An Investigation on Radiation Performance of λ/4 and 3λ/8 Dipole Antennas with Finite Ground Strips and Finite Conductivity Ground

λ/4 and 3λ/8 偶極天線於有限接地線及有限導電係數地面之輻射特性探討

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Abstract

The radiation characteristics of λ/4 and 3λ/8 dipole antennas with 50 ohm coaxial line feed, and the operating frequency in 1143 kHz, were investigated. By changing the number of conductor strips and the conductivity of the earth, the radiation characteristics of λ/4 and 3λ/8 dipole antennas were presented and compared.

Key word: dipole antenna, ground, conductor strip, finite conductivity.

摘要

本文探討操作頻率為 1143kHz, 50 **歐姆阻抗同軸線輸入,** λ/4 and 3λ/8 **偶極天線之輻射特性。 對於在不同接地導線數目以及不同導電係數地面的情形下,** λ/4 and 3λ/8 **偶極天線的各種輻射特性的影響與結果進行比較與分析。**

Introduction

Antennas had been widely used in radio and television broadcasting systems[1-3] for a long period. The applications of antennas are widely applied from high frequency(HF), very high frequency(VHF), up to microwave and millimeter-wave. The antenna is an apparatus transmitting radio wave into air or free space and also can receiving the radio wave from air or free space and is the necessary part in various wireless applications. In considering the system and the technical requirements such as operating frequency, bandwidth, power rating, beam width, polarization, antennas have various kinds of types, for example: dipole, loop, horn, lens, reflector, etc. to meet the system specifications[4-5].

Dipole antennas have been used in amplitude modulation (AM) broadcasting transmitting system for a long time. For strong receiving signal on the ground plane, the AM band (535-1605 kHz) transmitting antenna is normally set up in vertical direction; the antenna direction is perpendicular to the ground plane. In a simplified antenna design, the ground is assumed be a perfect electric conducting plane, the surface roughness is neglected, and the current flow on the antenna is assumed sinusoidal distributed. Under these assumption, the radiation characteristics of the vertical λ/4 dipole antenna will acts like λ/2 center-fed dipole antenna, except the radiation impedance is half of the λ/2 dipole antenna's value. Based on the same assumption, the characteristics of 3λ/8 dipole antenna is similar to 3λ/4 dipole antenna.

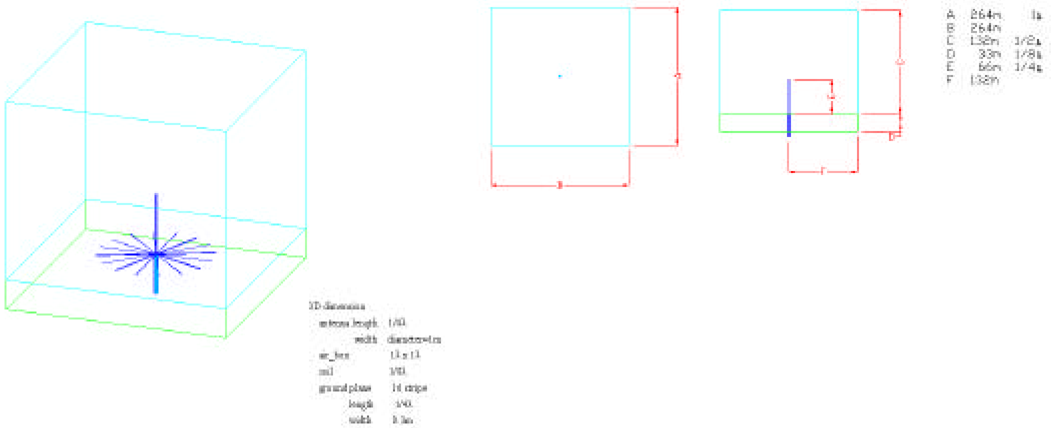
In this paper, we use an elaborate 3D model to simulate the actual AM antenna located at Peihou island, Taiwan, and use the finite element technique to analyze the radiation pattern of the antenna. The antenna stood on a sandy soil, with finite number conductor strips buried beneath the surface of the sandy soil as the ground plane. Both the lengths of λ/4 and 3λ/8 dipole antennas are investigated to understand the performances of the existed antenna (λ/4 dipole antenna) and to evaluate the performance of λ/8 dipole antenna for construction in the future.

Fig. 1 The AM λ/4 dipole antenna tower, 66m in height, operating at 1143 kHz, located in Peihou, Taiwan, and owned by Taiwan Fishery Station

Modeling the Problem

In order to find the effect of finite number of ground strips and the finite conductivity ground. We use the model, shown in Fig. 2, to simulate the antenna and its environment. Because the operating frequency is 1143 kHz, the corresponding one wavelength is equal to 264m.The antenna is located at the center position in xy plane. The distance among four side walls and the upper and bottom boundary are set as one wavelength, 264m. Considering the antenna is installed on the sandy soil, four sidewalls, the top and the bottom boundary conditions are set as absorption boundary which is intended to simulate the real environment. In Fig. 2, the antenna's height is

66m, this is exact the quarter wavelength of 1143 kHz. The height below the horizontal plane is 33m, the 1/8 wavelength at 1143 kHz. This underground layer is used to simulate the sandy soil, its relative dielectric constant is set 3.42 for lossless case, set 3.42+j0.67 for lossy case. The ground strip is 0.3 m (width) and 66 m (length).



(2a) (2b) xy and xz plane

Fig. 2 Modeling the antenna and its environment. (2a) the 3D view of the model, (2b) the 2D view in xy and xz planes.

Numerical Results

We adopted a finite element technique based CAD tool, high frequency structure simulator (HFSS) developed by Ansoft, for analyzing those cases. Figure 3 shows the 3D radiation pattern of a λ/4 dipole antenna in different ground planes conditions: (3a) the infinite perfect electric conductive (PEC) ground plane; (3b) finite PEC plane with lossless sandy soil ground, relative dielectric εr=3.42; (3c) with four horizontal radial direction conductive strips on lossless soil, relative dielectric εr=3.42. The λ/4 antenna on infinite PEC ground plane behaves like λ/2 antenna in free space. Since the radiation only in half space, no power radiated to the lower half space. When the ground plane is finite or forms by finite number of conductive strips, the radiation exists in lower half space. In Fig. 4, we shows the 2D radiation pattern from $\theta=-90^o$ to $\theta=90^o$ at $\phi=0^o$ of the infinite PEC ground plane, the finite PEC ground plane, and the 4 strips ground plane. As expected, the 4 strips ground plane has more radiation power in lower half space. In finite ground plane, the maximum radiation power has an angle around $\theta=50^o$, on 70% of the maximum power strength along the horizontal direction.

Since the antenna is installed on sandy soil, the properties of sandy soil will change the radiation pattern. As shown in Fig. 5, we investigated the 2D radiation pattern of the lossless and lossy sandy soil. In Fig. 5a, the sandy soil is set as lossless, its relative dielectric is 3.42[6]. The 2D radiation patterns of λ/4 antenna in three different number of conductive strips were presented. The results show that more number of strips the radiation pattern is much symmetric with respect to horizontal ground plane. In contrast with the lossless case, when the sandy soil is lossy, $\varepsilon r=3.42+j0.67$, the radiation pattern is less symmetric as the number of strips increases. These results were shown in Fig. 5b.

Referred to Fig. 6, the radiation patterns of different length antennas were also investigated. In the condition of finite ground plane, both the width and length were set as one wavelength, blue curve shows the 3λ/8 antenna, red curve shows the λ/4 antenna, the maximum radiation power direction moves toward horizontal direction as the length of the antenna changes from λ/4 to 3λ/8. The radiation characteristics of λ/4 and 3λ/8 antenna on lossless sandy soil with finite number of strips as ground plane were presented in Fig. 7. As shown in Fig. 7a and 7b, the number of conductive strips has less influence on the radiation pattern in 3λ/8 antennas.

Conclusion

We have constructed a model for analyzing the λ/4 vertical dipole antenna, located in Peihou, Taiwan. Based on this model and used the finite element technique, the radiation characteristics of two different lengths, λ/4 and 3λ/8 vertical dipole antennas in various conditions were investigated. The 3D view of radiation patterns of λ/4 antenna in infinite and finite PEC ground plane, and 4 strips were presented. The lossless and lossy sandy soil will change the radiation pattern in λ/4 antenna. The number of strips has less influence on radiation patterns in both λ/4 and 3λ/8 antennas. These results will help Taiwan Fishery Broadcast Station understanding the performance of the existing quarter wavelength AM antenna in Peihou, Taiwan.

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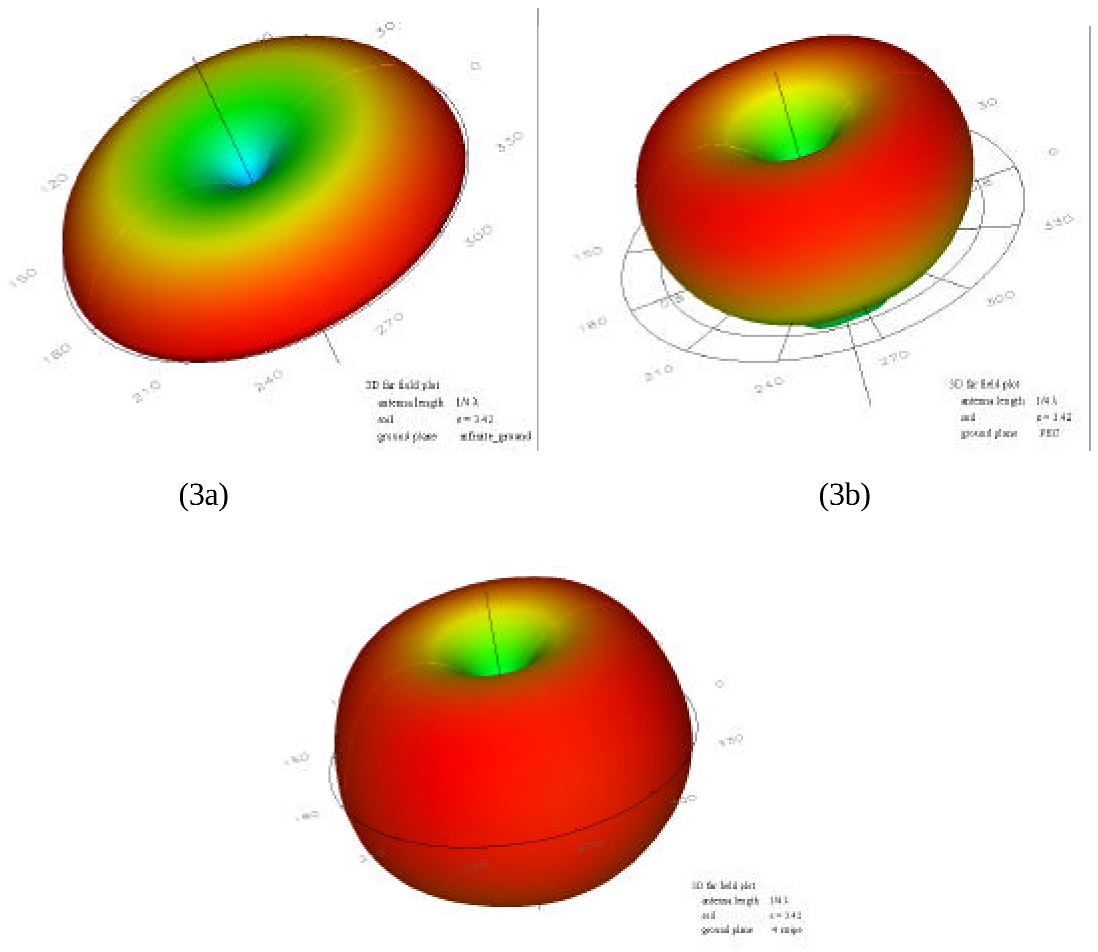
References

1. J. Perini, “TV transmitting antenna selection,” IEEE Trans. Broadcast., vol. BC-15, no.1, March 1969.
2. H. H. Riblet, “Microwave omnidirectional antennas,” Proc. IRE, vol.35, no.5, pp.474-478, 1947.

3. J. H. Moon, "Design of electromagnetic goniometers for use in medium frequency direction finding," J. IEE, vol. 94, p.69, January 1947.
4. S.A. Schelkunoff, "Theory of antennas of arbitrary size and shape," Proc. IRE, vol.29, pp.493-521, September 1941.
5. G. H. Brown, "Directional antennas," Proc. IRE, vol.25, pp.81-145, January 1937.
6. R.F. Harrington, Time-Harmonic Electromagnetic Fields, McGraw-Hill, Inc. 1961, pp.451-455.



(3a) (3b)

(3c)

Fig. 3: 3D radiation pattern of λ/4 vertical dipole antenna. (3a) on infinite PEC plane, (3b) on finite PEC plane with sandy soil ground, ε_r=3.42, (3c) on sandy soil ground, ε_r=3.42, with 4 horizontal strips spread out in radial direction.

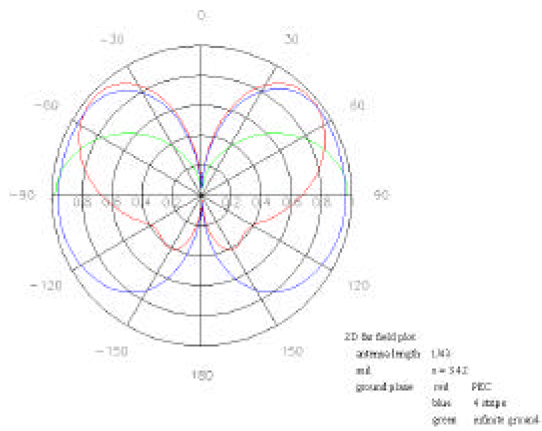
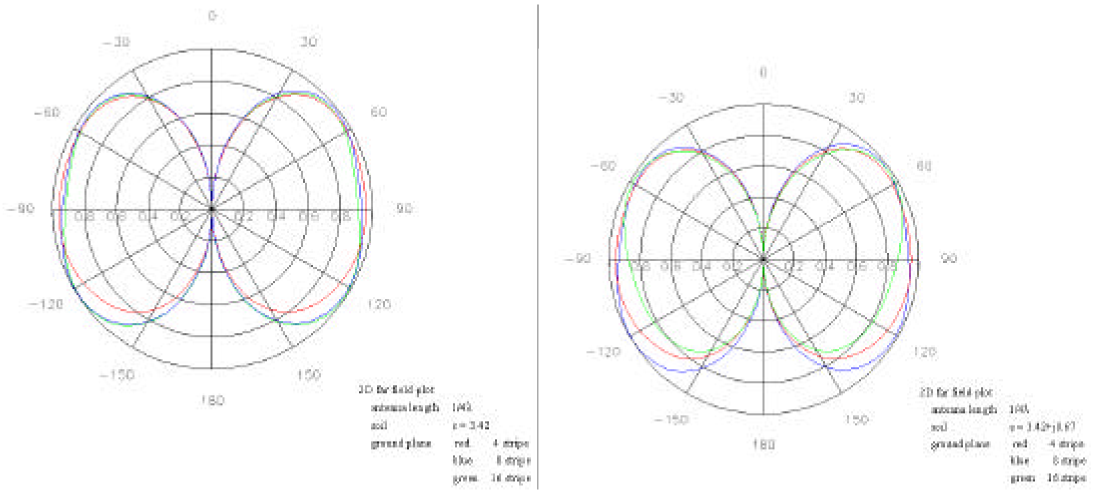


Figure 4: 2D radiation pattern of λ/4 dipole antenna with sandy soil (ε_r=3.42); green curve shows the infinite PEC ground plane; red curve shows the finite PEC ground plane, width=λ, length=λ; blue curve shows 4 horizontal conductive strips.



(5a) (5b)

Figure 5: 2D radiation pattern of λ/4 dipole antenna; red curve shows 4 strip; blue curve shows 8 strips; green curve shows 16 strips. (5a) sandy soil without loss, ε_r=3.42, (5b) sandy soil with loss, ε_r=3.42+j0.67.

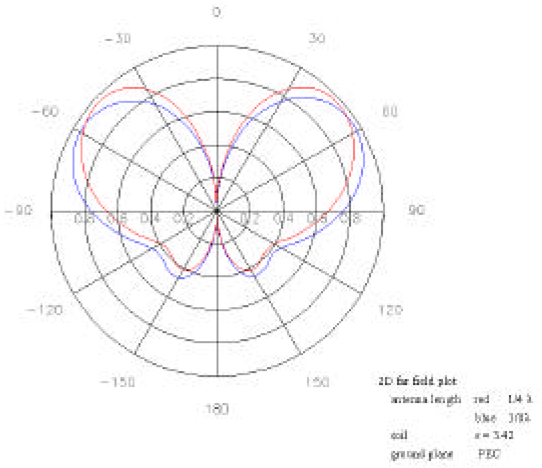
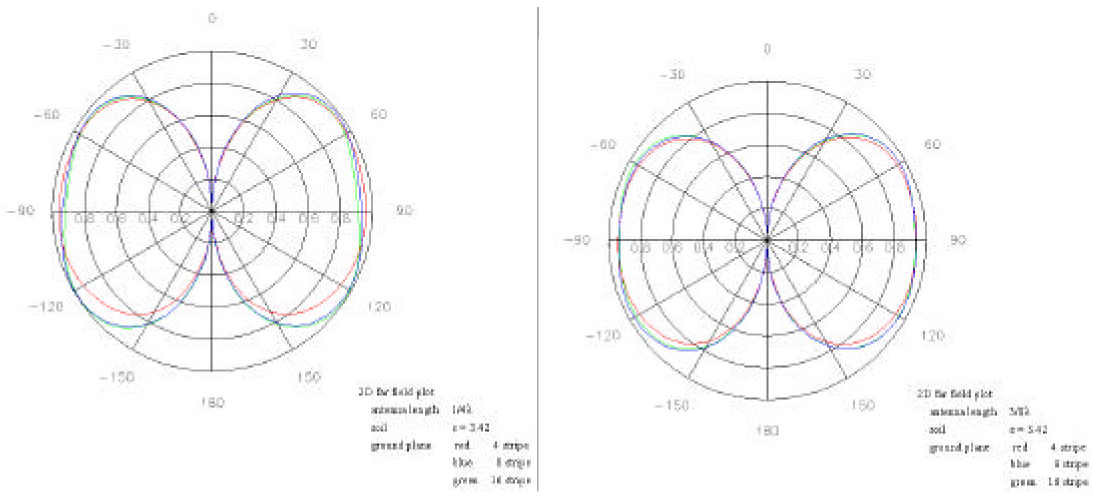


Figure 6: the 2D radiation pattern of λ/4 and 3λ/8 dipole antennas on finite PEC plane (width=length=λ) with sandy soil (ε_r=3.42).



(7a) (7b)

Figure 7: the 2D radiation pattern of λ/4 and 3λ/8 dipole antennas on sandy soil (ε_r=3.42) with finite number of conductive strips; red curve – 4 strips; blue curve – 8 strips; green curve – 16 strips.