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EED4106 Antenna and Propagation

Exp 3 - Calculation of Circular Loop Antenna Parameters with MATLAB

Std Name :	Std ID :

1 Information

A loop antenna is a coil carrying radio frequency current. It may be in any shape such as circular, rectangular, triangular, square or hexagonal according to the designer's convenience.

Loop antennas are usually classified into two categories, electrically small and electrically large. Electrically small antennas are those whose overall length (circumference) is usually less than about one-tenth of a wavelength ($C < \lambda/10$). However, electrically large loops are those whose circumference is about a free-space wavelength ($C \sim \lambda$). Most of the applications of loop antennas are in the HF (3–30 MHz), VHF (30–300 MHz), and UHF (300–3,000 MHz) bands. When used as field probes, they find applications even in the microwave frequency range. [1]

The polarization of the loop antenna will be vertically or horizontally polarized depending upon the feed position. The vertical polarization is given at the center of the vertical side while the horizontal polarization is given at the center of the horizontal side, depending upon the shape of the loop antenna.

The small loop antenna is generally a linearly polarized one. When such a small loop antenna is mounted on top of a portable receiver, whose output is connected to a meter, it becomes a great direction finder.

The circular loop antenna consists of a ring of radius b made of highly conducting metal with circular cross section of radius $a \ll b$.

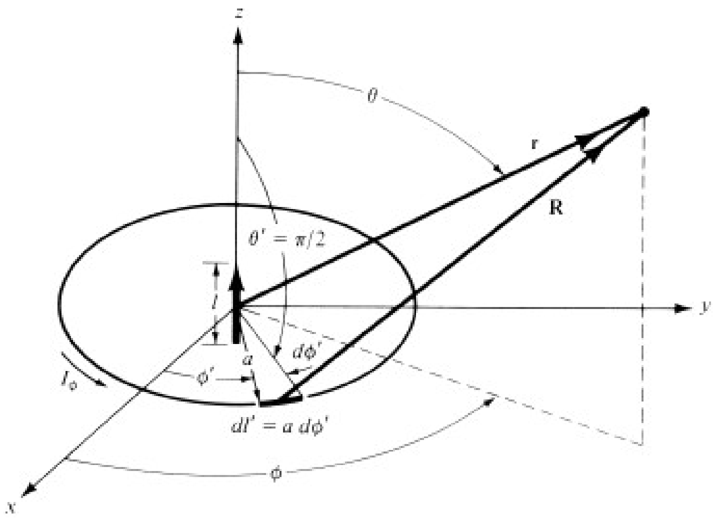

Figure 1: Geometry of Circular Loop

2 Objectives:

To understand radiation characteristics of the circular loop antenna;

- Read the loop antenna chapter of Antenna Theory and Analysis (Balanis) book

- Derive the equations related to the radiation characteristics of a small loop antenna and check the formulas in procedure part.

- Calculate the obtained general formulas by using numerical integration and plot the radiation pattern etc. via MATLAB.

3 Procedure

3.1 Find the equations of the radiation characteristics of the circular loop antenna of constant current.

Derive the radiation fields, time-avrage power density, radiated power, radiation resistance,directivity of the small loop antenna.

3.1.1 Normalized radiation pattern:

Derive the the fields radiated by the small loop. Check the following expressions for the field components of an infinitesmall loop of electric current were derived. The far-field components of the loop, the axis of which is along z.

$$E_\phi = \frac{(k_0 a Z_0)}{2}\frac{e^{-jkr}}{r} I_0 J_1(kasin(\theta)) \tag{1}$$

$$H_\phi = \frac{-E_\phi}{Z_0} = \frac{(-k_0 a)}{2}\frac{e^{-jkr}}{r} I_0 J_1(kasin(\theta)) \tag{2}$$

If $a < \lambda/20$ Bessel function small argument form. So for very small loop,

$$E_\phi = \frac{(k_0 a)^2 Z_0}{4}\frac{e^{-jkr}}{r} I_0 sin(\theta) \tag{3}$$

$$H_\phi = -\frac{(k_0 a)^2 e^{jkr}}{4r} I_0 sin(\theta) \tag{4}$$

3.1.2 Time-Average Power Density:

Derive the time-average power density formula of the small loop antenna. Check the following expressions.

Associated with the radiated power P_{rad} is an average power density W_{av}. It has only a radial component W_r which is related to the radiation intensity U . The time-average power density can be written as

$$W_r = \frac{(k_0 a)^2 Z_0}{8r^2} I_0^2 J_1^2(ka\sin(\theta)) \tag{5}$$

For very small loop;

$$W_r = \frac{(k_0 a)^2 Z_0}{8r^2} I_0 \frac{1}{4} sin^2(\theta) \tag{6}$$

$$W_r = W_0 sin^2(\theta) \tag{7}$$

where W_0 is constant.

3.1.3 Total Radiated power:

Derive the total radiated power formula of the small loop. Check the following expression.

The total radiated power of the loop can written as

$$P_{rad} = \frac{(k_0 a)^2 Z_0}{8} I_0^2 2\pi \int_0^{\pi} J_1^2(ka\sin(\theta))\sin(\theta)d\theta \tag{8}$$

3.1.4 Radiation Resistance:

Derive the radiation formula of the small loop. Check the following expressions.

The relation between radiation resistance and radiated power is

$$p_{rad} = \frac{1}{2} R_{rad} I_0^2 \tag{9}$$

The radiation resistance ;

$$R_{rad} = \frac{(k_0 a)^2 Z_0}{2} \pi \int_0^\pi J_1^2(ka \sin(\theta)) \sin(\theta) d\theta \tag{10}$$

The radiation resistance of the very small loop can be written as

$$R_{rad} = \frac{(k_0 a)^4 Z_0 \pi}{6} = 20\pi^2 (k_0 a)^4 \tag{11}$$

3.1.5 Directivity:

Derive the directivity formula of the small loop. Check the following expression.

The directivity of the loop can be written as

$$D_0 = 4\pi r^2 \frac{W_r(\theta)}{P_{rad}} \tag{12}$$

$$D_0 = \frac{3}{2} \tag{13}$$

Directivity of small loop is 3/2 like Hertz dipole since normalized radiation pattern is "$sin^2(\theta)$".

Note: If a is large ($a > \lambda/20$) becoming a large loop due to the reflections and wave effect constant current approximation is not veclited.

3.2 Plot the radiation characteristic of the small antenna via MATLAB.

- Plot the elevation plane amplitude patterns for a circular loop for $a = 0.2\lambda$, $a = 0.5\lambda$,$a = 0.61\lambda$, $a = 0.9\lambda$.

- Plot the radiation patterns (3D) for a circular loop for $a = 0.2\lambda$, $a = 0.5\lambda$,$a = 0.61\lambda$, $a = 0.9\lambda$.

- Plot radiation resistance for a constant current circular-loop antenna based on small loop approximations. Check the obtained figure with Figure 5.9 in Balanis's Book.

- Plot radiation resistance for a constant current circular-loop antenna for general cases Check the obtained figure with Figure 5.10 in Balanis's Book.

- Plot the directivity for circular loop of constant current.

Note: Add the Matlab codes in appendix part of your reports.