POS-A-26

OFFSET-FEED IMPEDANCE MATCHING OF A HALF-WAVELENGTH DIPOLE IN PROXIMITY TO A PEC PLANE

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1. Introduction

Dipole antennas have been extensively used for communication since the early days of radio transmission and they still remain one of the most popular options for variety of communication systems. A dipole antenna above a perfect electric conductor (PEC) plane, especially at a quarter wavelength distance is widely used for several purposes such as in space or aboard aircraft. However, a dipole antenna in proximity to a reflector has acquired much attention for practical reasons and due to the lack of its knowledge.

For a center fed half-wavelength dipole, the radiation resistance approaches zero when the dipole is closely located to a PEC plane [1]. Thus, it is difficult to match the antenna with the 50-Ω feeder. For practical purposes, it is necessary to raise the input impedance of the antenna. It was shown that a good impedance matching can be realized, even though the antenna model has vertical portions connected to the feed lines, which generate sidelobes [2].

In this paper, an alternative way the so-called offset feeding is proposed as an impedance matching technique. This new technique is applied first in the analysis by changing the feed point of the dipole from its center. Then, the experiment is performed to verify the ability of the technique. This antenna can be used effectively as an ultra low profile dipole antenna which has a small size, lightweight and wide radiation pattern.

2. Analysis

In the analysis, we consider the antenna model as shown in Fig. 1: a half-wavelength dipole is placed at a height h above a PEC plane. The operating frequency is 2GHz. We assume here that the radius of a dipole is infinitesimal. Thus, the current distribution along the dipole can be obtained as a sinusoidal with zero at both ends. The offset feeding technique is applied by shifting the feed point of the dipole from its center by length x_1 ($x_1 = 0, 0.01, 0.02, \ldots, 0.25\lambda$). First, the input impedance is calculated for different x_1 when h equals to 0.05λ ($\lambda = 150$mm). Then, it is considered for different h. The MMANA [3] program, which is based on the Method of Moment (MoM), is used as a computational tool.

In Fig. 2, the solid lines represent the input impedance at each offset feed length (x_1). It is apparent that at the center of the dipole the input impedance is almost zero and increases corresponding to the offset feed length, especially near the edge of the dipole. This is because the current distribution along a thin dipole is almost sinusoidal, and the input impedance is the ratio of the voltage and current at the feed point. If the voltage is fixed constant, the impedance is inversely proportional to the current. Hence it is possible to match the antenna with a 50-Ω feeder by adjusting the feed point.

The reactance associated with the input impedance of a dipole is a function of its length. To reduce the reactance to zero, the antenna is match or reduced in length until the reactance vanishes. We obtain the length of the dipole for first resonance is about 0.494λ. At the resonance with the dipole length 0.494λ, the input impedances at each offset feed point are plotted as the dotted lines in Fig. 2. It can be seen that the reactance is almost zero in all cases. However, the resistance does not change much from the off-resonance case so that it is independent on the frequency. At the offset feed length

ISBN: 4-88552-207-2 C3055©IEICE

of 0.2λ, we obtain the resistance about 43Ω, which is near the 50Ω characteristic impedance of some transmission lines. In this case, we can obtain a sinusoidal current distribution symmetrically on both sides as shown in Fig. 3 in comparison with a sine curve.

The optimum offset feed length and the resistances are calculated for different values of the height h. The results are shown in Fig. 4. It can be seen that the less the height is, the more the feed point is shifted from the center. The resistance of about 50Ω can be obtained for almost all the cases except at the height equal to quarter wavelength which the resistance exceeds 50Ω.

3. Antenna Design

The configuration of a constructed antenna is depicted in Fig. 5. A dipole consists of a short wire (l_1) and a long wire (l_2) with 1mm. in diameter, and it is fed by a single coaxial cable where a bazooka balun type is used. In this balun type a λ/4, where λ is wavelength, in length metal sleeve is required, and shorted at its one end, encapsulates the coaxial cable. The dipole installs in the hole located at the middle of a conductor plane sized 3λ × 3λ (λ = 150mm), which has exactly the same diameter as that of outer metal sleeve so that the metal sleeve is shorted to the plane. Aluminum plate, which has a thickness of 3mm., is used as a conductor plane because it is very good conductor (conductivity 38MS/m), incident wave will reflect almost entirely from the plate.

This research is pursued to experimentally determine the dipole at the height of 0.05λ above a conductor plane under the frequency of 2 GHz and the design parameters l_1 and l_2 in order to realize a good impedance matching with the desired impedance characteristic of 50-Ω feeder.

4. Impedance Characteristic

The impedance characteristic of the antenna under test is measured with a network analyzer (HP8510A) and a synthesized sweeper (HP86640A) as shown in Fig. 5. In this measurement, the lengths of the short wire (l_1) and long wire (l_2) are varied until the input impedance of the antenna is match with the characteristic impedance of 50-Ω coaxial cable.

We obtain the optimum lengths of 6mm. and 49mm for l_1 and l_2, respectively. Therefore, the feed point is located about one-tenth from the edge. The return loss of -11dB is observed as shown in Fig. 6, and this antenna has the input impedance of about 33Ω as shown in a smith chart plot in Fig. 7. In the constructed antenna, the outer metal sleeve of a dipole is shorted to the conductor plane. Thus, the input impedance tends to be very low. Also, the total length of the dipole measured from one tip of a short wire to the other tip of a long wire is only 57mm., a larger segment has to be removed from λ/2 to achieve resonance.

The impedance characteristic of the experimental model seems to be different from that of the analysis mentioned in the previous section. This is probably due to the metal sleeve of the experimental model shorted to the conductor plane. As the resonant wavelength is almost equal to the sum of l_1, l_2 and the double of the height h, it can be assume that the current is induced and flows on the sleeve. This fact alters not only the input impedance but also the radiation pattern.

5. Radiation Patterns

We measured the radiation patterns in the E-plane and H-plane. The coordinate system is shown in Fig. 5. The E and H planes are the x-z plane and y-z plane, respectively. Figure 8 shows the radiation patterns as a function of zenith angle (θ). The maximum gain of 5.7dBi occurs in the boresight direction (θ = 0°). The half power beamwidth (HPBW) is about 120° and 86.5° measured in the E and H planes, respectively. The radiation pattern of this antenna is very wide and it is comparable to the dipole at a quarter wavelength above a PEC plane.

From the computational results, we obtain the maximum gain of 8.9dBi in the boresight. The HPBW of 90° and 60° in E and H plane, respectively. These discrepancies are caused probably by the effects of the sleeve which are not modeled in the analysis.

6. Conclusions

It is found concerning the impedance matching of a half-wavelength dipole located in proximity to a PEC plane as follows:

(1) In the analysis, at h equals to 0.05λ, the optimum feed point located at 0.2λ from its center in which the resistance of about 43Ω is obtained.
(2) The less the height is, the more the feed point is shifted from the center.
(3) At the resonance, we can obtain a sinusoidal current distribution symmetrically on both sides.
(4) In the experiment, we obtain the optimum lengths of the short wire and long wire as 6mm and 49mm, respectively which gives much shorter length than the half-wavelength.
(5) By using these lengths, the return loss of about -11dB is observed, and the input impedance is 33Ω
(6) The maximum gain of 5.7dBi occurs in the boresight direction (θ = 0°). The HPBW is about 120° in the E-plane and 86.5° in the H-plane. These HPBWs are comparable with the dipole at a quarter wavelength above a PEC plane
(7) The offset feeding technique is verified by the analysis but the characteristic values are different from the experiment ones. The reason is expected to be the effects of the sleeve.

References

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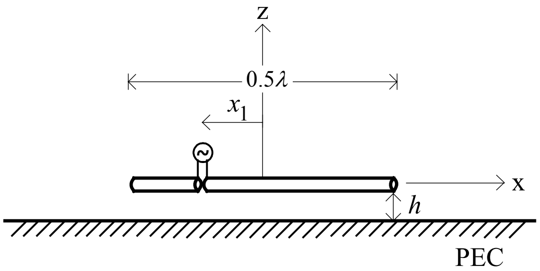


Fig. 1 Configuration of an offset fed half-wavelength dipole above a PEC plane

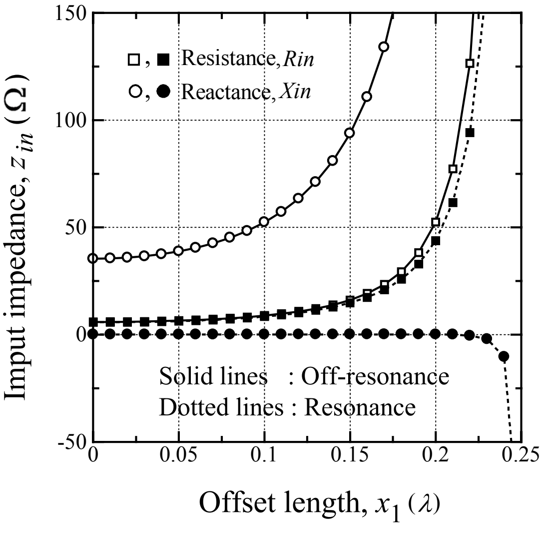


Fig. 2 Input impedance at different offset length
Dotted lines : resonance

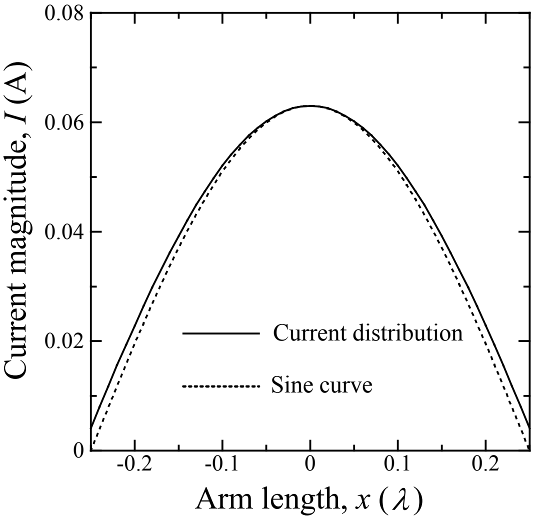


Fig. 3 Current distribution along a resonant dipole

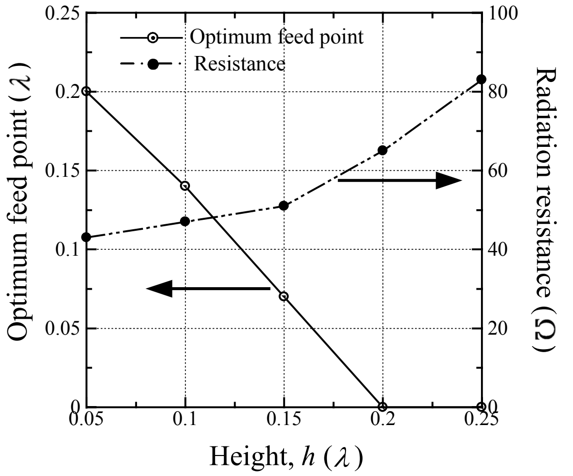


Fig. 4 Optimum feed point and radiation resistance at different height

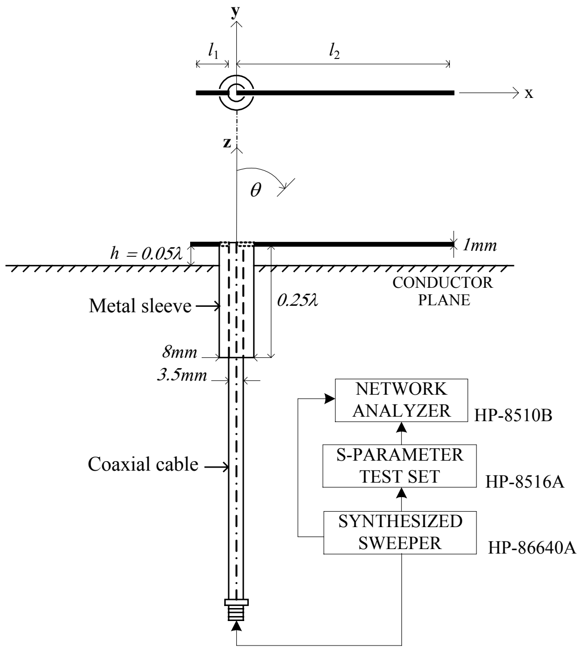


Fig. 5 Configuration of the antenna under consideration and its impedance measuring system

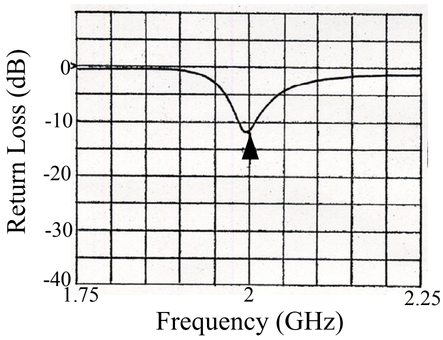


Fig. 6 Measured return loss against frequency

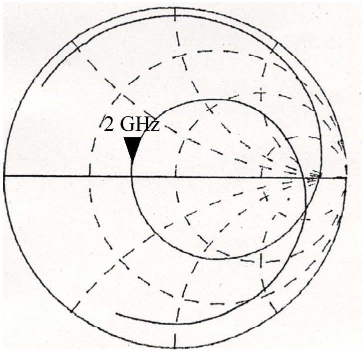
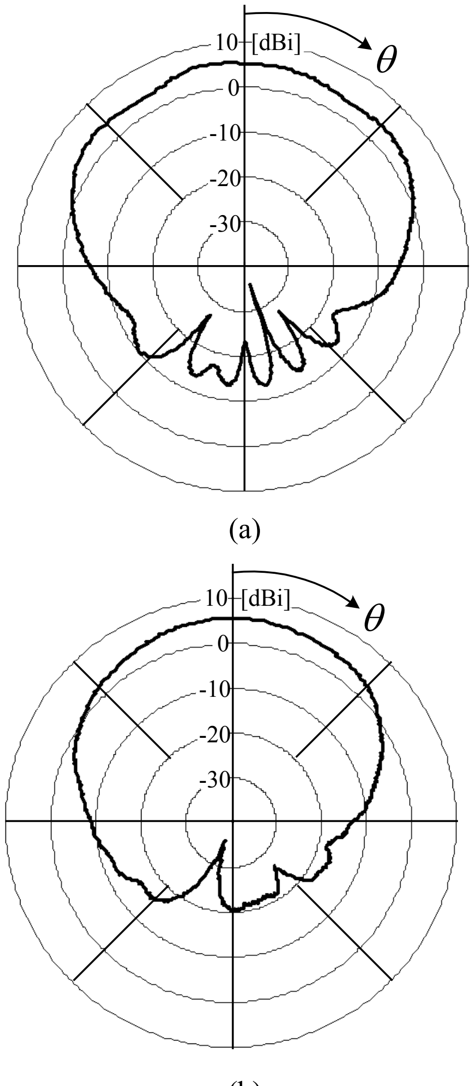


Fig. 7 Smith chart plot



(a)

(b)

Fig. 8 Measured radiation patterns

(a) E-plane (x-z plane)

(b) H-plane (y-z plane)