On the Field Measurement of a Highly Efficient Reflectarray Antenna Using Electromagnets

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***Abstract*—This paper introduces a measurement on a highly efficient reflectarray antenna using electromagnets. Since the reflectarray antenna under test is electrically large, conventional measurement in an anechoic chamber is not available and field measurement is required. To eliminate the reflection interference from the ground, two approaches are proposed and utilized in the measurement. As a result, by simultaneously applying both methods, the measurement error is improved around 2.5 dB. This work provides another option to measure the reflectarray antenna with comparatively lower cost without significantly sacrificing the percision and accuracy.**

***Index Terms*—Reflectarrays, Electromagnets, Magnetostatics, On-off control**

I. Introduction

A reflectarrays (RAs) is a promising antennas with a surface composed of array elements whcih are excited by a primary source. The RA antennas are firstly investigated as an array of bulky waveguides [1]. After this, RAs now envolved into planar [2]- [7], multi-layered [8], [9], and 3D-printed configurations [10]- [13], as well as combinations with phased arrays [14]- [15].

Usually the RA antennas are measured in a anechoic chamber whereas wave scattering on the wall can be eliminated. To validate the beam scanning ability of RA antenna, it is common that the aperture of the RA surface is intentionally designed to be as large as possible. However, such measurement would then require large anechoic chamber in order to fullfill the far-field measuring condition (i.e. $d \gg 2D^2/\lambda$). Another alternative is to use compact range system to convert spherical wave into plane wave. Both methods are expensive in the device, thus most of the work were measured in a near-field condition. Therefore, field measurement become an option to measure the beam-forming performance in an outdoor environment.

This work is an extension of our previous work [16]. In this paper, we introduce the field measurement of a highly efficient RA antenna system using electromagnets. The experiment set-up and measuring process are discussed in detail. Two approaches are proposed to decrease the ground reflection and improve the precision of the results. In the end, the results are analyzed quantitatively to estimate the overall error.

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II. Field Measurement Set-up

The antenna under test (AUT) is a highly efficient 1-bit RA antenna, with its dimension around 7.33λ in x-direction and 5.83λ in y-direction ($lambda$ is at frequency of 4.4 GHz) [16]. To demonstrate the high efficiency feature of the RA antenna, it is important to ensure the measurement validity. To measure the radiation pattern of the RA antenna over its xoz-plane, the receiver antenna should be placed at least 4.2m away from the geometry center of the AUT. However, this distance is unavailable due to the laboratory condition. A field measurement is then proposed to measure the AUT in an outdoor environment.

The measurement set-up is shown in Fig. 1. In the outdoor field measurement, a major interference is caused by the reflection from the ground plane. The ground reflection has a vector relation with the desired direct wave emitted from the AUT, and can be in phase or out of phase. When the ground reflection is in phase with the direct wave, the received wave strength will be larger then the real value, and when the ground reflection is 180° out of phase, the received wave strength will be declined.

To improve the ground reflection, two approaches are taken into consideration. The first one is to place EM absorbers at the specular reflection point between the AUT and the receiver antenna. This method is aim to decrease the specular reflection intensity. Another approach is to utilize the vector network analyzer (VNA) time gating function. By enabling the time gating function, the ground reflection wave can be filtered in the time domain, thus raise the precision of the measurement.

III. Field Measurement Results

To demonstrate the ground reflection intensity to the direct wave, so-called height pattern is measured and shown in Fig. 2. The transmission coefficient S21 is plotted with respect to the height H, which is a relative height of AUT. The receiver antenna's height is adjusted along with height H, so that the phase center of the receiver antenna is always horizontally aligned with the geometry center of the AUT. The height is varied for 200 mm (2.93λ at 4.4 GHz).

The results show a standing wave like distribution of S21 over the height H, which is within the expectation that the ground reflection has a vector relationship with the direct wave. Without any reflection eliminating approaches, the

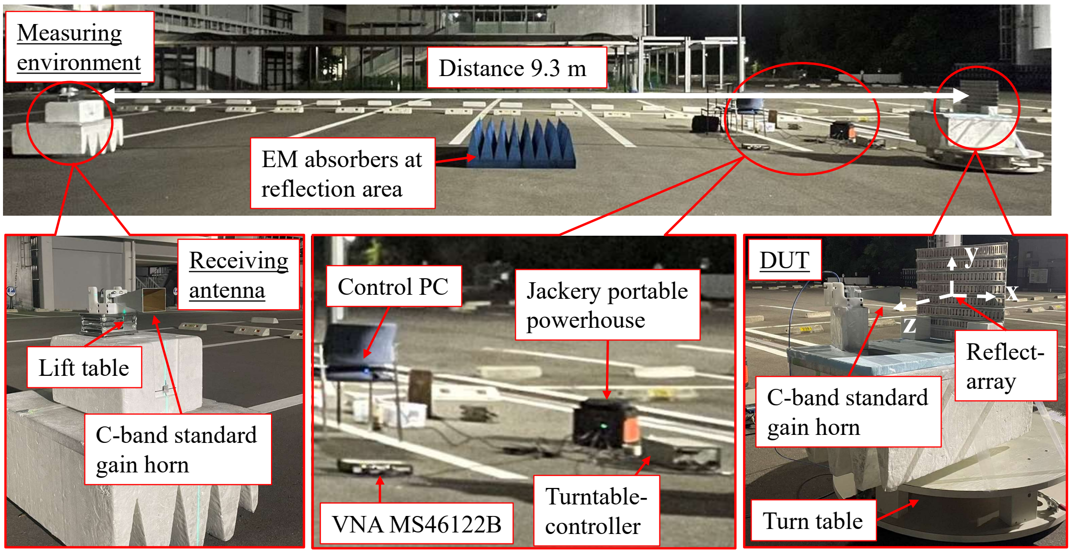

Fig. 1: Demonstration of field measurement set-up for measuring proposed RA antenna system at outdoors environment. Located at Aobayama campus, Tohoku Univ., Sendai city, Miyagi, Japan.

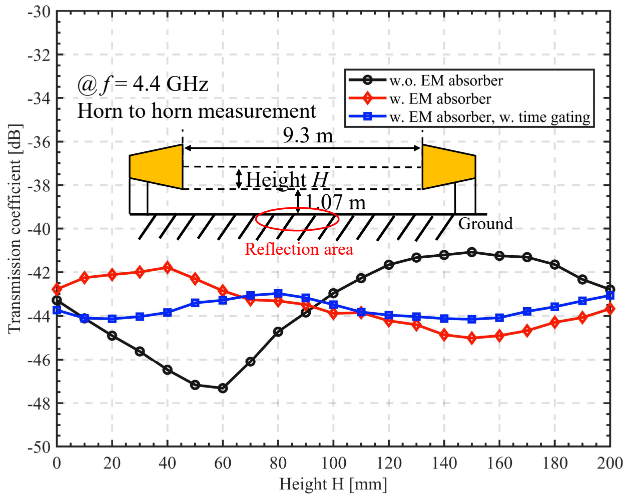

Fig. 2: The transmission coefficient between AUT and receiving antenna with respect to height H.

transmission coefficient S21 suffers a variation around ±3 dB. By placing EM absorbers at specular reflection point of AUT and Receiver antennas, the variation decrease to ±1.5 dB. Based on the results of using EM absorbers, by turning on time gate function, the variation decrease to ±0.5dB, which is an acceptable value that the total error is improved by around 2.5 dB. By taken the mean value of the height pattern data, the gain pattern of the AUT can be measured to be around 22.7 dBi. It can be concluded that both method are valid in improving the ground reflection brought by the field measurement.

IV. Conclusion

In this paper, we have introduced the field measurement on a highly efficient RA antenna. To eliminate the reflection interference from the ground, two approaches were proposed and utilized in the measurement. As a result, by applying both methods, the measurement error was improved around 2.5 dB. This work provided another option to measure the RA antenna with comparatively lower cost without significantly sacrificing the percision and accuracy.

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