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Far field Antenna Factor Estimation for a Single Antenna Measurement Using Time Frequency Analysis

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Abstract - **We have already proposed a single antenna method for estimating an antenna factor of log-periodic dipole array antenna at 10 m antenna distance. In this paper, we apply a time-frequency analysis to suppress some undesired reflection waves for our single antenna method. And, we estimate the far field antenna factor using estimated antenna distance that determined by the time-frequency analysis. Further, we apply the antenna radiation center distance modified equation for estimate the far field antenna factor of log-periodic dipole array antenna. We show the result that compare with the estimated far field antenna factor and antenna factors using other methods. The estimated antenna factor by our proposed method has good agreement with far field gain that is less than 0.3 dB difference in the frequency range from 300 MHz to 1000 MHz at antenna height D= 5 m.**

Index Terms — **Antennas factor, log-periodic dipole array antenna, single antenna method, time-frequency analysis, time-domain analysis.**

I. Introduction

We have already proposed a single antenna method for an antenna factor estimation [1]. Our method makes it possible to measure separately the reflection wave at the ground plane and the intrinsic self-reflection wave of the antenna under test (AUT) using time-domain subtraction. However, our previous proposed method uses the fixed antenna distance. For this reason, main source of measurement uncertainty of far field antenna factor estimation is dependence of antenna distance. In order to decrease a measurement uncertainty, we propose a new estimation method for determining the antenna distance at each frequency that to estimate the far field antenna factor. Our proposed method is based on the techniques of a time domain analysis and a time-frequency analysis using a short time Fourier transform. This method can determined the antenna distance at each frequency. In this paper, we explain the single antenna method to estimate a free space transmission wave of a log-periodic antenna (LPDA), which is commercially available. Next, difference between the estimated antenna factor and a far field antenna factor using phase center modified Friis transformation is explained.

II. Single Antenna Method

First, we explain our method for the calibration of LPDA. The experimental setup is schematically shown in Fig. 1. All the measurements were made on the ground plane in a semi-anechoic camber. LPDA is used as an AUT. The antenna is set perpendicularly to the ground plane with the variable position from 1 m to 5 m high above it.

The reflection coefficient $s_{11}(\omega)$ is measured by a VNA in frequency- domain, and it is transformed to the corresponding time-domain reflection coefficient $s_{11}(t)$. $s_{11}(t)$ is calculated by the inverse Fourier transform $F^{-1}(\omega)$ with the Hamming frequency-domain window $W(\omega)$ as given by

$$s_{11}(t)= F^{-1}(W(\omega)\, s_{11}(\omega)) \quad (1)$$

The $s_{11}(t)$ consists of $s_{11\mathrm{intrinsic}}(t)$, $s_{11\mathrm{ground\_ref}}(t)$, and other undesired waves. The former is the intrinsic reflection by the internal structure of the antenna. The latter is the perpendicular incidence reflection wave at the ground plane. The other undesired reflection waves have undesired ambient reflection waves, such as antenna masts and so on [2]. The estimated time-domain waveform is shown in Fig. 2. To estimate free space antenna factor, we must pick up the reflection wave at perpendicular incidence from the ground plane. At first, we estimate the $s_{11\mathrm{intrinsic}}(t)$ by averaging $s_{11}(t)$ because the phase of $s_{11\mathrm{intrinsic}}(t)$ is invariant even if the position height is changed over the ground plane. On the contrary, the phase of $s_{11\mathrm{ground\_ref}}(t)$ is changing along the two-way propagation from the ground plane. By averaging $s_{11}(t)$ along with scanning the antenna perpendicularly, only the invariant component $s_{11\mathrm{intrinsic}}(t)$ remains and can be taken out from $s_{11}(t)$. That is, the invariant $s_{11\mathrm{intrinsic}}(t)$ appears at a constant delay time on time axis. Then we can get the direct reflection wave $s_{11\mathrm{ground\_ref}}(t)$ by subtracting the $s_{11\mathrm{intrinsic}}(t)$ out from the time-domain $s_{11}(t)$ as

$$s_{11\mathrm{ground\_ref}}(t)= s_{11}(t)- s_{11\mathrm{intrinsic}}(t) \quad (2)$$

Estimated $s_{11\mathrm{ground\_ref}}(t)$ is shown in Fig. 3.

III. Antenna Distance Determination Using Time Frequency Analysis

In order to determine the antenna distance $D=z(\omega)$ at each frequency, we calculate time-frequency response of

$s_{11\text{ground\_ref}}(t)$ using the short time Fourier transform (STFT) with hamming type time window. The time domain hamming window width is 20 ns. Number of Fourier transform is 8196. Then, we estimate the antenna factor from the estimated antenna distance using equation (3).

$$af^2(\omega,z)=\eta_0\cdot\left[Z_0\cdot\lambda_0\cdot D(\omega)\cdot s_{11\text{ground\_ref}}(\omega,z)\right]^{-1} \tag{3}$$

where η_0=120π Ω is the free space characteristic impedance, Z_0=50 Ω is the characteristic impedance of the coaxial cable and λ_0 is the free space wave length, respectively. $D(\omega)$ is the two-way distance from the radiation point of AUT to the ground plane. In the case of LPDA, $z(\omega)$ shows equation (4).

$$D(\omega)=z+2\times d_{1-f}-\lambda \tag{4}$$

Where, z is the two-way distance from the tip of AUT to the ground plane, d1-f is a distance between the tip of antenna and radiation point of LPDA.

Further, we show another far field antenna factor estimation method that uses antenna amplitude center location as equation (4) [3][4][5]

$$af_{\text{far}}^2(\omega)=\frac{\eta_0\cdot k_0}{Z_0}\left(\frac{1}{s_{21}(\omega,z_1)}-\frac{1}{s_{21}(\omega,z_2)}\right)\frac{1}{z_1-z_2} \tag{4}$$

where $af_{\text{far}}(\omega)$ is the far field antenna factor.

Figure 4 shows the difference between the far field antenna factor and estimated antenna factor using our proposed method, respectively. In the frequency range from 300 MHz to 1000 MHz, difference between far field antenna factor and estimated antenna factor using our proposed method of is less than 0.3 dB at antenna height D= 5 m.

IV. CONCLUSION

We propose a new method for estimating a far field antenna factor using single antenna method and time-frequency analysis for LPDA. The estimated antenna factor by our proposed method has good agreement with far field gain, that is less than 0.3 dB difference in the frequency range from 300 MHz to 1000 MHz at antenna height D= 5 m.

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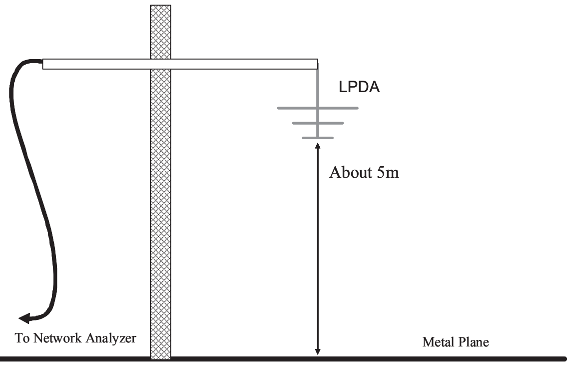

Fig. 1 Setup for the measurement of antenna factors using our antenna self-calibration method.

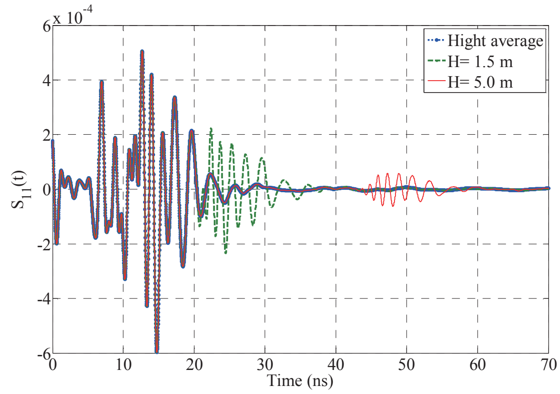

Fig. 2 $S_{11}(t)$ calculation results of LPDA.

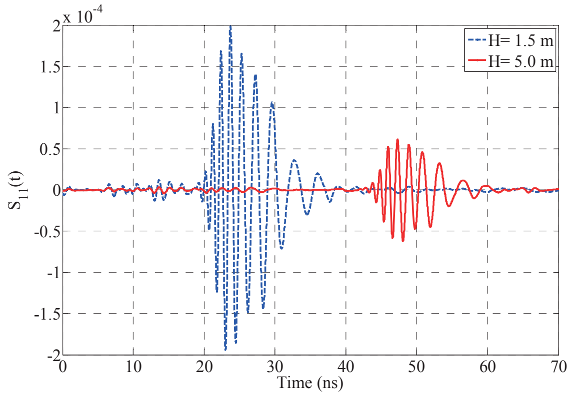

Fig. 3 Estimated $S_{11\_\text{ground\_ref}}(t)$ of LPDA

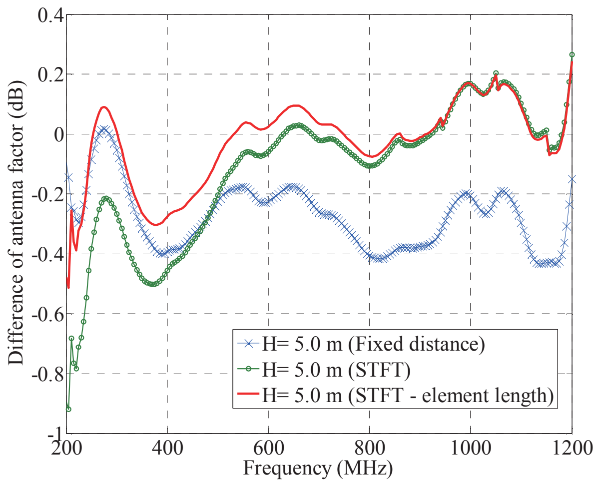

Fig. 4 Difference between estimated far field antenna factor and antenna factors using other methods.