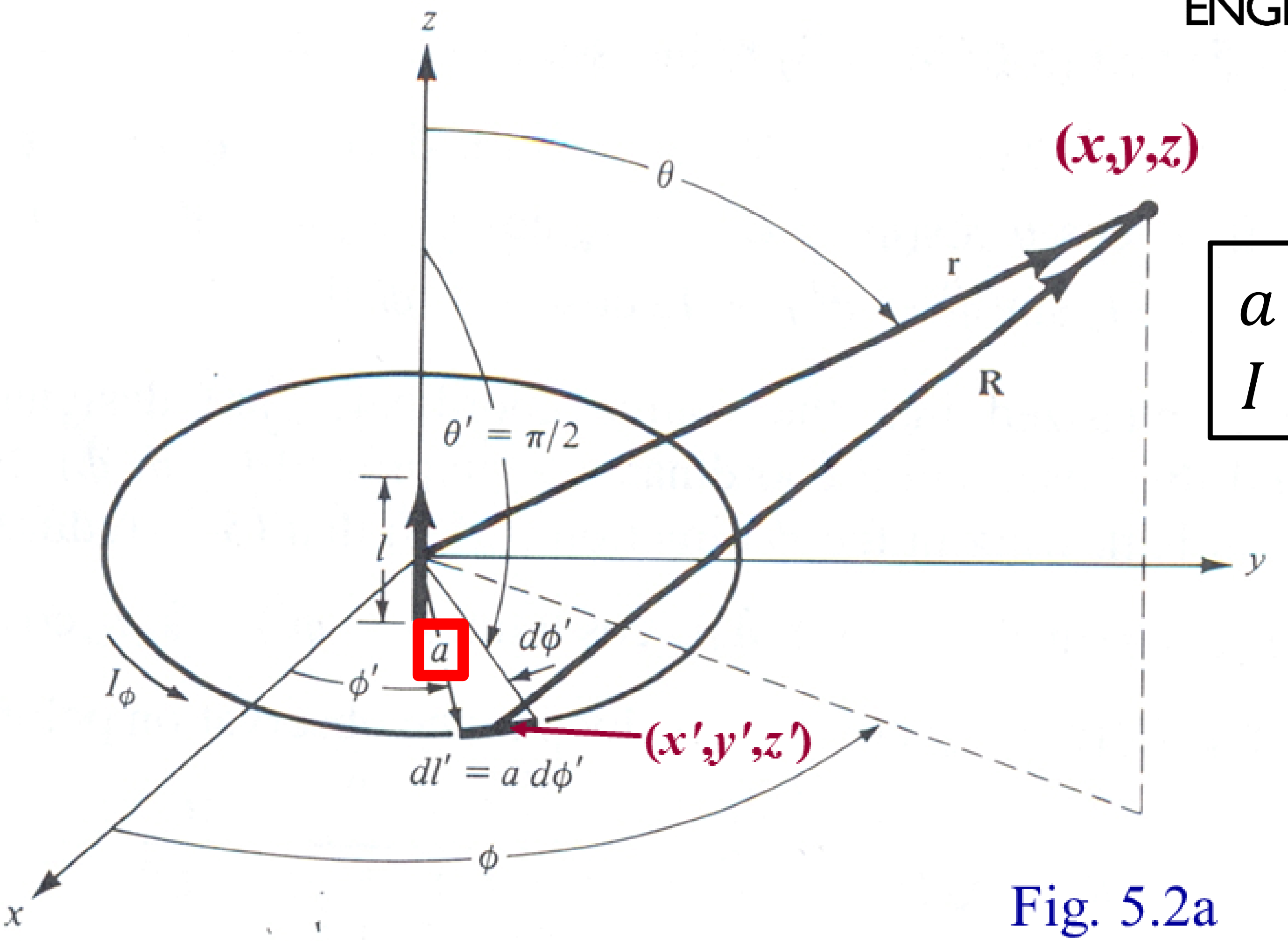
It is the equivalent to the magnetic dipole, in comparison to the electrical dipole.

They are classified into electrically small and electrically large.



Small Circular Loop

Geometry for Circular Loop



$a \ll \lambda$

$I = I_0$

Fig. 5.2a

Chapter 5
Loop Antennas

Small Circular Loop - Fields

$$H_r = j\frac{ka^2 I_0 \cos(\theta)}{2r^2}\left[1 + \frac{1}{jkr}\right]e^{-jkr}$$

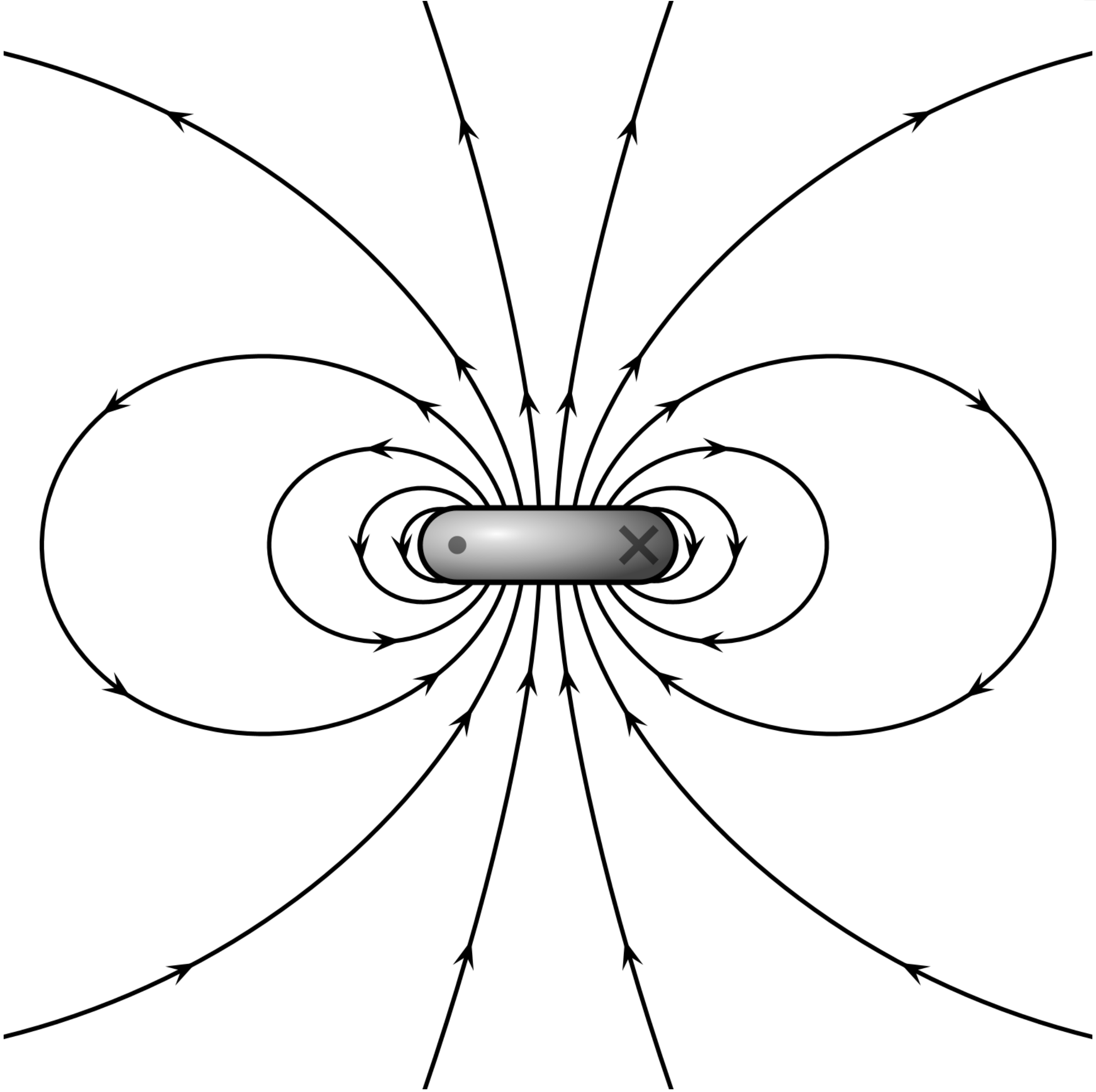
$$H_\theta = -\frac{(ka)^2 I_0 \sin(\theta)}{4r}\left[1 + \frac{1}{jkr} - \frac{1}{(kr)^2}\right]e^{-jkr}$$

$$H_\phi = 0$$

$$E_r = E_\theta = 0$$

$$E_\phi = \eta\frac{(ka)^2 I_0 \sin(\theta)}{4r}\left[1 + \frac{1}{jkr}\right]e^{-jkr}$$

Small Circular Loop- Fields



Power Density and Radiation Resistance

$$R_r = \eta\left(\frac{\pi}{6}\right)(k^2a^2)^2 = \eta\frac{2\pi}{3}\left(\frac{kS}{\lambda}\right)^2 = 20\pi^2\left(\frac{C}{\lambda}\right)^4 \cong 31{,}171\left(\frac{S^2}{\lambda^4}\right)$$

$$R_r = \eta\left(\frac{2\pi}{3}\right)\left(\frac{kS}{\lambda}\right)^2 N^2 = 20\pi^2\left(\frac{C}{\lambda}\right)^4 N^2 \cong 31{,}171N^2\left(\frac{S^2}{\lambda^4}\right)$$

$$S = \pi a^2$$
$$C = 2\pi a$$

Effect of turns on circular loop antenna

As with the inf/short dipole, the short loop suffers from very small radiation resistance and big radiation losses. However this can be accounted for by multiturn loop antennas.

Current distribution in multiturn antennas is complex and experiments are employed to measure the radiation efficiencies.

The total ohmic resistance for an N-turn circular-loop antenna is

$$R_{ohmic} = \frac{Na}{b} R_s \left(\frac{R_p}{R_0} + 1 \right)$$

$$a = \text{loop radius}$$

$$b = \text{wire radius}$$

$$2c = \text{loop separation}$$

$$\mathrm{R_p} = \text{ohmic resistance per unit length based on proximity effect}$$

$$R_0 = \frac{NR_s}{2\pi b} = \text{ohmic skin effect resistance per unit length}$$

Effect of turns on circular loop antenna

Ohmic Resistance Due To Proximity

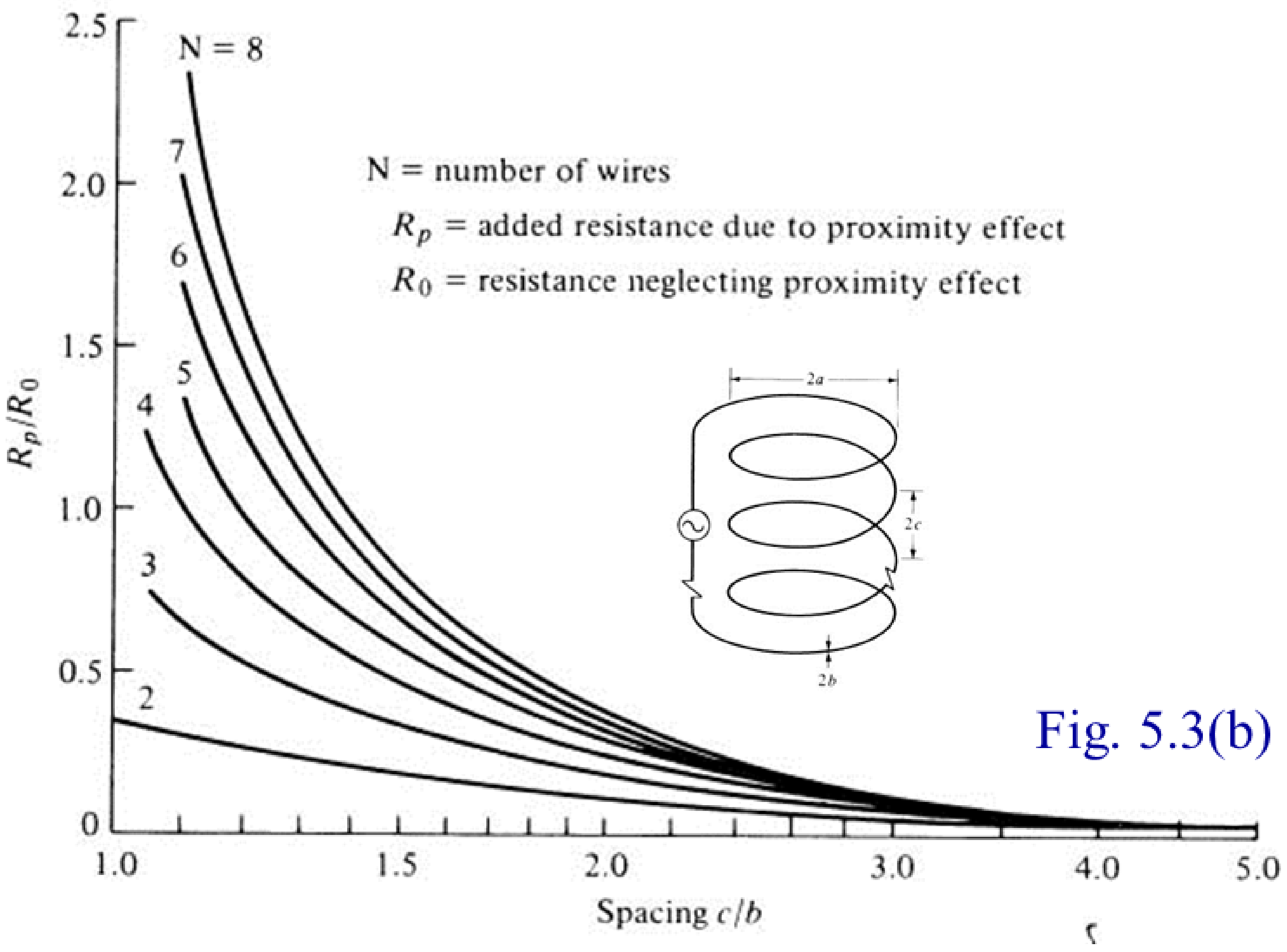


Fig. 5.3(b)

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Small Circular Loop Antenna – Examples

Find the radiation resistance of a single-turn and eight-turn small circular loop. The radius of the loop is $\frac{\lambda}{25}$ and the medium is free-space.

Small Circular Loop Antenna – Examples

Find the radiation efficiency of a single-turn and an eight-turn small circular loop at $f = 100\ \mathrm{MHz}$. The radius of the loop is $\frac{\lambda}{25}$, the radius of the wire is $10^{-4}\lambda$. The turns are spaced $4 \times 10^{-4}\lambda$ apart. Assume the wire is copper with conductivity of $5.7 \times 10^{7}\ \left(\frac{S}{m}\right)$ and the antenna is radiating into free-space.