Proceedings of ISAP’04, Sendai, JAPAN

3B2-2

MICROSTRIP LINE ANTENNAS COMPOSED OF LOOP RADIATION CELLS

K. Hirose, Chonfa Park, and H. Nakano†
School of Science and Engineering, Tokyo Denki University, Saitama 350-0394, Japan
†College of Engineering, Hosei University, Tokyo 184-8584, Japan
hirose@f.dendai.ac.jp

1. Introduction

A loop-line antenna is known as a circularly polarized (CP) radiation element [1]. Although some investigations for this antenna have been made [2], a detailed investigation is required to aid in the design. For this requirement, this paper presents the radiation characteristics of two types of loop-line antennas; one is an open-loop line antenna and the other is a closed-loop line antenna.

First, the open-loop line antenna is investigated, where each loop cell has an open gap. The key to formation of a CP radiation beam is revealed. Further consideration is given to deterioration in the axial ratio when the number of cells is decreased. Next, to improve the axial ratio, a line antenna consisting of closed-loop cells is proposed. The difference between the radiation mechanisms of the closed- and open-loop line antennas is emphasized and discussed.

2. Open-loop line antenna

Fig. 1 shows the antenna configuration and coordinate system. A microstrip line is printed on a grounded dielectric substrate of relative permittivity ε_r and thickness B. The line is periodically bent and forms N radiation cells. The cell consists of three parts: a feed line of length L_f, a square loop of circumference C, and connection lines of length ℓ, as shown in Fig. 1(b). The loop has an open gap of distance Δd, and is called an *open loop*. The antenna is fed from a coaxial line at the left terminal F. The right terminal T is open-circuited.

The antenna is optimized to radiate a CP wave in the direction normal to the antenna plane, using the method of moments [3]. Calculations for $N = 12$ reveal that the connection line length ℓ is one of key parameters to be appropriately selected. In other words, the length ℓ significantly affects both the axial ratio and the beam direction. This fact is shown in Fig. 2. It is found that the normal beam of $\theta_m = 0°$ is obtained at $\ell = 0.06\lambda_0$, with an axial ratio of less than 3 dB.

Fig. 3 shows the radiation pattern in the $\phi = 0°$ plane for $\ell = 0.06\lambda_0$. The radiation field is decomposed into right- (E_R) and left-hand (E_L) CP wave components. It is observed that a narrow CP radiation beam is formed, with a half-power beamwidth of 6°. The frequency responses of the gain and axial ratio are shown in Fig. 4. The axial ratio is less than 3 dB over a frequency range of $0.95f_0$ to $1.05f_0$ (10%), in which the gain is more than 15 dBi.

The discussions described so far have been restricted to the case for $N = 12$. Further consideration

ISBN: 4-88552-207-2 C3055©IEICE

is given to the radiation characteristics as a function of N. The dotted line in Fig. 5 shows the axial ratio versus N, where the axial ratio deteriorates with decrease in N. The axial ratio for $N = 4$, for example, is 5 dB. Improvement in the axial ratio is discussed in the next section.

3. Closed-loop line antenna

The deterioration in the axial ratio for a few radiation cells is due to the radiation mechanism, where the rotational sense of a CP wave generated from the traveling current along the line is opposite to that from the reflecting current. Another loop-line antenna having a new radiation mechanism is proposed in this section. The antenna configuration and coordinate system are shown in Fig. 6. The antenna has the same structure shown in Fig. 1 except that the loop is closed (called a *closed loop*). In addition, the loop has a perturbation segment of length Δd for the CP radiation.

Preliminary calculations for $N = 12$ show that the key to forming a CP normal beam is to appropriately select the connection length ℓ, as in the previous open-loop line antenna. It should be noted, however, that ℓ affects only the axial ratio, leading to simple antenna design. The antenna is found to radiate the CP normal beam with an axial ratio of 0.3 dB for $\ell = 0.3\lambda_0$.

Now, the number of radiation cells is decreased and the axial ratio is evaluated. The results are shown by the solid line in Fig. 5. It is clear that the antenna can radiate a CP wave even for a few cells. For example, the axial ratio for $N = 4$ is 0.4 dB. It can be said that the antenna has a new radiation mechanism, where both the traveling and reflecting currents contribute to the same rotational sense of the CP radiation.

Fig. 7 shows the radiation pattern in the $\phi = 0°$ plane for $N = 4$. A CP beam is radiated in the direction normal to the antenna plane. The frequency responses of the axial ratio and gain are shown by the solid lines in Fig. 8. It is found that the antenna has the CP bandwidth and the constant gain that are comparable to those for $N = 12$ (dotted lines). The CP bandwidth for a 3-dB axial-ratio criterion is 3 %, where the gain is almost constant at 14.5 dBi.

4. Conculusions

An open-loop line antenna has been designed for forming a CP radiation beam normal to the antenna plane. Calculations reveal that loop connection length ℓ is one of key parameters to be appropriately selected. Another loop-line antenna composed of closed-loop cells is also analyzed. The antenna is found to have a new radiation mechanism, where both the traveling and reflecting currents along the line contribute to the same rotational sense of the CP radiation.

References

[1] J.R. James and P.S. Hall, *Hand book of microstrip antennas*, ch. 13, Peter Peregrinus, 1989.

[2] T. Makimoto and S. Nishimura, “Circularly polarized microstrip line antenna,” *US Patent* 4398199, 1983.

[3] H. Nakano, *Analysis methods for electromagnetic wave problems*, E. Yamashita ed., vol. 2, ch. 3, Artech House, 1995.

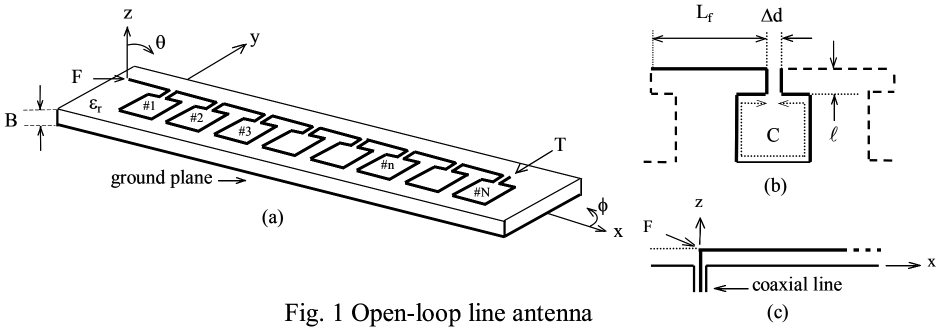

Fig. 1 Open-loop line antenna

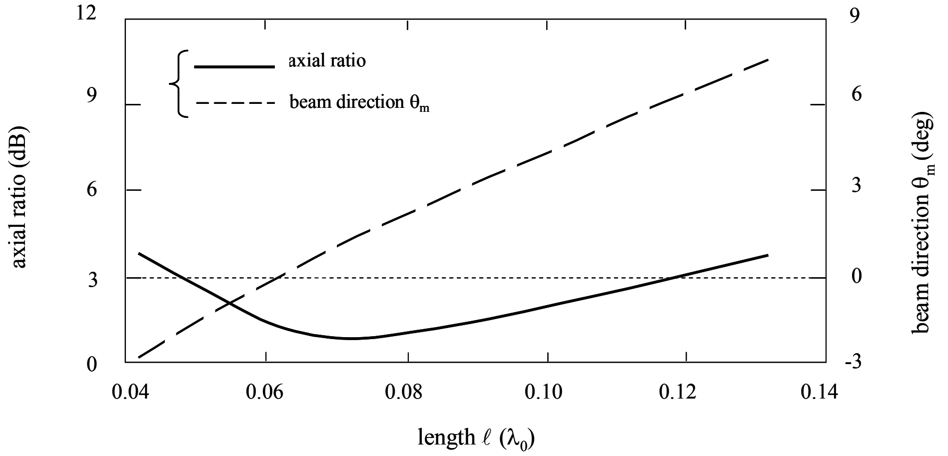

Fig. 2 Axial ratio and beam direction vs. length ℓ for N = 12

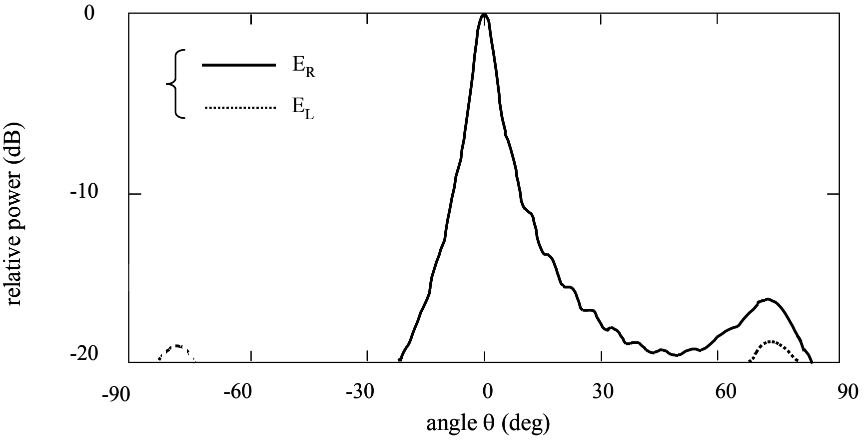

Fig. 3 Radiation pattern ϕ = 0° plane for N = 12

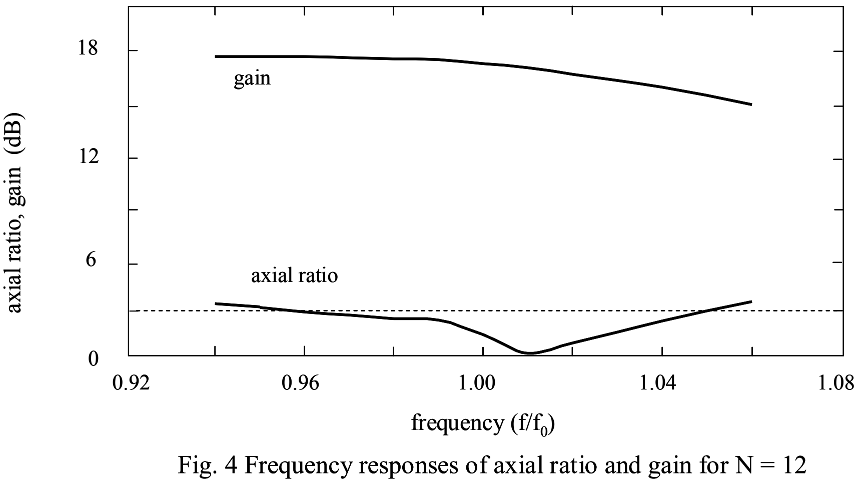

Fig. 4 Frequency responses of axial ratio and gain for N = 12

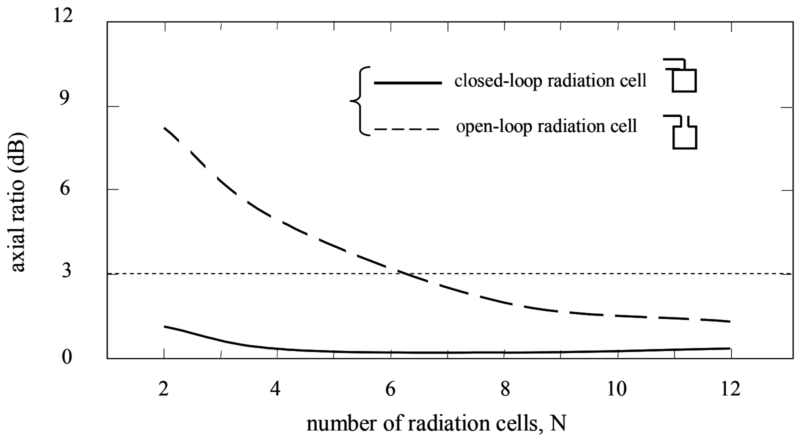

Fig. 5 Axial ratio vs. number of radiation cells, N

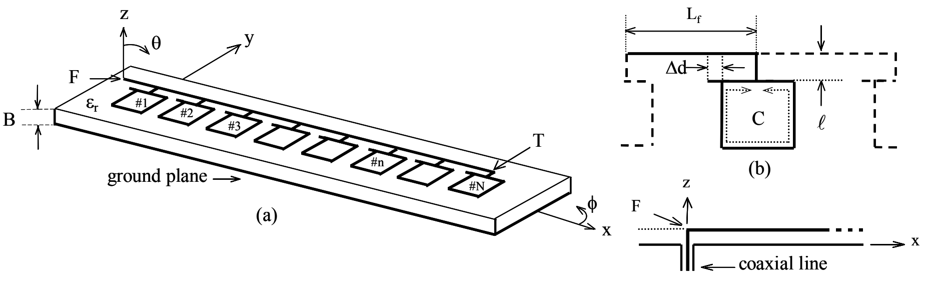

Fig. 6 Closed-loop line antenna

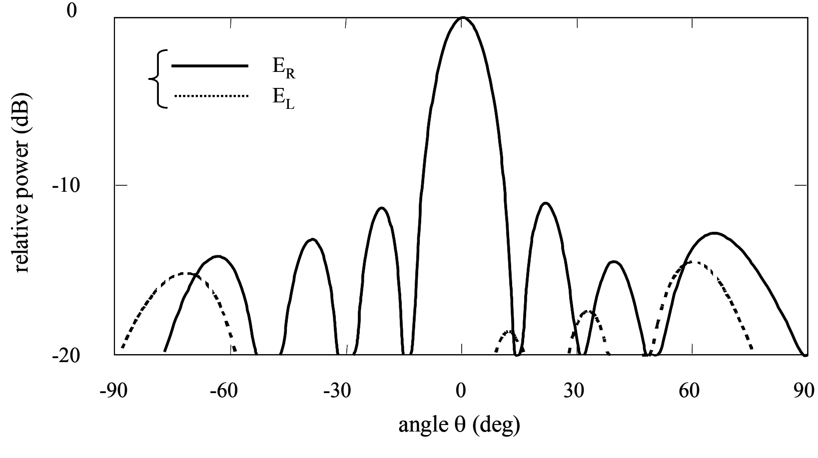

Fig. 7 Radiation pattern φ = 0° plane for N = 4

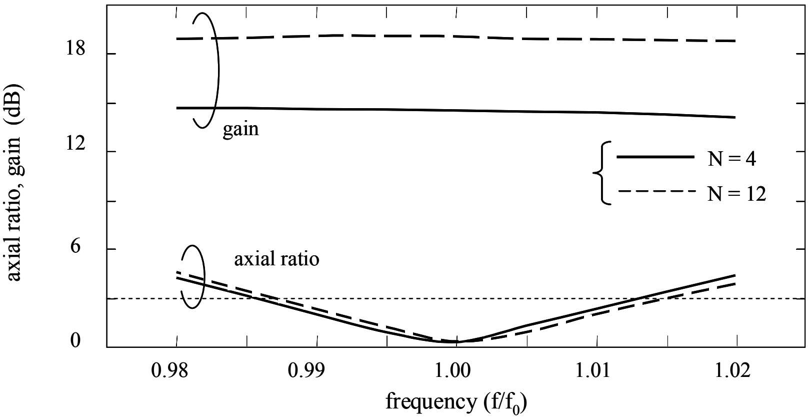

Fig. 8 Frequency responses of axial ratio and gain