Design of Reflectarrays Focusing on Near-Field Region Using Method of Moments

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***Abstract*—In this paper, reflectarrays focusing on near-field region are designed. Differential spatial phase delay between reflectarray elements is compensated so that scattering fields from the reflectarray elements are in-phase at the focal point. Numerical simulation is performed using in-house code of method of moments (MoM) and the scattering performance of the designed reflectarrays is demonstrated.**

***Index Terms*—Reflectarray, Near-field, MoM**

I. Introduction

According to recent advancements of wiress communication systems, high frequency band such as millimeter-wave band has been explored. One of the challenging problems on the wireless communication systems using the millimeter-wave band is to eliminate a coverage hall. In order to eliminate the coverage hall, beam scanning capability is necessary for antennas of the wireless communication systems using the millimeter-wave band.

Reflectarrays are promising techologies for beam scanning because their mainbeam can be directed to a specific angle [1]-[3]. Reflectarrays are composed of a lot of elements and are illuminated by incident wave from a primary source. The reflectarray elements are designed so that their scattering fields are in-phase at a specific direction. In previous studies, it has been demonstrated that reflectarrays are applicable to eliminating the coverage hall [4], [5].

Although numerous reflectarrays have been developed so far, most of those reflectarrays are expected to focus its mainbeam in far-field region. On the other hand, reflectarrays for the wireless communication systems using the millimeter-wave band are expected to be high gain in order to compensate high propagation loss in free-space. As a result, size of the reflectarrays becomes large and the reflectarrays must focus its mainbeam in near-field region.

In this paper, reflectarrays focusing on near-field region are designed. Reflectarrays are designed so that differential spatial phase delay between reflectarray elements is compensated using exact spacing between reflectarray elements and a specific focal point, not an array factor. Scattering performance of the designed reflectarrays is demonstrated using the MoM.

II. Design of Reflectarrays

In advance of designing reflectarrays, reflection coefficient of reflectarray elements is obtained. The reflectarray element is a planar dipole element backed by an infinite ground plane. The reflection coefficient of reflectarray elements is obtained

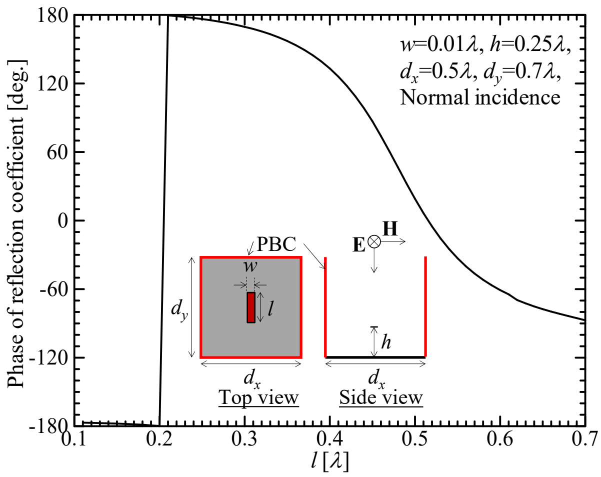

Fig. 1. Reflection coefficient of planar dipole element backed by ground plane.

using the MoM with periodic Green's function (PGF) [6], [7] Poor convergence of the PGF is improved using Ewald transformation with the optimum splitting parameter [8]-[10]. Singularity at a source point is annihilated using L'Hospital rule [11], [12]. Rao-Wilton-Glisson (RWG) basis function is used as basis/testing functions [13].

Simulated phase of the reflection coefficient of the planar dipole element backed by the infinite ground plane is shown in Fig. 1. It has been demonstrated that the phase of the reflection coefficient varies as the length of the planar dipole element varies. Variation of the phase is approximately 280 deg.

According to the simulated reflection coefficient, reflectarrays focusing on near-field region are designed. Fig. 2 illustrates the conventional and proposed design method of reflectarrays. Reflectarrays focusing on far-field region are designed so that scattering fields of reflectarray elements are in-phase at a specific angle. An array factor is applicable to express the differential spatial phase delay between reflectarray elements because scattering fields of the reflectarrays are focusing in the far-field region. On the other hand, reflectarrays focusing on the near-field region are designed so that scattering fields of reflectarray elements are in-phase at a specific focal point. The array factor is inapplicable to express the differential spatial phase delay between reflectarray elements because scattering fields of the reflectarrays are focusing on

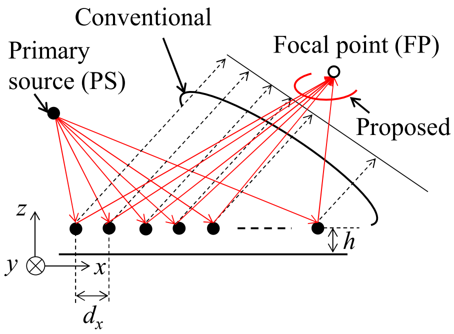

Fig. 2. Conventional and proposed design methods of reflectarrays.

the near-field region. Therefore, the differential spatial phase delay between reflectarray elements is obtained using exact spacing between reflectarray elements and the focal point in the proposed method. According to the phase of reflection coefficient shown in Fig. 1, length of the planar dipole element is tuned so that scattering fields of reflectarray elements are in-phase at the focal point.

III. Scattering Performance of Designed Reflectarrays

According to the proposed design method, 21×21 reflectarrays are designed using the proposed method and their scattering performance is demonstrated numerically. Full-wave simulation of the designed reflectarray has been performed using the MoM with layered media Green's function (LMGF) in order to model an infinite ground plane efficiently [14]. Direct wave component from the source is extracted from Sommerfeld integral and evaluated in the spatial domain so that the poor convergence of the LMGF is improved [15], [16]. Sommerfeld integral is evaluated in advance of the numerical simulation and interpolated using Taylor expansion [17], [18]. Asymptotic expansion of Bessel function is also used in order to reduce computational cost of the Sommerfeld integral. RWG basis function is used and singularity at a source point is annihilated using coordinate transformation and analytic integral [13], [19], [20].

Simulated near-field distribution of the reflectarrays is shown in Fig. 3. It is demonstrated that the reflectarrays designed by the proposed method are able to focus on the focal point whereas those designed by the conventional method just focus on broadside direction in far-field region. Therefore, it can be said the reflectarrays focusing on the specific focal point in the near-field region should be designed using the proposed method.

IV. Conclusions

In this paper, reflectarrays focusing on the near-field region have been designed and their scattering performance has been demonstrated numerically using the MoM. According to the results of numerical simulation, it has been demonstrated that the scattering field strength of the reflectarrays designed using the proposed method is much higher than that using the conventional one.

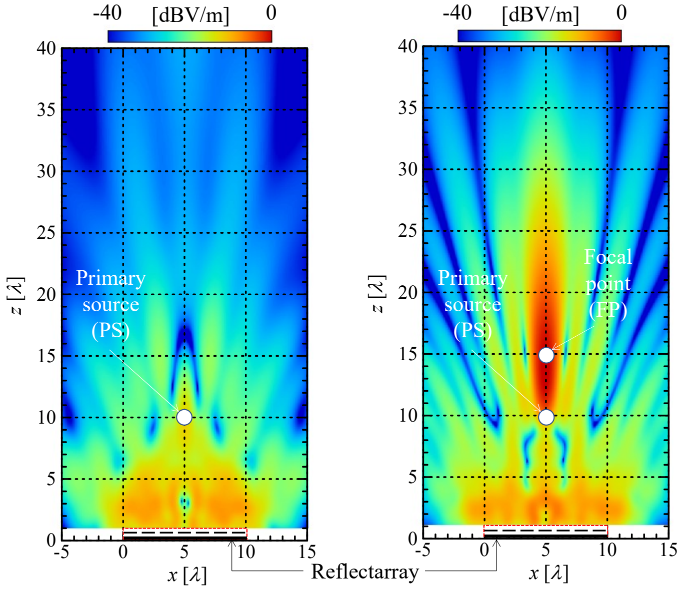

Fig. 3. Near-field distribution of designed reflectarrays (Left: Reflectarrays focusing on broadside direction in far-field region, Right: Reflectarrays focusing on a specific focal point, $y = 7\lambda$, E_y components).

Acknowledgment

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