MEASUREMENTS OF MICROWAVE ABSORPTION DUE TO A LOSSY MEDIUM NEAR A DIPOLE ANTENNA USING A CYLINDRICAL NFM SYSTEM

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INTRODUCTION

Total radiated power from an antenna can be obtained by integrating an outgoing power over a surface surrounding the antenna. If there exists a lossy medium near an antenna, a part of the radiated power would be absorbed in the medium, which results in the decrease of the total radiated power. The absorbed power due to the medium is thus estimated as the difference between the total radiated powers with and without the medium. In recent years, absorption of microwaves radiated from a portable radiophone or other radio equipments with a human body has become a problem from a radiation hazard point of view. In this paper, we present a preliminary result of absorbed power estimation with a cylindrical scanning NFM technique.

MICROWAVE ABSORPTION MEASUREMENT USING CYLINDRICAL NFM

There are three major strategies of probe scanning for near field antenna measurements, i.e., planar, cylindrical and spherical scannings according to the shape of the surface over which electric fields from an antenna under test are measured and sampled. We developed a cylindrical scanning NFM system(1) by introducing an azimuth rotation function of an antenna under test to a planar scanning NFM system(2) developed previously. In a cylindrical system as shown in Figure 1, the cylindrical surface is covered with a probe for field detection by a vertical probe scanning and an azimuth rotation of an antenna under test. From the measured distribution of electric fields over the cylindrical surface, we can calculate the total radiated power by using the theory of Yaghjian(3), which is described briefly as follows.

An electric field $\mathbf{E}$ in a cylindrical coordinates (ρ, ϕ, z) can be expressed uniquely by the expansion coefficients $B_n^1(\gamma)$ and $B_n^2(\gamma)$ as follows:

$$\mathbf{E}(\rho,\ \phi,\ z)=\sum_{n=-\infty}^{\infty}\int_{-\infty}^{\infty}\{B_n^1(\gamma)\mathbf{M}_{n\gamma}+B_n^2(\gamma)\mathbf{N}_{n\gamma}\}d\gamma, \tag{1}$$

$$\gamma = k\cos\theta$$

where $\mathbf{M}_{n\gamma}$ and $\mathbf{N}_{n\gamma}$ are eigenvector functions of a cylindrical wave, and k and θ are the wavenumber and the polar angle measured from the vertical axis, respectively. The expansion coefficients can be derived from a measured electric field distribution $\mathbf{E}(\rho_0, \phi, z)$ over the cylinder, where ρ_0 is the radius of the cylinder, by inverse Fourier transforms with respect to ϕ and z. The total radiated power can therefore be calculated by using the expansion coefficients as follows:

$$P = \frac{1}{2Z_0}\int_0^{\pi}\int_0^{2\pi}|\mathbf{E}|^2 r^2 \sin\theta d\theta d\phi$$

$$= \frac{4\pi}{kZ_0}\sum_{n=-\infty}^{\infty}\int_{-k}^{k}\kappa^2\{|B_n^1(\gamma)|^2+|B_n^2(\gamma)|^2\}d\gamma, \qquad (2)$$

$$\kappa = k\sin\theta$$

where Z_0 is the characteristic impedance in a free space.

EXPERIMENT

In the experiment, we have used a half-wavelength dipole antenna as a radiation source, and a polyethylene tank of its capacity being 18 liters filled with salt water as a lossy medium. The distance between the antenna and the tank has been fixed to be about 10 cm throughout the experiment. An open-ended rectangular waveguide has been used as a probe for electric field detection. The measurement frequency has been 1.6 GHz. The length of vertical probe scanning has been 4 m and the horizontal distance between the probe and the axis of antenna rotation has been 0.69 m.

Prior to the measurements with the lossy medium, total radiation power from the dipole antenna has been measured as the reference. Then, the measurements have been continued for the antenna-lossy medium (tank) system, and the results have been compared with the reference total power. To check the influence of the tank itself, the measurement has also been made for the vacant tank. An example of the measurement data with the cylindrical NFM system is shown in Figure 2 for the case with salt water tank. It must be noted that the influence of the salt water tank can be clearly seen near the center of the figure. Table 1 summarizes the result of the total radiated power measurements. The results are normalized to the value for the case only with the dipole antenna.

Table 1. Comparison of total radiated powers from the dipole antenna and from the antenna-tank system. The values are relative to that for the case with dipole antenna only.

	Dipole antenna only	Dipole+vacant tank	Dipole+salt water tank
relative power	1 (0 dB)	0.98 (-0.09 dB)	0.88 (-0.58 dB)

It can be seen that the salt water tank causes decrease of total radiated power by 0.58 dB measured with the present cylindrical scanning NFM system.

DISCUSSION

Although the decrease of total radiated power has been detected using the cylindrical scanning NFM system, there would be some causes of the power decrease other than that due to the absorption with the salt water tank. Here we examine the possible two major causes, i.e., variation of the input impedance of the dipole antenna due to the presence of the salt water tank and scattering of the wave due to the salt water tank toward the top or bottom circular surfaces at which no measurement has been made in the cylindrical scanning NFM system. The measurements of VSWRs of the antenna with and without the salt water tank have at first made using a network analyzer. No significant VSWR variation has been recognized in the measurements, so that the presence of the salt water tank have not caused the variation of the radiated power from the dipole.

A half-wavelength dipole has a radiation pattern with its maximum in the normal direction to the element. In the present situation, the dipole has been oriented vertically, so that almost all of the radiation power (99.5 %) has been detected by the present NFM system of the vertical scanning length being 4 m and of the cylinder radius being 0.69 m. The extent of the antenna-tank system seen from the top or bottom surfaces of the cylinder is about 30 cm at the maximum. Provided that the system acts as an antenna excited uniformly, its beamwidth seen from the both surfaces would be approximately 36 degrees at 1.6 GHz. Since the vertical motion of the probe covered the angular range of ± 71 degrees measured from horizon, increase of the signal level must be detected at the top or bottom of the cylinder if the wave scattering is significant. But, we have recognized no difference between the two measurements with and without the salt water tank and the values themselves has been low. Thus, it can be said that there is no influence of scattering due to the salt water tank on the total radiated power measurement with the present cylindrical NFM system. Summarizing the above considerations, decrease of the total radiated power by 0.58 dB measured with the cylindrical NFM system would be considered to be due to the power absorption with the salt water tank placed near the dipole.

CONCLUSION

We have measured a microwave absorption due to a lossy medium placed near a dipole antenna with a cylindrical NFM system. The decrease of total radiated power by 0.58 dB was detected for the dipole antenna-salt water tank system. Since the other causes than absorption with the salt water tank are estimated to have no significant influence on the decrease of total radiated power from the system, it would be possible to conclude that the detected decrease in the total radiated power is due to the absorption with the salt water tank. The present result demonstrates the usefulness of a cylindrical NFM system not only for antenna characteristics measurements but also for radiation hazard problems.

REFERENCES

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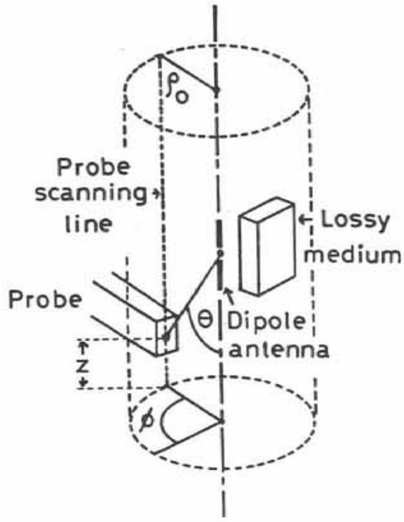

Figure 1. Configuration of a cylindrical scanning NFM system for microwave absorption measurements.

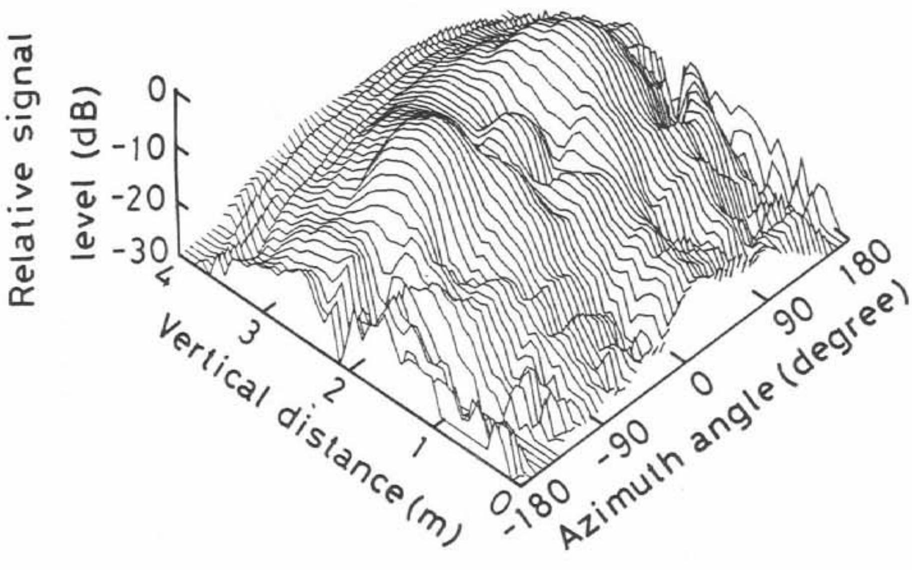

Figure 2. Example of the near field measurement data of the antenna-water tank system.