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WIDE-BAND DIPOLE ANTENNAS WITH A CONSTANT GAIN CHARACTERISTIC FOR DIRECTION OF ARRIVAL ESTIMATION USE

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1. Introduction

As a large variety of radio communication waves which have different frequencies each other are propagating in the space, antenna elements for Direction-Of-Arrival (DOA) estimation should have wide-band characteristics. Additionally, in order to monitor the unknown radio signals, these antennas are expected especially to have an isotropic radiation in the horizontal plane because of catching signals from every direction. From these demands and having simple geometry, monopole or dipole antennas are widely applied as the elements for DOA finding. Judging from their geometries, radiation characteristics of the monopole antenna are influenced by the ground condition. On the other hand, the dipole antenna can be preventing the effect by being located it upper the ground. However, we usually need to prepare a prop and a boom to achieve the above configuration, and the dipole's radiation patterns may be influenced by them. Therefore, it is strongly desired that the dipole antenna does not involve them to achieve the ground effect suppression.

In this paper, a dipole antenna fed by a coaxial line is taken up and a new method to analyze the input impedance is proposed, where this antenna is supported itself and located over the ground. The method is derived using the equivalent model of the feed section as a circular radial line [1], [2]. Numerical simulations using the Method of Moment (MoM) and experimental results of a prototype model are shown to confirm the method. In addition, the mutual coupling is compared between the MoM and the experiment, and from the correspondence, it is also shown that this antenna can achieved a constant gain characteristic over the wide-band by optimizing geometric parameters.

2. Antenna Geometry

The external appearance of the prototype of the dipole antenna is shown in Fig. 1. The radiating part of the dipole consists of two cylindrical conductors, of which each opposite base is stretched by a circular conductor plate. A coaxial cable for feed is wiring inside the lower cylindrical conductor and symmetrically excites the antenna at the center of the base plate as shown in Fig. 2. Between the two conducting plates, an inner conductor of the coaxial cable is extended through the gap of the two plates and finally connected to the upper plate, and the outer conductor of that is connected to the lower plate. This feed structure is free of a balun and therefore it is easy to fabricate and capable of reducing costs. The section of the feed is filled with an insulator (a circular dielectric substrate) which maintains the feed configuration. To keep the location of this antenna above the ground, the insulator

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is also filled between the lower cylindrical conductor and the ground. The length and the diameter of the dipole are $2L$ and $2b$, respectively.

3. Method of Analysis of the Input Impedance

Structural parameters are shown in Fig. 2. The feeding structure is considered to be similar to the behavior of a radial waveguide excited symmetrically at its center by a line current. The ρ axis is directed along the radius. The radius of the inner line and the base plate are δ and b, respectively. The distance between the two plates is d, and the permittivity of the dielectric substrate is ε_r.

Consider that only TEM mode may exist in the radial waveguide and excite the dipole so that the input impedance will be derived here by using a radial waveguide transmission line model. Fig. 3 shows the equivalent model of the feed region, where it is assumed that the radial waveguide is terminated (at $\rho = b$) by an admittance Y_t of the dipole having the length $2L$ and the diameter $2b$. When it is assumed that the radius of the radial waveguide is continuous between ρ_1 and ρ_2, a fundamental matrix $F_{\rho 1 \rho 2}$ is given the following expression:

$$F_{\rho_1\rho_2} = \begin{bmatrix} f_{11} & f_{12} \\ f_{21} & f_{22} \end{bmatrix} = \frac{\pi k \rho_2 Z_{\rho_2}}{4} \begin{bmatrix} -\frac{1}{jZ_{\rho_2}} P_{01}(k\rho_1, k\rho_2) & P_{00}(k\rho_1, k\rho_2) \\ \frac{1}{Z_{\rho_1} Z_{\rho_2}} P_{11}(k\rho_1, k\rho_2) & \frac{1}{jZ_{\rho_1}} P_{10}(k\rho_1, k\rho_2) \end{bmatrix}, \tag{1}$$

with

$$Z_\rho = \frac{\eta d}{2\pi\rho} = \frac{1}{Y_\rho}, \tag{2}$$

$$\begin{aligned} P_{nm}(x, y) &= H_n^{(2)}(x) H_m^{(1)}(y) - H_n^{(1)}(x) H_m^{(2)}(y) \\ &= 2j\{J_n(x) N_m(y) - N_n(x) J_m(y)\} \end{aligned} \tag{3}$$

where k is wave number in the waveguide, $\eta = \sqrt{\mu_0 / \varepsilon_0 \varepsilon_r}$, $H_v^{(1)}$, $H_v^{(2)}$ are the notations of the v-th order Hankel functions of the first and second kind, respectively, and J_v, N_v are the notations for the Bessel and Neumann functions of orders v, respectively.

Therefore, the input impedance Z_{in} is given by

$$Z_{in} = \frac{f_{11} + f_{12} Y_t}{f_{21} + f_{22} Y_t}, \tag{4}$$

where $I(b) = Y_t V(b)$ is defined.

4. Measured and Simulated Results

Fig. 4 shows theoretical and measured values of the input impedance, as a function of frequency. The simulated ones by using a wire grid model based on MoM are also plotted in the same figure. Measured and simulated results corresponded closely with theoretical ones so that the proposed analytic method is verified. When the impedance characteristics have to be analyzed over a wide-band, this method has an advantage over the wire grid method in calculation time and a memory capacity.

Fig. 5 shows measured and simulated values of the mutual coupling between two elements. Both coupling values versus frequency correspond well. These results prove that the simulation model is useful to get the antenna characteristics.

Fig. 6 shows the gain of simulated value for the abovementioned model versus frequency with the same parameters in Fig. 4. The gain curve is a flat locus. Note that this antenna can be designed to have constant gain characteristics over a wide-band frequency range by selecting parameters of the geometry. In case of obtaining the constant gain, the keys to design of the parameters are as follows: the reactance component of the input impedance decreases with increase of the radius *b* and increases with increase of the feeding gap *d*.

5. Conclusion

An analytic method has been proposed for the input impedance of self-supported dipole antenna for estimating the DOA. Numerical results based on the method have been compared with the measured ones and the effectiveness of it has been carried out. In addition, it has been shown that the antenna designed by using optimum parameters has a constant gain characteristic over wide-band region.

References

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[2] D. L. Sengupta and L. F. Martins-Camelo, "Theory of dielectric-filled edge-slot antennas," *IEEE Trans. Antennas Propagat.*, vol. AP-28, No. 4, pp. 481-490, July 1980.

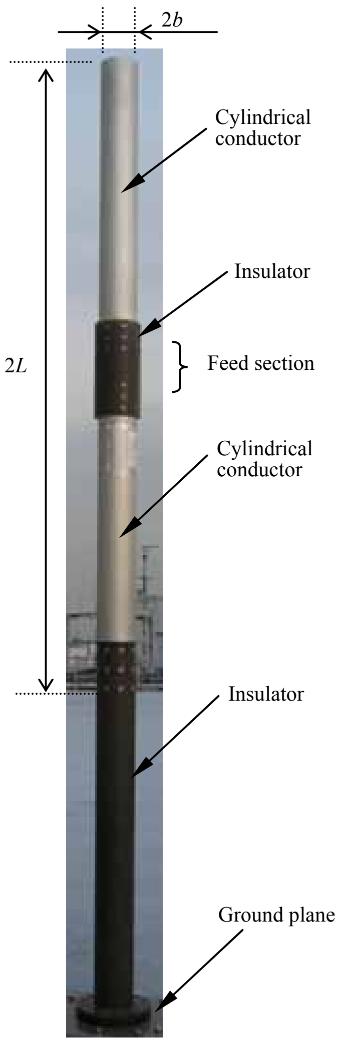

Fig. 1. External appearance of prototype of the self-supported dipole antenna.

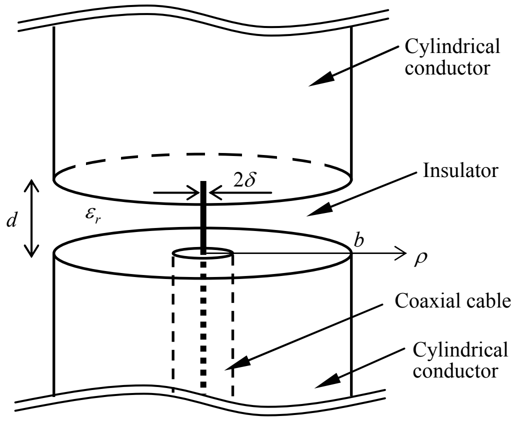

Fig. 2. Detailed configuration of the feed section.

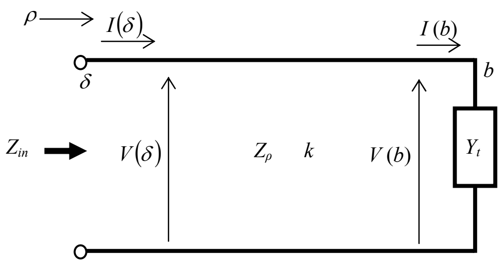

Fig. 3. Equivalent transmission line model of the feed region.

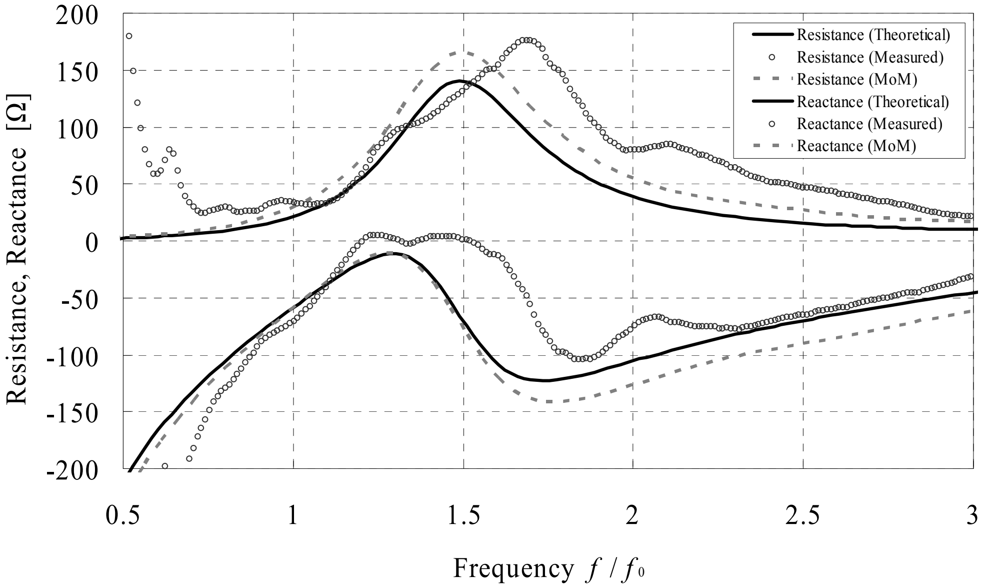

Fig. 4. Input impedance of the antenna in Fig. 1. The antenna is designed to be resonant at f_0.

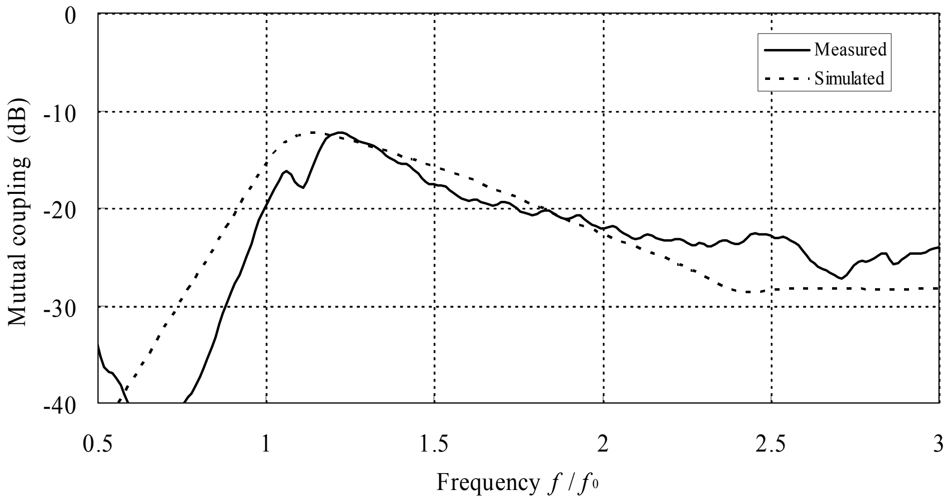

Fig. 5. Mutual coupling between two antennas in Fig. 1. The distance between antennas is 0.32 λ_0.

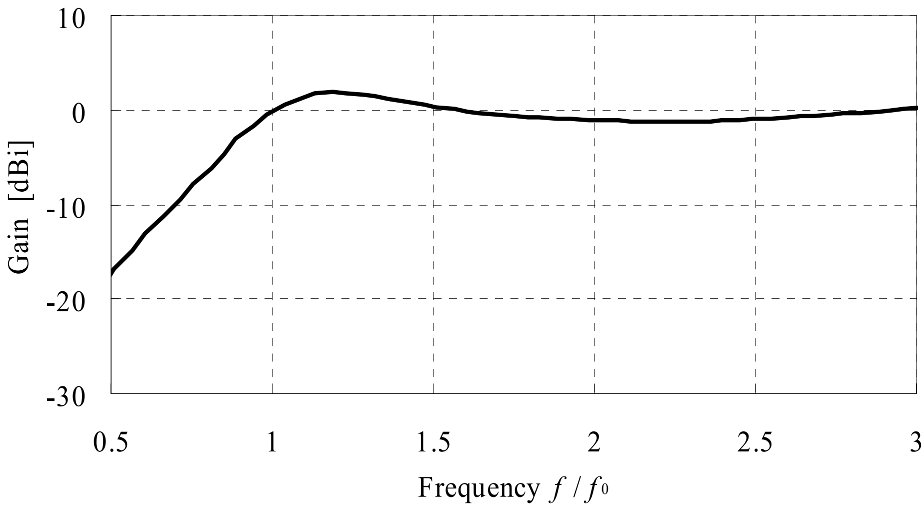

Fig. 6. Gain as a function of frequency for the antenna designed using the same parameters in Fig. 4.