EXPERIMENTAL STUDY OF SELF-CALIBRATION METHOD FOR LOG-PERIODIC DIPOLE ANTENNA

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1. Introduction

We propose a self-calibration method for antennas and examine it about a log-periodic antenna. The technique uses both the information obtained by the measurements in frequency- and time-domains in order to estimate the free-space antenna factor. The method is based on a time-domain data processing, which enables us to separate the self-reflected wave from the desired wave of the antenna under test (AUT) by a time gate in time-domain after Fourier transform.

At first we explain the measurement setup and secondly propose the technique to decompose the time domain data, which consists of the intrinsic self-reflection wave of the AUT and the ambient reflected waves from the ground plane and other structures. Then we can estimate the wide-band free-space antenna factor of the log-periodic antenna. To validate our proposed method, we compare our proposed time-domain method with that by time-domain three antenna method. These results indicate that our method can be used to estimate the free-space antenna factor in a semi-anechoic chamber, which is usually used for the EMI measurement.

2. Measurement setup and the measurement results

All the measurements are made in the NMIJ semi-anechoic camber with a ground plane. Log-periodic antennas of UHALP9108A1 are used as the AUT. The AUT is set perpendicularly to the ground plane above about 5m high. Frequency domain $S_{11}(\omega)$ is measured by E8356A (a vector network analyzer manufactured by Agilent Technology Inc). The measurement setup is schematically shown in Fig.1.

The time domain $S_{11}(t)$ is calculated by the inverse Fourier transform $F^{-1}(t)$ of the IMSL mathematical library and applying the Hamming type frequency-domain window $W(\omega)$ as given by

$$S_{11}(t) = F^{-1}(W(\omega) \cdot S_{11}(\omega)) \qquad (1)$$

The measured data of $S_{11}(\omega)$ in the frequency domain and its transformed $S_{11}(t)$ into the time-domain are shown in Fig. 2 and Fig. 3, respectively. The index [Free] in Fig. 2 and Fig. 3 means the

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$S_{11\text{intrinsic}}(t)$ measured in free space includes only the intrinsic reflection from the antenna structure itself.

The index [H=5m] in Fig. 2 and Fig. 3 indicates that the AUT is set about 5m high above the ground plane. In this case, the $S_{11}(t)$ includes the $S_{11\text{ambien\_ref}}(t)$ due to the ambient reflected waves on the ground plane and other structures in addition to the intrinsic reflection $S_{11\text{intrinsic}}(t)$. The $S_{11}(t)$ in Fig. 3 shows it is difficult to simply separate the free space $S_{11\text{intrinsic}}(t)$ from the $S_{11\text{ambien\_ref}}(t)$ representing the reflected wave on the ground plane only by a simple time gate, since they are closely overlapped to each other.

3. Antenna factor estimation

To estimate the free space antenna factor, we must take the ambient reflected waves $S_{11\text{ambien\_ref}}(t)$ out from $S_{11}(t)$. Then we propose to get the $S_{11\text{intrinsic}}(t)$ of the AUT in quasi free space by using an averaging technique. When the AUT height is changed, the intrinsic reflection $S_{11\text{intrinsic}}(t)$ from the antenna structure does not change because of no dependence on the surroundings. However the $S_{11\text{ambien\_ref}}(t)$ is varied and its phase changes in particular due to the distance to and from the ground plane in the case as Fig.1. Due to the phase variation it is useful to average the signals in order to separate these different reflecting signals. To average S_{11} with vertically scanning the antenna removes the reflection component from the ground plane but keeps the intrinsic reflection from the antenna structure at the same delay time. Then we can get the reflection component $S_{11\text{ambien\_ref}}(t)$ by subtracting the intrinsic component $S_{11\text{intrinsic}}(t)$ out from the time-domain $S_{11}(t)$ as follows

$$S_{11\text{ambient\_ref}}(t) = S_{11}(t) - S_{11\text{intrinsic}}(t) \qquad (2)$$

Fig.4 shows the time-domain waveforms. The index [Free] indicates the intrinsic reflection coefficient $S_{11\text{intrinsic}}(t)$ of the AUT. The index [Receive] indicates the estimated ambient reflection waveform. To calculate the antenna factor in frequency domain, the $S_{11\text{ambient\_ref}}(\omega)$ is necessary. It is calculated by the Fourier transform $F(t)$ of the IMSL mathematical library by dividing the Hamming window $W(\omega)$ in frequency-domain as given by

$$S_{11\text{ambient\_ref}}(\omega) = F\left(S_{11\text{ambient\_ref}}(t)\right)/W(\omega) \qquad (3)$$

Finally, we estimate the free space antenna factor $AF(\omega)$ obtained by [1]

$$AF(\omega) = \sqrt{\frac{\eta_0 \exp(-jkr)}{jZ_0 \lambda r S_{11\text{ambient\_ref}}(\omega)}} \qquad (4)$$

where $\eta_0 = 120\pi$ ohm is the free space characteristic impedance, $Z_0 = 50$ ohm the characteristic impedance of the coaxial cable, r the two-way distance from the tip of AUT to the ground plane, and $k = 2\pi / \lambda$ the free space wave number, respectively.

Fig.5 shows the estimated antenna factors. The curves indicated as [Proposed method] and [Three antenna method] show the obtained antenna factors by the proposed Self-Calibration method and by the time-domain three-antenna method [2]. They were measured in the semi-anechoic chamber and the open-area test site in NMIJ, respectively. In the case of the proposed Self-Calibration method, the result has a small undulation due to some undesired reflection from the absorbing materials in the semi-anechoic chamber.

Fig.6 shows the difference of these antenna factors. The small deviation shows good agreement of the [Proposed method] and [Three-antenna method] results within $\pm 0.9\mathrm{dB}$ over the range from 300 MHz to 1900 MHz. It is worth to note that deviation decreases from -0.15 dB to +0.7 dB in the range from 430 MHz to 1580 MHz. This result clearly shows the proposed method a new method of promise. It is the time-domain self-calibration method for free-space antenna factor estimation in the EMI semi-anechoic chamber.

4. Conclusion

We have proposed a self-calibration method for the estimation of the free-space antenna factor of a broadband antenna. The method is effective to evaluate a log-periodic antenna and so on, which are widely used in EMI measurement. The antenna factors obtained by the proposed and the three-antenna method are compared with each other. The difference is less than $\pm 0.9\mathrm{dB}$ from 300 MHz to 1900 MHz, though the estimated antenna factor by the proposed method has a little undulating deviation from the one by three-antenna method due to the undesired reflection waves from the surrounding absorbing material and others. This result clearly shows the propose method promising. That is, the proposed self-calibration method can be used for the estimation of free space antenna factors in the EMI semi-anechoic chamber.

We are planning to verify the proposed method further by applying the method for the measurements in the NMIJ open-area test site.

Reference

[1] S. Ishigami, H. Iida, T. Iwasaki, ``Measurements of complex antenna factor by the near-field 3-antenna method," IEEE Trans. Electromagn. Compat., vol. 38, no. 3, pp.424-432, Aug., 1996.

[2] S. Kurokawa, K. Komiyama, T. Sato,``Experimental Study of Antenna Factor Measurement for Log periodic Antenna with the Time Domain Method," Proceeding of CPEM2004, Tu4c23, pp.196-197, 2004.

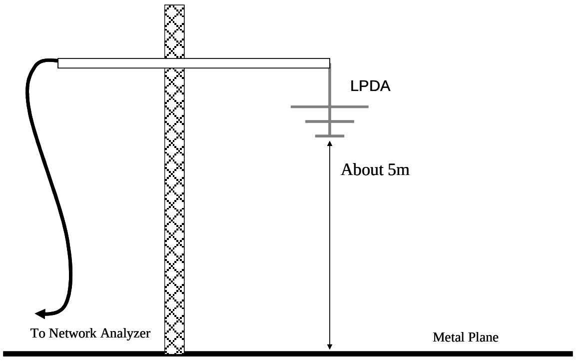

Fig.1 Setup for the measurement of antenna factors.

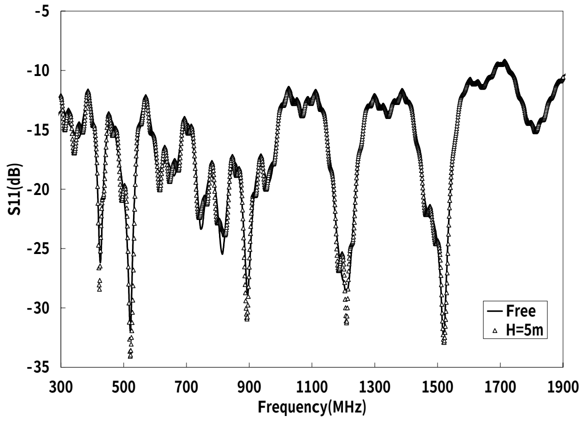

Fig.2 Measured spectral characteristic of the reflection coefficient $S_{11}(\omega)$ of a log-periodic antenna

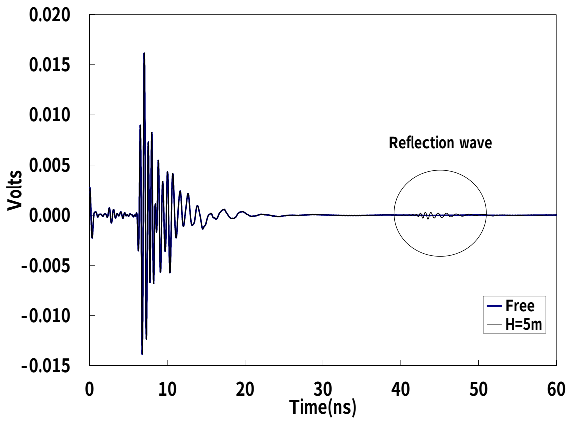

Fig.3 Time-domain scattering coefficient of $S_{11}(t)$. It is transformed from the spectral scattering coefficient.

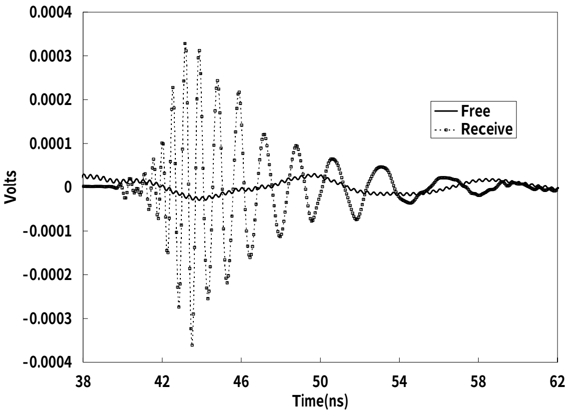

Fig.4 Estimated time-domain waveform of the wave reflected on the ground plane and from the antenna structure itself.

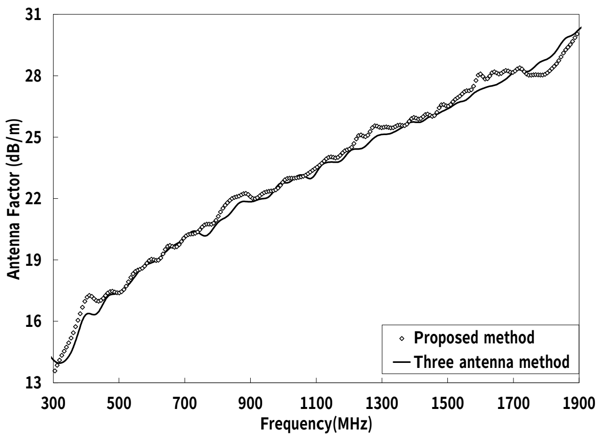

Fig.5 Comparison of free-space antenna factors estimated by the proposed method and conventional three-antenna method.

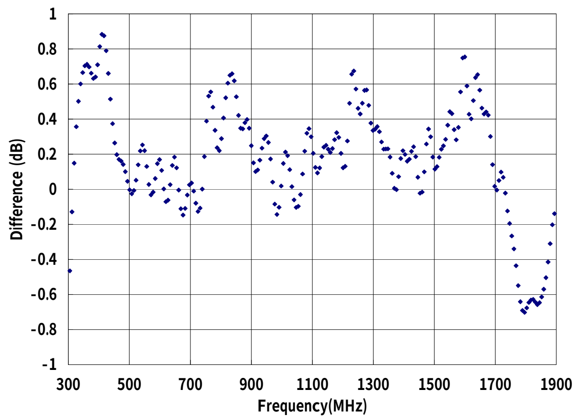

Fig.6 The deviation of the antenna factor by the proposed self-calibration method from the one by a conventional three-antenna method