Experiment No. 7 STUDY OF CIRCULAR LOOP ANTENNA

Aim:

To study and observe the radiation patterns of electrically small and electrically large loop antennas.

Software requirements:

Software- 4nec2
Operating System- Windows 7 and above

Theory:

Loop antenna is a simple, inexpensive and very versatile type of antenna. It takes many different forms such as rectangle, square, triangle, circle and many other configurations. Because of simplicity in analysis and construction, the circular loop is very popular. They are widely used in applications up to the microwave bands (up to ≈ 3 GHz). In fact, they are often used as electromagnetic (EM) field probes in the microwave bands, too.

Loop antennas are usually classified as electrically small ($C < \lambda/10$) and electrically large ($C \sim \lambda$). Electrically small loops of single turn have very small radiation resistance (comparable to their loss resistance). Their radiation resistance though can be substantially improved by adding more turns. Multi-turn loops have better radiation resistance but their efficiency is still very poor. That is why they are used predominantly as receiving antennas, where losses are not so important. The radiation characteristics of a small loop antenna can be additionally improved by inserting a ferromagnetic core. Radio-receivers of AM broadcast are usually equipped with ferrite-loop antennas. The small loop antenna is shown in following Figure 1-

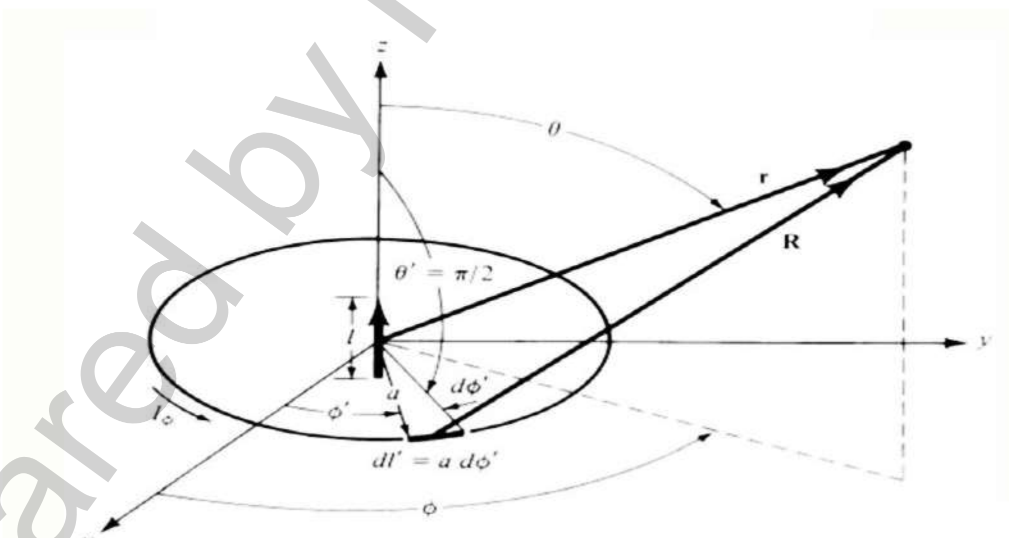

Fig. 1: Geometry for Circular Loop Configuration

The radius is a, and is assumed to be much smaller than a wavelength ($a << \lambda$). The loop lies in the x-y plane. Since the loop is electrically small, the current within the loop can be approximated as being constant along the loop, so that $I = I_0$.

The magnetic field components are given as:

$$\boxed{\begin{aligned} H_r &= j\frac{ka^2 I_0 \cos\theta}{2r^2}\left[1 + \frac{1}{jkr}\right]e^{-jkr} \\ H_\theta &= -\frac{(ka)^2 I_0 \sin\theta}{4r}\left[1 + \frac{1}{jkr} - \frac{1}{(kr)^2}\right]e^{-jkr} \\ H_\phi &= 0 \end{aligned}}$$

The corresponding electric field components can be written as-

$$\boxed{\begin{aligned} E_r &= E_\theta = 0 \\ E_\phi &= \eta\frac{(ka)^2 I_0 \sin\theta}{4r}\left[1 + \frac{1}{jkr}\right]e^{-jkr} \end{aligned}}$$

Parameters:

1. Radiation resistance:

The radiated power is given by-

$$P_r = \eta\left(\frac{\pi}{12}\right)(ka)^4|I_0|^2\left[1 + j\frac{1}{(kr)^3}\right]$$

and whose real part is equal to

$$P_{rad} = \eta\left(\frac{\pi}{12}\right)(ka)^4|I_0|^2$$

Radiation resistance is found by equating above equation to $I_0^2 Rr/2$ and which reduces to –

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

The above equation is for single loop, for N loops it is extended as –

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

2. Radiation intensity:

The radiation intensity U is given by

$$U = r^2 W_r = \frac{\eta}{2}\left(\frac{k^2 a^2}{4}\right)^2 |I_0|^2 \sin^2\theta = \frac{r^2}{2\eta}|E_\phi(r, \theta, \phi)|^2$$

The maximum value occurs at θ = π/2, and is given by

$$U_{max} = U|_{\theta=\pi/2} = \frac{\eta}{2}\left(\frac{k^2 a^2}{4}\right)^2 |I_0|^2$$

3. Directivity:

Using the equation of radiation intensity and radiated power, directivity is given by –

$$D_0 = 4\pi \frac{U_{max}}{P_{rad}} = \frac{3}{2}$$

4. Maximum effective aperture:

$$A_{em} = \left(\frac{\lambda^2}{4\pi}\right) D_0 = \frac{3\lambda^2}{8\pi}$$

Observations:

For f = 300 MHz (i.e., λ = 1m)

Sr. No.	Loop Diameter (D)	Maximum Gain (in dBi)
1.	λ/10	
2.	λ/8	
3.	λ/4	
4.	λ/2	
5.	λ	

Conclusion:

By performing this experiment, we can observe the effect of variation of loop diameter on the antenna radiation pattern and found that the maximum gain for the loop antenna increases with increase in loop diameter.