Propagation Analysis of DGPS Antenna for Radial Ground and Obstacle

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Abstract— **The DGPS transmits the enhancement signal to GPS using the medium frequency band. The NDGPS service that covers the Korean peninsula has been started since 2009. The service area of ocean-based DGPS(maritime-DGPS) reference stations covers the 100NM, but land-based DGPS(land-DGPS) covers 80km service area less than that of maritime DGPS. The DGPS's antenna has the top-loaded monopole antenna type. Top-loaded monopoles are the logical antennas to be used in order to get a low profile antenna and a performance according to the broadcaster and communication needs. The antenna needs to get the ground plane with good conductivity characteristics and flat ground plane without obstacle near to the transmitting antenna.**

In this paper, the radiation characteristics of an equivalent MF antenna are analyzed in view points of the ground conductivity and the ground plane with obstacle near to the antenna.

Index Terms— **DGPS, Top-loaded antenna, DGPS's antenna, Radial ground.**

I. INTRODUCTION

KOREAN nationwide DGPS(NDGPS) constructed by the ministry of Land, Transport and Maritime Affairs (MLTM), consists of ocean-based DGPS (maritime-DGPS) for ocean service and land-based DGPS(land-DGPS) for land service. The Differential Global Positioning System(DGPS) is an enhancement to GPS that uses the DGPS reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions. The DGPS broadcast the difference between the measured satellite pseudo-ranges and actual pseudo-ranges, and receiver stations may correct their pseudo-ranges by the same amount.

The maritime-DGPS of 11 reference stations and the land-DGPS of 6 reference stations are operating and providing the differential GPS service nationwide. The DGPS reference stations provide the service information via radio signal of the medium frequency(MF) band(283.5 kHz ~ 325 kHz). The transmitting antenna of the DGPS reference stations usually is the top-loaded antenna type[1],[2]. A top-loaded vertical antenna has several advantages over the conventional vertical, but the biggest advantage is that it's shorter in length. The ground side of the antenna is a series of radials that all group into a connection at the base of the antenna. The radials are installed as the same length with the transmitting antenna. Radials are crucial in the design of a top-loaded antenna as the electrical properties of the antenna require the reaction between the top-loaded portion and the ground system. Also the top-loaded antenna should have the ground plane with good conductivity. The top-loaded antenna for land-DGPS has the good ground plane characteristics than that of the maritime, which may be the ground plane with obstacles near to the antenna. The radiation pattern of the DGPS antenna has effects due to the ground plane. To evaluate the radiation characteristics of DGPS according to the ground plane, the radiation pattern and input impedance of the antenna need to be analyzed via the antenna field strength analysis of the MF band.

In this paper, the radiation characteristics of an equivalent MF antenna are analyzed in view points of the ground conductivity and the ground plane with obstacle near to the antenna.

II. WAVE PROPAGATION OF MF ANTENNA

The Fig. 1 shows the ground wave configuration with a direct wave, a ground-reflected wave, and a surface wave.

From Fig 1 in the MF band, the voltage V induced at receiving antenna R from the transmitting antenna T with a distance of r can be expressed as vector sum of a direct wave and a ground-reflected wave, and surface wave[3]:

$$V = QI\{Q_1 \frac{\exp(-jkr_1)}{r_1} + Q_2 \frac{\exp(-jkr_2)}{r_2} + S\frac{\exp(-jkr_2)}{r_2}\} \quad (1).$$

where, I is a current at transmitting antenna, Q_1 and Q_2 means the polar diagram of transmitting antenna and receiving antenna, respectively.

In (1), S denotes the surface wave component and gets the various values according to the electric characteristics of ground surface, polarization, frequency, and a position of transmitting antenna and receiving antenna.

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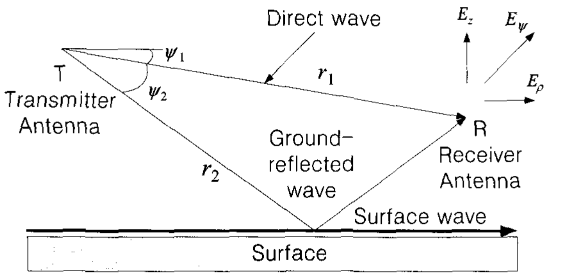


Fig. 1. Ground wave configuration.

From (1), the ground wave field intensity at the surface of the earth as radiated from a short vertical antenna is deduced as[4],[5]:

$$E_z = j30kIdl\ [\{\cos^2\psi_1 \frac{\exp(-jkr_1)}{r_1} + \cos^2\psi_2 R_v \frac{\exp(-jkr_2)}{r_2}\} + \{(1-R_v)(1-u^2+u^4\cos^2\psi_2)F\frac{\exp(-jkr_2)}{r_2}\}] \quad (2)$$

$$E_\rho = j30kIdl\ [\sin\psi_1\cos\psi_1 \frac{\exp(-jkr_1)}{r_1} + \sin\psi_2\cos\psi_2 R_v \frac{\exp(-jkr_2)}{r_2} - \cos\psi_2(1-R_v)u\sqrt{(1-u^2\cos^2\psi_2)} \quad (3).$$
$$\{1-\frac{u^2}{2}(1-u^2\cos^2\psi_2)+\frac{\sin^2\psi_2}{2}\}F\frac{\exp(-jkr_2)}{r_2}]$$

where, ψ_1, ψ_2 is shown in Fig.1, and j denotes $\sqrt{-1}$. k is a wave constant of $2\pi/\lambda$, Idl means the dipole moment. R_v is a reflection coefficient of vertical polarization wave by the surface of the earth and F is a attenuation factor.

The attenuation factor F is expressed as[4],[6]:

$$F = [1 - j\sqrt{\pi\omega}\exp(-\omega)\{erfc(j\sqrt{\omega})\}] \quad (4).$$

where, the parameters in (4) are as follows:

$$erfc(x) = 1 - erf(x)\,, \quad \omega = \frac{-j2kr_2u^2(1-u^2\cos^2\psi_2)}{(1-R_v)^2}\,,$$

$$u^2 = \frac{1}{(\varepsilon_r - jx)}\,, \quad x = \frac{\sigma}{\omega\varepsilon_0} = 1.8x10^{10}\frac{\sigma}{f}\,.$$

The parameters of σ and $\varepsilon_r = \varepsilon/\varepsilon_o$ means the conductivity of the ground and relative dielectric constant, respectively.

In the case that the transmitting and receiving terminals have a low profile type, the direct wave and ground-reflected wave is cancelled from Fig. 1. By the conditions of $R_v = -1$ and $\psi_1 = \psi_2 = 0$, the ground wave field intensity of (2) and (3) can be simply expressed as:

$$E_z = j60kIdl\ (1-u^2+u^4)F\frac{\exp(-jkr)}{r} \quad (5)$$

$$E_\rho = j30kIdl\ \{u\sqrt{(1-u^2)}(2-u+u^4)\}F\frac{\exp(-jkr)}{r} \quad (6)$$

III. MF ANTENNA MODELING AND RADIATION ON RADIAL GROUND WITH OBSTACLE

To evaluate the antenna radiation pattern of DGPS antenna, the top-loaded antenna is modeled as the λ/4(250 m length at 300 kHz) monopole antenna with ground plane. The ground plane was installed as radial ground type with ground wires of 250 m. The radial ground has the physical characteristics of 60 ground wires that installed as angle space of 6°. Fig. 2 shows the antenna layout model for antenna performance simulation.

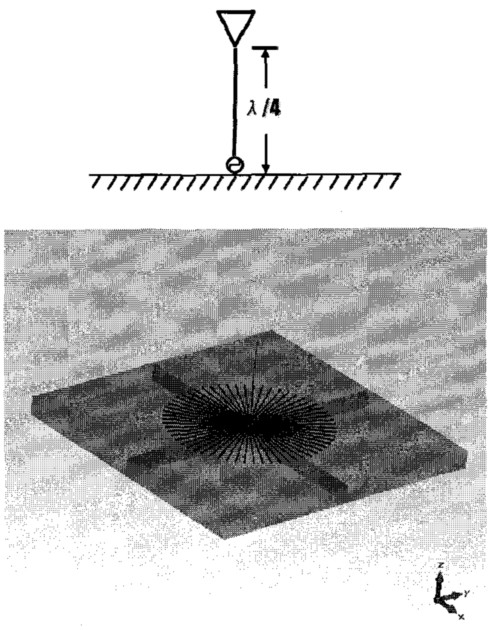
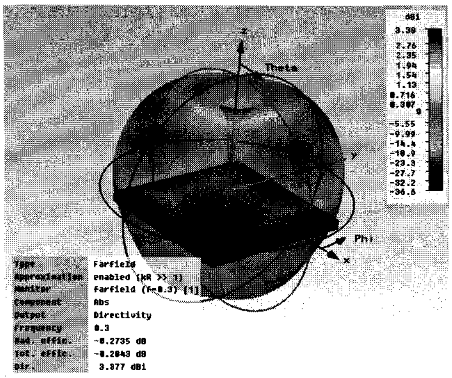


Fig. 2. Antenna layout model for simulation.

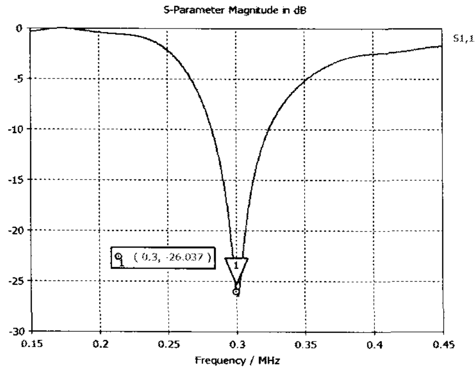
The ground wires were installed in the ground plane with some conductivity. The conductivity of the ground plane was classified as a general ground (0.01 S/m), a wet ground (0.1 S/m), and a hilly districts (0.0005 S/m).

Fig. 3 shows the radiation pattern and input impedance characteristics of the antenna on the general ground plane. The radiation pattern of the antenna has symmetrical omni-directional characteristics in horizontal region. The input impedance of the antenna gets the good matching characteristics with s_{11} parameter of about -26 dB, which shows the inductive reactance of 40.7+j0.14Ω. It is known that the antenna characteristics show the conventional λ/4 monopole antenna characteristics.

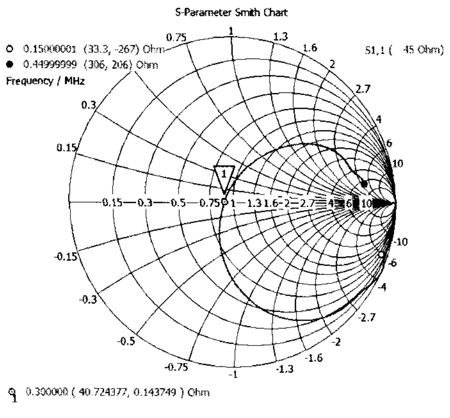
The radiation pattern and input impedance characteristics of the antenna on the hilly ground plane are shown in Fig. 4.



(a) Radiation pattern



(b) Return loss



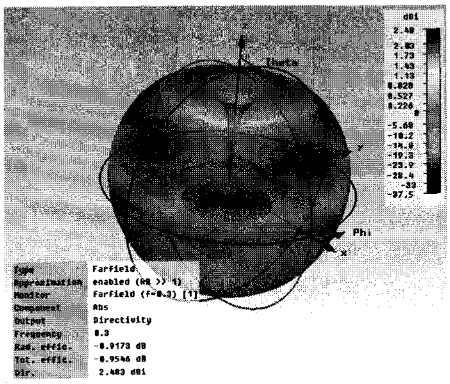
(c) Input impedance

Fig. 3. Performance characteristics of antenna on the general ground plane.

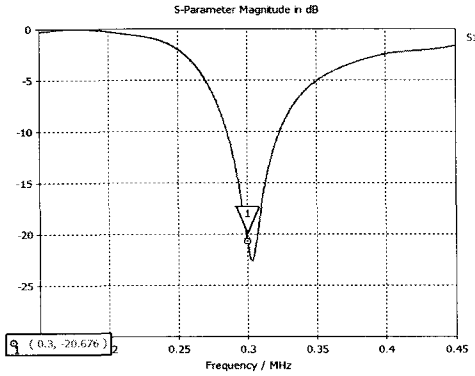
The radiation pattern of the antenna has the same symmetrical characteristics with that of the antenna on the general ground plane. Also, the antenna on the hilly ground plane shows a good matching condition.

However, the return loss is somewhat degraded than that of the antenna on the general ground plane. This is why the resistance component of the ground plane is increased by the conductivity of the hilly ground plane.

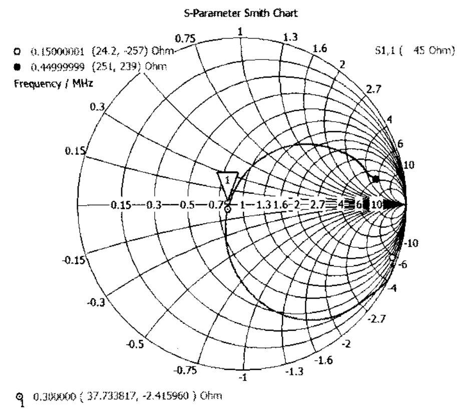
The input impedance of the antenna shows the capacitive reactance of 37.7-j2.42Ω.



(a) Radiation pattern



(b) Return loss

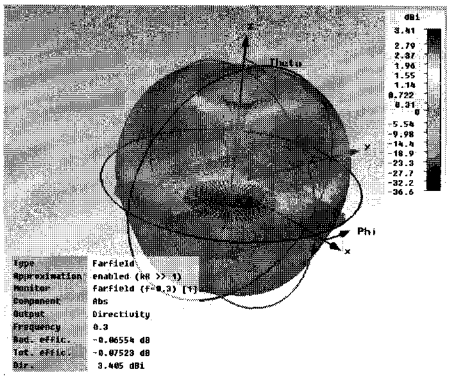


(c) Input impedance

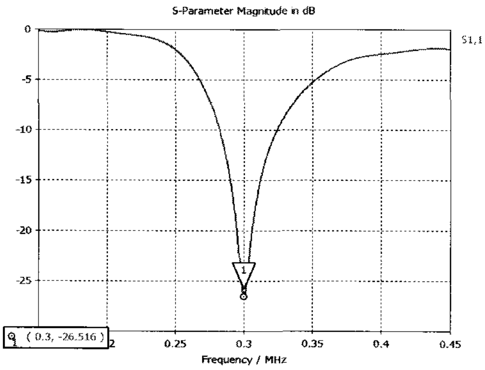
Fig. 4. Performance characteristics of antenna on the ground plane with hilly districts.

Fig. 5 shows the radiation pattern and input impedance characteristics of the antenna on the wet ground plane. The performance characteristics of the antenna on the wet ground plane are a good radiation pattern in omni-direction and matching condition(about -26.5 dB) like the others. The input impedance of the antenna shows the inductive reactance of 41.2+j1.39Ω.

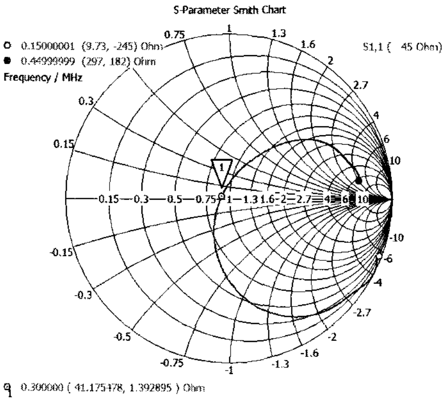
From Fig. 3 ~ Fig. 5, it is known that directivity of the antenna(2.48 dB ~ 3.41 dB in this analysis) is increased as the conductivity of the ground plane is high.



(a) Radiation pattern



(b) Return loss



(c) Input impedance

Fig. 5. Performance characteristics of antenna on the wet ground plane.

This is why the ground resistive loss is decreased as the conductivity of the ground plane is high. The efficiency of the antenna will be varied according to conductivity of the ground plane. It is clear that the MF antenna should be installed on the ground plane with a good conductivity.

The DGPS antenna may be constructed on the irregular ground plane or with obstacle. Fig. 6 shows the antenna layout with obstacle(mountain) near to the antenna. Also, Fig. 7 shows the cross-sectional view of the antenna with obstacle.

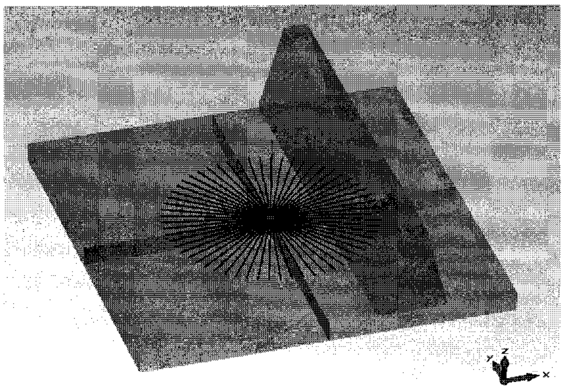


Fig. 6. Antenna layout model with obstacle(mountain) near to the antenna.

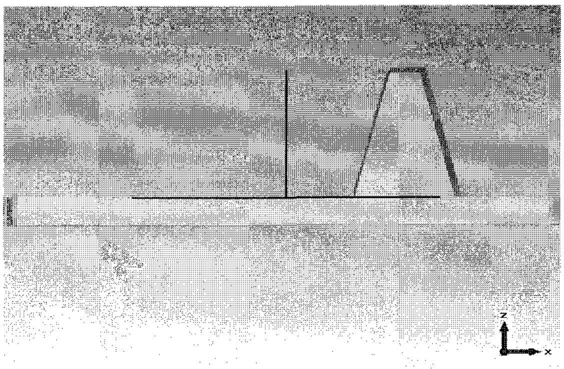
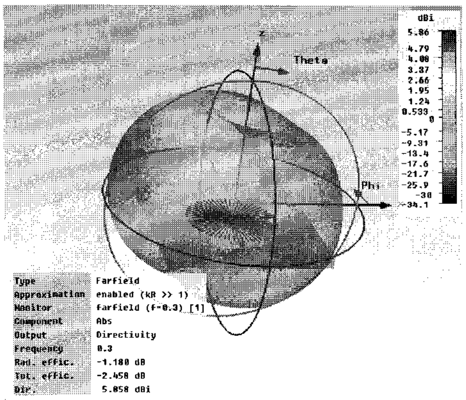
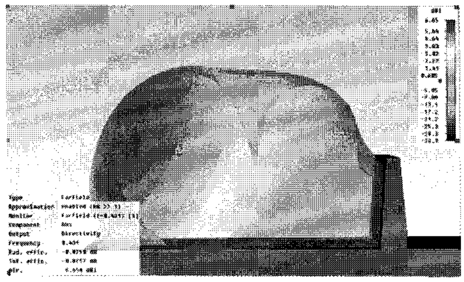


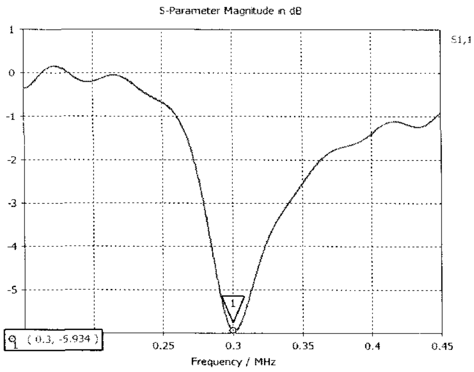
Fig. 7. A cross-sectional view of antenna with obstacle.

Fig. 8 shows the performance characteristics of the antenna with obstacle near to the antenna. The radiation pattern of the antenna shows asymmetric characteristics, which shows a radiation pattern of a directional antenna type. The major part of the radiation power is propagated toward the region opposite the obstacle. This is why the radiation pattern is affected by the reflection phenomenon from the obstacle near to the antenna.

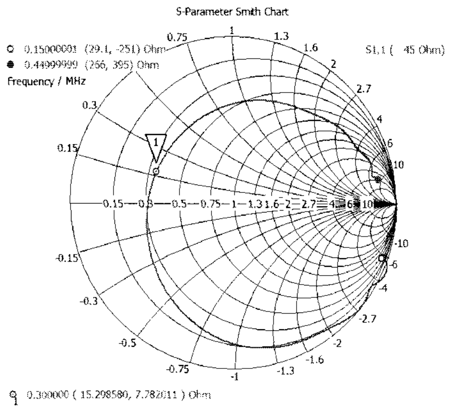




(a) Radiation pattern



(b) Return loss



(c) Input impedance

Fig. 8. Performance characteristics of antenna on the general ground plane with obstacle near to the antenna.

By the effects of the obstacle near to the antenna, the performance characteristics of the antenna are degraded from the conventional monopole antenna with a regular ground plane. The input impedance of the antenna becomes far from the matching point, so the return loss characteristic of the antenna is deteriorated. It may be difficult to get a proper matching condition because the input impedance of the antenna is inductive reactance with a large inductive component.

To get the good propagation characteristics, the MF antenna for DGPS reference station should be considered to get a flat ground plane with a high conductivity.

IV. CONCLUSIONS

The radiation characteristics of an equivalent MF antenna are analyzed in view points of the ground conductivity and the ground plane with obstacle near to the antenna. The antenna with enough radial ground plane gets a good performance characteristics as MF antenna, although the directivity of the antenna on the ground plane with a high conductivity is better.

The performance characteristics of the antenna installed on the irregular ground plane or with obstacle near to the antenna show the degraded characteristics than those of the conventional antenna. The MF antenna for DGPS reference station should be considered to get a flat ground plane with a high conductivity.

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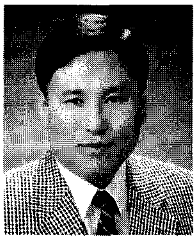

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