EIRP Measurement of Base-Station Antenna Using Fresnel Region Measurement Method

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Abstract

We describe an EIRP measurement technique for base-station antenna using the Fresnel region measurement method. Base-station antennas installed in real environments unavoidably suffer far-field multipath interference, so the Fresnel region measurement method is optimal. We also apply a simple phase retrieval method for magnitude data obtained one-plane. The transformed far-field pattern agreed closely with the reference far-field pattern.

Keywords : Antenna Measurements, EIRP, ERP

1. Introduction

As wireless communication services with low power are developed, protection from high-power radiation devices and facilities such as base stations and digital broadcasting stations becomes important. The equivalent isotropically radiated power (EIRP) is generally used to restrict the radiation power from wireless devices or facilities. The EIRP measurement of base-station antenna installed in real environments is a major challenge. First, the type of measurement technique should be considered. Base-station antennas unavoidably bring multipath interference when they are measured in the far-field region, because of reflection from, for example, buildings, the ground, and trees. The near-field method seems to be a good alternative, but probes placed close to a base-station antenna could disturb communications and would have long scanning and processing times [1]. For these reasons, the Fresnel field measurement method [2-5] could be optimal for EIRP measurements of base-station antenna. Second, only magnitude data can be detected, because the base-station is in operation and the reference phase cannot be obtained. A phase-retrieval technique for near-field and Fresnel field [1,6] has been developed. In real situation for EIRP measurements, the data acquisition on two planes is difficult so that only one-plane phase-retrieval method can be applied. Here, a simple phase-retrieval method provided with the priori information is applied to EIRP measurement of a base-station antenna in an anechoic chamber.

2. Measurement Theory

The measurement scheme is illustrated in Fig. 1. The base-station antenna is fixed and the probe is moved with separation distance R_1. This is similar to the height-variation method [3]. As shown in Fig. 1, the movement trace of the probe is linear because the base-station antenna with dimensions $Lx \times Ly$ is elongated. This is why the Fresnel field measurement method is fast [3-5], and better than the near-field measurement method. As the probes moves linearly in the y-direction, the magnitude of the field is detected and compensated by $|E_{R1,compensated}|=|E_{R1,detected}|*(1+\Delta R/R_1)$ [3]. As shown in Fig. 1, the circled point means the detection position and its corresponding compensated field are marked by the dotted point. The differential angle $\Delta\beta$ is the angle between the first point, with n = 0, and the second point, with n = 1. It is determined by $\Delta\beta = \lambda/Ly$ [3], where λ is the wavelength. The number of required data N for one far-field direction is $N = L_y^2/\lambda R + 1$ for moderate accuracy and $N = L_y^2/\lambda R + 5$ for high accuracy [4]. Figure 1 shows the case N = 5 for $\theta = 0°$.
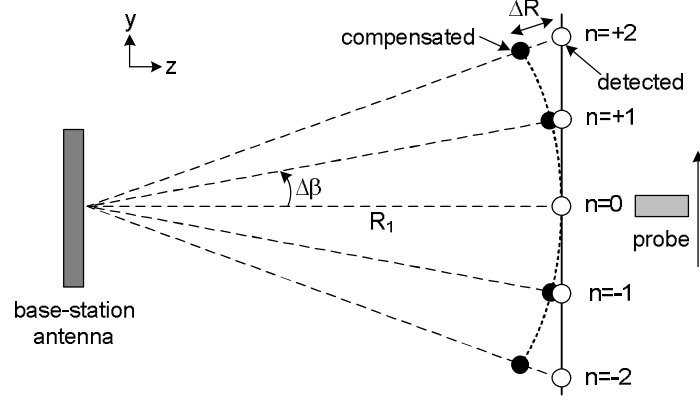
Figure 1: Measurement scheme, including detection and compensation.

The detected and compensated fields contain only the magnitude. The phase information also needs to be retrieved. In this paper, a fast, simple phase-retrieval technique is proposed, as follows:

(I) Estimate the complex distribution f(x,y) over the artificial aperture. The distribution is based only on the simple formula (1).

$$f(x, y) = \cos^p (c \times y),$$ (1)

where p and c is the tuning parameter. The base-station antenna is elongated, so variation along the y-direction is sufficient. The aperture is subdivided by $\lambda/8$ spacing, which has been verified to have an accurate results from our simulation and experimental results.

(II) Calculate the field at R_1 using

$$E_{R1} = \iint_S f(x,y) e^{+jk(x \sin a + y \cos a \sin b)} e^{-j\frac{p}{1R_1}(x^2+y^2)} dxdy,$$ (2)

where α is the angle from the y-z plane and β is the angle from the x-z plane.

(III) Compare between the calculated magnitude pattern $|E_{cal}|$ from (1) and the measured pattern $|E_{meas}|$ in the normalized value. The minimization factor is $\Sigma ||E_{cal}| - |E_{meas}||^2$.

(IV) If the two patterns agreed over the lower level range to within 15 dB, determine the phase distribution at R_1 by the calculated phase pattern from (1). If not, go back to procedure (I) and adjust the parameter p, and repeat procedures (2) and (3).

Since the simple formulas of (1) and (2) are utilized, the proposed phase-retrieved technique can be fast. However, one might think that the formula of (1) is too simple to estimate the field distribution over the aperture. Practically, however, the information for base-station antenna such as beam pattern and gain is already submitted to the organization of examination. So, the database of formula such as (1) could be utilized.

The measured magnitude and retrieved phase value at R_1 are inserted into (3), and transformed into the far-field value, which results in P_{R2} [5].

$$E_{R_2} = \frac{R_1}{R_2} e^{-jk(R_1-R_2)} \sum_{n=-N}^{+N} k_{mn} E_{R_1}(b + n\Delta b),$$ (3)

where k_{mn} is Fourier coefficient.

Now, EIRP is directly calculated by EIRP = $P_{R2}/G_{probe} \times (4\pi R_2/\lambda)^2$, where G_{probe} is the gain of the receiving probe.

3. Experimental Results

The base-station antenna for the Personal Communication Service (PCS) was chosen because of testing convenience. The frequency was set to 1.8 GHz, and its dimensions were 0.15 m

× 0.6 m in the x- and y-directions, respectively. The measured far-field gain was G_t = 13.65 dBi. The field detecting probe was designed with a tapered slot antenna, and the gain was G_{probe} = 9.21 dBi. Figure 2 shows a photograph of the experiment with separation distance of R_1 = 0.6 m between the base-station antenna and the probe. The input power to the base-station antenna was P_t = 6.7 dBm. The exact EIRP from EIRP = $P_t \times G_t$ was thus 20.36 dBm.

The magnitude field is detected and then compensated as shown in Fig. 3(a). The phase-retrieval technique described in previous section was performed. After several iterations for the parameter p and c in (1), the final value was p = 1 and c = 0.8. The calculated retrieved-magnitude field is compared to the measured field as shown in Fig. 3(a). They almost agree over the 15 to 0 dB (-40° to +40°) range. The retrieved phase is plotted in Fig. 3(b). This was used for the transformation from the Fresnel field at R_1 = 0.6 m to the far-field at R_2 = 4.7 m.

The transformed far-field pattern, P_{R2}, is shown in Fig. 4. For comparison, the far-field pattern acquired in the far-field chamber is also shown in Fig. 4. The normalized patterns agreed closely over the range θ = -20° to +20°. The disagreement outside this range was due to the lack of Fresnel-field, caused by the scanning limitations in the y-direction. The P_{R2} at θ = 0° was -22.12 dB, so that EIRP = 19.66 dBm. The difference between the transformed and reference EIRPs was 0.69 dB. This is a slightly large error. From the simulation results, the error was only 0.2 dB, so we can estimate that this difference includes errors from the probe, receiving power, and the reference EIRP.

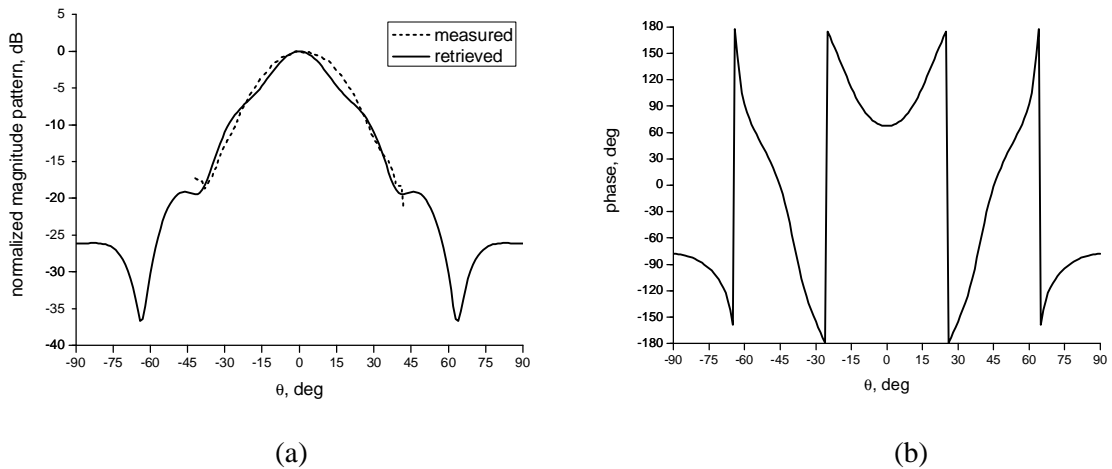Figure 2: Photograph of experiment in the anechoic chamber.

(a)

(b)

Figure 3: Comparison between the measured and calculated patterns. (a) magnitude (b) phase
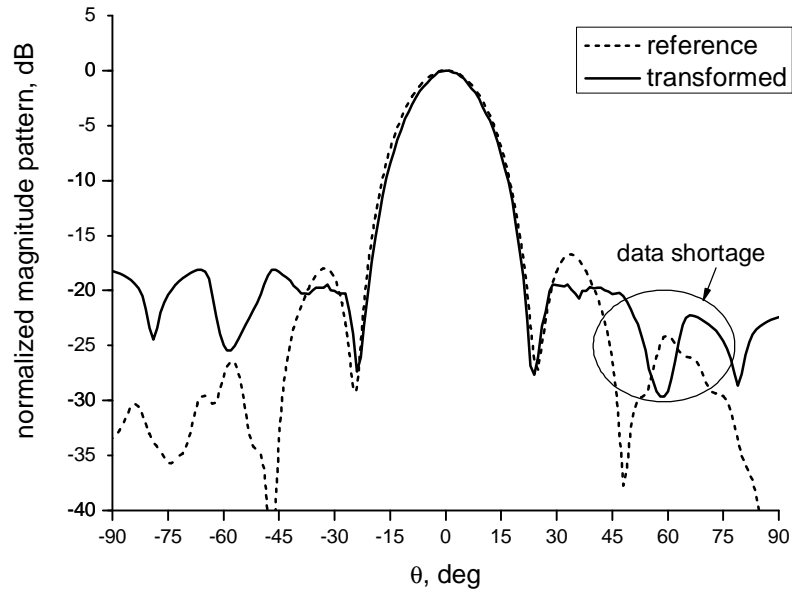
Figure 4: Transformed and reference far-field patterns.

4. Conclusion

We describe an EIRP measurement technique for base-station antenna. A Fresnel region measurement method was chosen to remove multipath interference and to shorten the processing time. A simple phase-retrieval technique provided with the priori information is proposed, so that the data acquisition on only one-plane is required. The transformed far-field pattern agreed closely with the reference far-field pattern. The proposed phase-retrieval technique is expected to be applicable to measurements of various elongated antenna.

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