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ELECTRICALLY-SMALL EMI DIPOLE ANTENNAS FOR FREQUENCIES BELOW 80 MHz

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1. Introduction

The EMI antennas for measuring electromagnetic interferences are necessary to measure radiated emission from electronic equipments and systems or site attenuations of an open area test site. The various kinds of antennas have been already developed and used for EMI antennas, but half-wavelength(half wavelength resonance) dipole antenna is most basic[1][2]. Since a half-wavelength dipole antenna becomes longer in lower frequencies, a horizontally polarized antenna bends down to a cantilever and a vertically polarized antenna buckles. At frequencies below 80 MHz, the antenna length is prescribed to fixed to resonate at 80 MHz, the use of lower frequencies than 80 MHz results in short dipole, and hence worse sensitive characteristic[3].

In this paper, we proposed an electrically-small EMI dipole antenna with improved characteristics, such as higher sensitive characteristic, less buckling and bending. The method of loading reactance is applied to shorten the antenna. And Roberts Balun[4] is attached to the input port of the antenna. In theoretical analysis, integral equation for unknown current distribution is solved by applying Galerkin's Method of Moment with piecewise sinusoidal functions. The determining equation for reactance value is derived by regarding the antenna as a two-port network. From the result of theoretical analysis, we can sure that the small EMI dipole antenna is able to realize, if the suitable reactance is loaded.

2. Theoretical Analysis

Figure 1 shows the structure and coordinate of an electrically-small EMI dipole antenna with loaded-reactance. The dipole antenna of length L, radius a is placed along the z-axis. The reactance elements are loaded at $z=c, z=-c$. And Roberts Balun is connected to the antenna terminal. Assuming the radius of the antenna is much smaller than wavelength and the antenna is fed by a delta-gap generator as the voltage source, the integral equation for the current distribution $I(z)$ can be written as

$$\frac{1}{j\omega\varepsilon_0}\int\left(\frac{\partial^2}{\partial z^2}+k^2\right)G(z,z')I(z')dz' = -V\delta(z-s)+jXI(c)\delta(z-c)+jXI(-c)\delta(z+c) \tag{1}$$

where, $G(z,z')$ is the free space Green function, k is the wave number in free space, ω is the angle frequency, ε_0 is free space permittivity, $\delta(*)$ is the Dirac delta function, $I(c)$ and $I(-c)$ are currents at the loading point, X is a loaded-reactance.

3. Determining Equation for reactance value

Treating the antenna in Fig.1 as a two-port network with the driving point at port 1 and the loading point at port 2, considering the symmetry, the input impedance of the antenna can be expressed as the following equation using admittance parameter y_{ij} $(i, j = 1, 2)$.

$$Z_{in} = \frac{y_{22} + Y}{y_{11}(y_{22} + Y) - y_{12}^{2}} \qquad (2)$$

where, $Y = 1/jX$.

There are generally two different methods to obtain the forced resonance of antenna. One is the perfect matching which is totally matched with transmission line. The other is the partial matching which is partially matched with transmission line. We just used the partial matching because a loaded-reactance can achieve the similar characteristic of perfect matching according as the location of reactance element is controlled. The resonant condition for the partial matching of the reactance-loaded antenna in Fig.1 is given by

$$\mathrm{Im}\{Z_{in}(y_{ij}, jX)\} = 0. \qquad (3)$$

Substituting Eq. (2) into Eq. (3), the value of reactance to satisfy the resonant condition is expressed as

$$X = \left(\frac{2y_{11}^{I}}{-E \pm \sqrt{E^{2} + 4y_{11}^{I}F}} \right) \qquad (4)$$

where,

$$E = (y_{12}^{I})^{2} - 2y_{22}^{I}y_{11}^{I} - (y_{12}^{R})^{2}, \qquad (5)$$

$$F = y_{11}^{I}(y_{22}^{R})^{2} + y_{11}^{I}(y_{22}^{I})^{2} - 2y_{22}^{R}y_{12}^{R}y_{12}^{I} - y_{22}^{I}(y_{12}^{I})^{2} + y_{22}^{I}(y_{12}^{R})^{2}, \qquad (6)$$

y_{ij}^{R} and y_{ij}^{I} denote the real part and the imaginary part of y_{ij}, respectively. The reactance X which satisfies the resonant condition(Eq. (3)) is called the forced-resonant loading reactance. The plus sign in Eq. (4) corresponds to the series resonance and the minus sign to the parallel resonance. Since the short-circuited transmission line with characteristic impedance Z_0 and length l constitutes the loading reactance, the length of reactance can be also obtained by substituting the reactance value into Eq. (4).

4. Antenna Factor

The antenna factor of the small EMI dipole antenna with Roberts Balun in Fig. 1 is obtained, neglecting the conduction loss in B/M circuit and cable, as the following form[2].

$$K = \frac{2}{h_e}\sqrt{\frac{R_a}{R_L}}K_B = K_0 K_B \qquad (7)$$

where R_a is the input resistance of the antenna and R_L is the input resistance of the receiver. K_0 is the antenna factor in case the ideal B/M circuit is used, K_B is the variation of the antenna factor caused by the impedance mismatch due to insertion of the B/M circuit. If the B/M circuit is lossless, K_B is given by

$$K_B = \sqrt{\frac{|Z_{b1} + Z_a|^2}{4R_a R_{b1}}} \qquad (8)$$

where $Z_{b1}(= R_{b1} + jX_{b1})$ is the input impedance of the antenna seen from the input terminal of the B/M circuit into the receiver. We assumed an ideal case of no reflection from the receiver terminal in this paper.

5. Numerical Results and Discussion

Figure 2 shows the value of forced-resonant reactance dependent on the loading position. And the input resistance in such a case is also represented. As shown in Fig. 2, if the antenna length is shorter than 0.3λ, the real part of the input impedance becomes smaller and the matching with Balun would be difficult. Therefore it is found that the antenna of length 0.3λ is effective. Fig. 2 is the result of the plus sign in Eq. (4). In this paper, only the series resonance is investigated since the input resistance is much larger in parallel resonance. It can be found that the loading position with the input resistance $50\ \Omega$ exists from Fig. 2(b) when the 0.3λ antenna is used. If the reactance is loaded at $c = 0.12\lambda$, the forced-resonant loading reactance of $X = 291.6\ \Omega$ and the input impedance of $50.18\ \Omega$ are obtained, and hence the perfect impedance matching can be obtained since the resonance is occurred near the input resistance of $50\ \Omega$.

Figure 3 shows the current distribution when the forced-resonant loading reactance $X = 291.6\ \Omega$ is loaded at $c = 0.12\lambda$ in Fig. 2(b). Although large current flows at the loading point, the form of total current distribution is sinusoidal, we can find that the radiation pattern is similar to that of the dipole antenna.

Figure 4 shows the frequency characteristics of the antenna factor. K_B is the variation of the antenna factor due to the insertion of the Balun, K_0 is the perfectly-matched antenna factor when the receiver is connected directly to the antenna terminal. K is the antenna factor into account of all characteristics of the Balun.

6. Conclusions

This paper proposed a small EMI dipole antenna for frequencies below 80 MHz is proposed and its basic characteristics are analyzed. Roberts Balun is connected to the antenna terminal, and the loading reactance is used for downsizing of the antenna. As the results, if the forced-resonant loading reactance is appropriately loaded on the 0.3λ antenna, we can realize a small EMI dipole antenna of the input resistance $50\,\Omega$.

References

[1] ANSI C63.4-1992.

[2] K.C.Kim and S. Tokumaru; “Antenna Factors of Half-wavelength Dipole Antennas with Roberts Balun”, IEICE Trans., vol. J78-B-II, no. 11, pp. 717-724, Nov. 1995.

[3] K.C.Kim and S. Tokumaru; “Antenna Factors of Short Dipole Antennas with Roberts Balun”, IEICE Trans., vol. J81-B-II, no. 1, pp. 119-122, Jan. 1998.

[4] W.K. Roberts; “A New Wide-Band Balun”, Proc. of the IRE, vol. 45, no. 12, pp. 1628-1631, Dec. 1957.

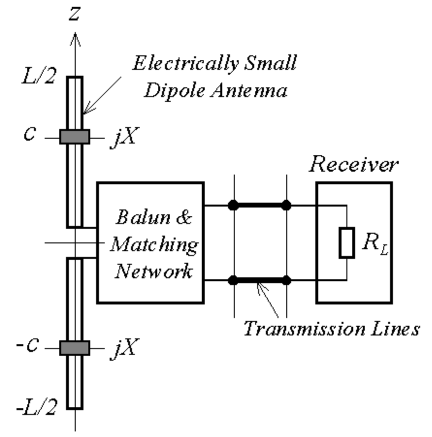
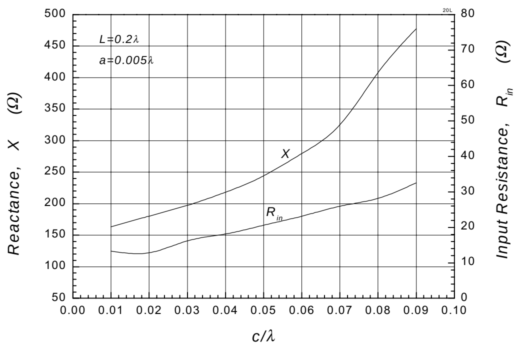
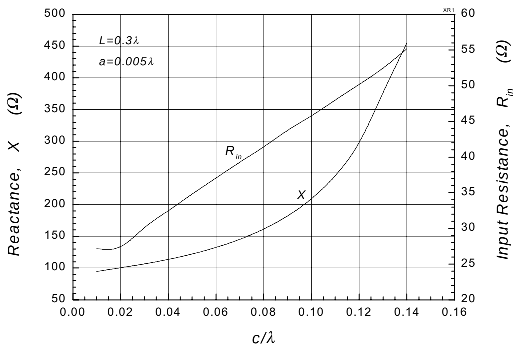


Fig. 1. Electronically small EMI dipole antennas with Roberts balun.



(a) ***L* = 0.2λ**



(b) ***L* = 0.3λ**

Fig. 2. Loading reactance and input resistance vs. loading position.

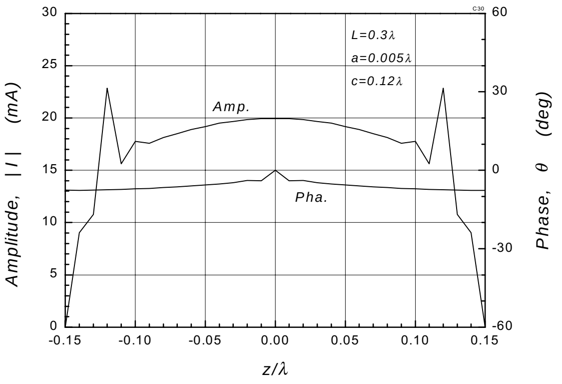


Fig. 3. Current distributions.

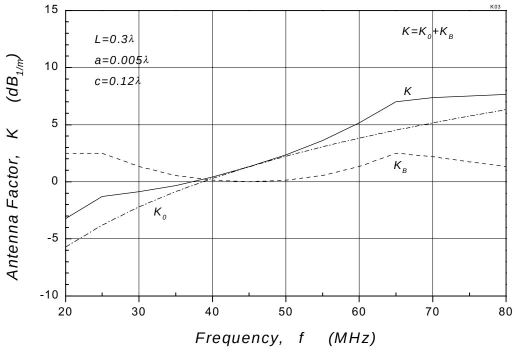


Fig. 4. Frequency characteristics of antenna factor.