Communications

Shortening Ratios of Modified Dipole Antennas

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Abstract—**Two types of modified dipole antennas, zigzag and meander-line types, are analyzed and the shortening ratios are calculated. A zigzag dipole antenna with a wire length of 0.58 wavelengths has a shortening ratio of 24 percent with a resonant resistance of 46 Ω. A meander-line dipole antenna with a wire length of 0.70 wavelengths has a shortening ratio of 30 percent with a resonant resistance of 43 Ω. It is found that the radiation patterns of these two types of antennas are similar to the radiation pattern of a conventional half-wave linear dipole antenna.**

INTRODUCTION

There have been some attempts to make a compact resonant antenna without using a lumped loading. Rashed and Tai proposed a new type of meander monopole antenna and obtained useful results for reducing the antenna size [1]. Recently, the authors numerically and experimentally investigated bent dipole antennas [2].

In this communication, two types of modified dipoles are discussed, paying attention to shortening the axial length. One is called a zigzag dipole antenna, and the other a meander-line dipole antenna. Shortening ratios and radiation characteristics of these two types of dipole antennas are presented with experimental results.

ZIGZAG DIPOLE ANTENNA

Fig. 1 shows the antenna configuration and the coordinate system. The arms of a conventional linear dipole antenna are bent into a zigzag configuration with an edge angle τ. The decrease in the edge angle shortens the axial length $2L_{\text{ax}}$ of the zigzag dipole antenna, whose wire length is defined as $2L_{\text{wire}}$ ($=2\Sigma e_i$, e_i is element length).

First, consider the zigzag dipole with a constant wire length of a half-wavelength ($2L_{\text{wire}} = \lambda/2$, λ is an operating wavelength), shortening the axial length from 0.5λ to 0.3λ. The shortening ratio (SR) is defined as

$$\text{SR} = \frac{\lambda/2 - 2L_{\text{ax}}}{\lambda/2}. \tag{1}$$

The current distribution along the arm is determined by applying a simplified integral equation [3]. From the analyzed current distribution, the input impedance Z_{in}, the radiation pattern, and the absolute gain are calculated.

Fig. 2 shows the input impedance ($Z_{\text{in}} = R_{\text{in}} + jX_{\text{in}}$) as a function of the axial length $2L_{\text{ax}}$. For comparison, the results of the linear dipole with the same axial length are shown in this figure. The resistance of the zigzag dipole R_{in} is almost the same

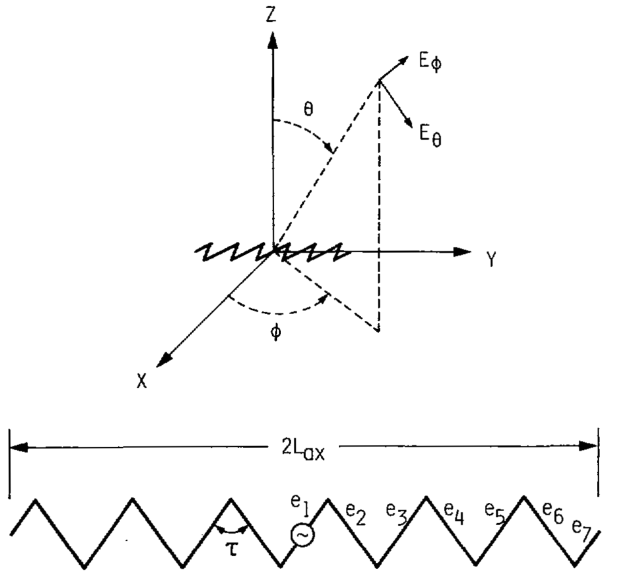

Fig. 1. Configuration and coordinate system of zigzag dipole antenna. $2L_{\text{wire}} = 0.5\ \lambda$, $e_1 = e_7 = 0.0208\ \lambda$, $e_2 = e_3 = \cdots = e_6 = 0.0416\ \lambda$.

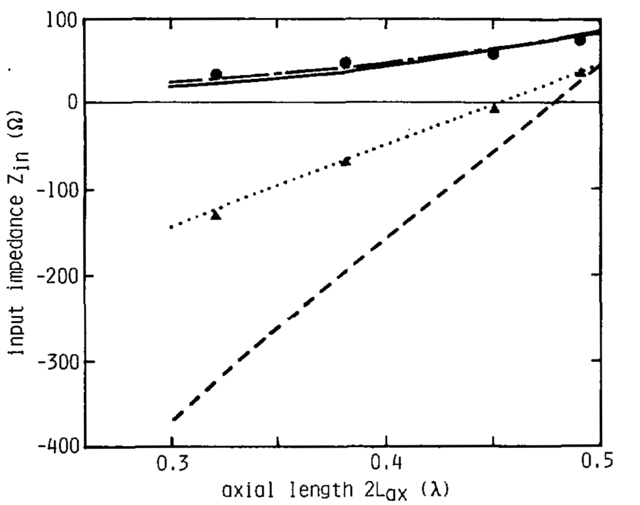

Fig. 2. Input impedance $Z_{\text{in}} = R_{\text{in}} + jX_{\text{in}}$. Linear dipole antenna, theoretical: R_{in} ——, X_{in} – – –. Zigzag dipole antenna ($2L_{\text{wire}} = 0.5\ \lambda$), theoretical: R_{in} ——, X_{in} · · · · ·, experimental: R_{in} ●●, X_{in} ▲▲.

as that of the linear dipole, and the reactance curve of the zigzag dipole is located above that of the linear dipole. This leads to the fact that the zigzag dipole resonates at the axial length of less than a self-resonant length of the half-wave linear dipole, 0.48 λ. The resonance of the zigzag dipole occurs at $2L_{\text{ax}} = 0.45\ \lambda$ ($\tau = 129°$) with a resonant resistance of $R_{\text{res}} = 65\ \Omega$. The SR of the zigzag dipole is 10 percent, while the linear dipole is 4 percent.

Fig. 3 illustrates a radiation pattern of the zigzag dipole with $2L_{\text{ax}} = 0.45\ \lambda$. Since the pattern is symmetrical with respect to

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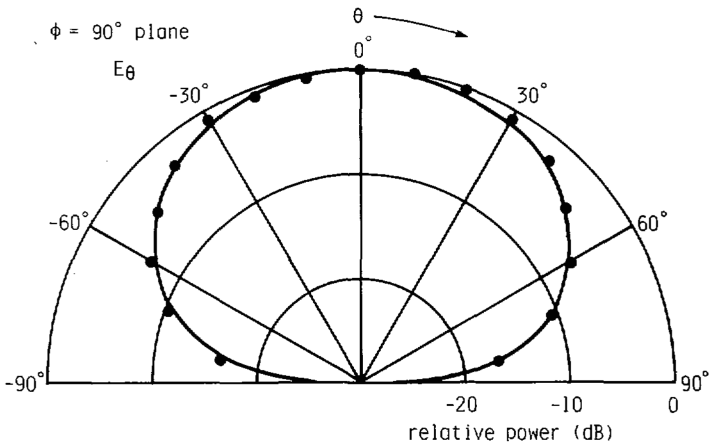

Fig. 3. Radiation pattern of zigzag dipole antenna ($2L_{wire} = 0.5\ \lambda$, $2L_{ax} = 0.45\ \lambda$, $\tau = 129°$). Theoretical: ——. Experimental: ●●.

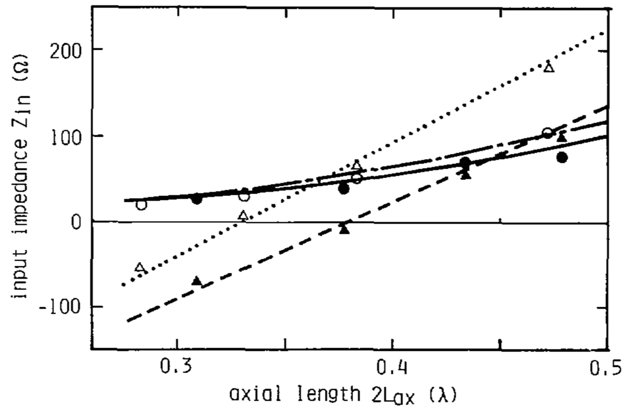

Fig. 4. Input impedance $Z_{in} = R_{in} + jX_{in}$ of zigzag dipole antenna. $2L_{wire} = 0.58\ \lambda$, $e_1 = e_8 = 0.0208\ \lambda$, $e_2 = e_3 = \cdots = e_7 = 0.0416\ \lambda$, theoretical: R_{in} ——, X^{in} - - -, experimental: R_{in} ●●, X_{in} ▲▲. $2L_{wire} = 0.67\ \lambda$, $e_1 = e_9 = 0.0208\ \lambda$, $e_2 = e_3 = \cdots = e_8 = 0.0416\ \lambda$, theoretical: R_{in} ——, X_{in} · · · · ·, experimental: R_{in} ○○, X_{in} △△.

the $x - y$ plane, only half of the pattern is shown. The half-power beamwidth (HPBW) of the E_θ component is ±40°, which is close to a HPBW = ±39° of the half-wave linear dipole. Although the undesirable component of E_ϕ exists, it does not appear in Fig. 3 because the E_ϕ component is less than −30 dB. The gain for $2L_{ax} = 0.45\ \lambda$ is 2.1 dB.

Secondly, consider the SR of the zigzag dipole with a constant wire length $2L_{wire}$ of more than a half-wavelength, shortening the axial length $2L_{ax}$ by narrowing the edge angle τ. If an input impedance of 50 Ω is obtained, the impedance matching to a common coaxial cable becomes practical. Fig. 4 shows the input impedance for two zigzag dipoles as a function of the axial length $2L_{ax}$. One has a wire length of $2L_{wire} = 0.58\ \lambda$, the other $2L_{wire} = 0.67\ \lambda$. The zigzag dipole with $2L_{wire} = 0.58\ \lambda$ resonates at $2L_{ax} = 0.38\ \lambda$ ($\tau = 81°$) with $R_{res} = 46\ \Omega$, while the zigzag dipole with $2L_{wire} = 0.67\ \lambda$ resonates at $2L_{ax} = 0.33\ \lambda$ ($\tau = 59°$) with $R_{res} = 37\ \Omega$. The SR's are 24 and 34 percent for the former and the latter dipoles, respectively.

Further calculation shows that the HPBW and the gain have not significant changes in two dipoles. For the dipoles with $2L_{ax} = 0.58\ \lambda$ and $2L_{ax} = 0.67\ \lambda$, the HPBW's are ±41° and ±42°, respectively, while the gains are 2.0 dB and 1.95 dB, respectively. The HPBW and the gain are comparable to those of a conventional linear dipole antenna.

MEANDER-LINE DIPOLE ANTENNA

As another possible bent configuration, a meander-line arm shown in the insert of Fig. 5 is investigated. In order to obtain a an input impedance close to 50 Ω, the axial length is shortened by cutting the wire length.

Fig. 5 shows the input impedance as a function of $2L_{ax}$. It is found that as $2L_{ax}$ is shortened, the resistance decreases gradually and the reactance changes from positive to negative values. The resonance of the meander-line dipole occurs at $2L_{ax} = 0.35\ \lambda$ ($2L_{wire} = 0.70\ \lambda$, $e = 0.0133\ \lambda$) with a $R_{res} = 43\ \Omega$, and the SR is 30 percent.

The radiation pattern is similar to that obtained in the zigzag dipole shown in Fig. 3. The HPBW and the gain for $2L_{ax} = 0.35\ \lambda$ are ±42° and 1.95 dB, respectively. It can be said that the meander-line configuration also contributes to making a compact structure without significantly deteriorating the radiation characteristics of the half-wave linear dipole antenna.

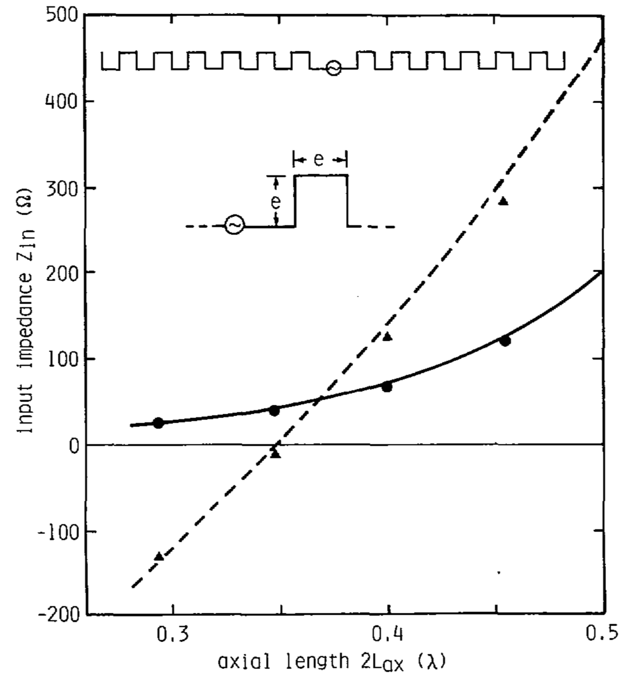

Fig. 5. Input impedance $Z_{in} = R_{in} + jX_{in}$ of meander-line dipole antenna $e = 0.0133\ \lambda$. Theoretical: R_{in} ——, X_{in} - - -. Experimental: R_{in} ●●, X_{in} ▲▲.

CONCLUSION

Two types of modified dipole antennas have been discussed from an aspect of achieving a compact structure. It is demonstrated that a zigzag dipole with $2L_{wire} = 0.58\ \lambda$ resonates at $2L_{ax} = 0.38\ \lambda$ with $R_{res} = 46\ \Omega$, having the absolute gain and the half-power beamwidth comparable to those of a half-wave linear dipole. The SR is 24 percent.

In a meander-line dipole, the SR of 30 percent is obtained with $R_{res} = 43\ \Omega$ at the resonance.

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