

Fundamental Study on Computational Microwave Imaging Using Conducting-Reflector-Backed Dipole Metasurface

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Abstract – In this paper, the distribution of elements of a conducting-reflector-backed dipole metasurface (CRBDM) for computational microwave imaging (CMI) to enhance the frequency-diversity and orthogonality between measurement modes is studied. The CMI system requires diverse measurement patterns, which can be generated by placing the CRBDM behind the target and altering patterns of excited elements. A comparison of near-field patterns and characteristics of distributions of elements for enhanced frequency-diversity and orthogonality between measurement modes are presented in this report.

Keywords — Computational microwave imaging, Metasurface, Near field, Reflection, Frequency diversity.

I. INTRODUCTION

Microwave imaging gathers great interest for a wide range of applications since microwaves can propagate through optically opaque materials and achieve high resolution [1][2]. These technologies conventionally rely on mechanical or electrical scanning [3][4] and suffer from long data acquisition time and hardware complexity.

Computational Microwave Imaging (CMI) has emerged as an alternative to conventional imaging systems since it allows to overcome these drawbacks.

In the CMI, it is necessary to illuminate the target by diverse measurement patterns to multiplex the information. A key study in this framework is therefore to enhance the diversity of measurement modes [5].

We propose a novel imaging scheme with a conducting-reflector-backed dipole metasurface (RBDM) which controls the excitation of its dipole elements by diode switching. Fig 1 describes the concept of this scheme. A CRBDM is placed behind the target and the patterns of excited elements are varied. The reflection fields from the target scene and CRBDM are measured. The shape of the target is estimated from the equivalent current distribution by solving the inverse matrix problems. It is possible to multiplex the information since it can illuminate the target with diverse measurement patterns.

In this paper, we describe the characteristics of distribution of elements for the enhanced frequency-diversity and orthogonality between measurement modes by comparing the near-field simulation results of several CRBDMs.

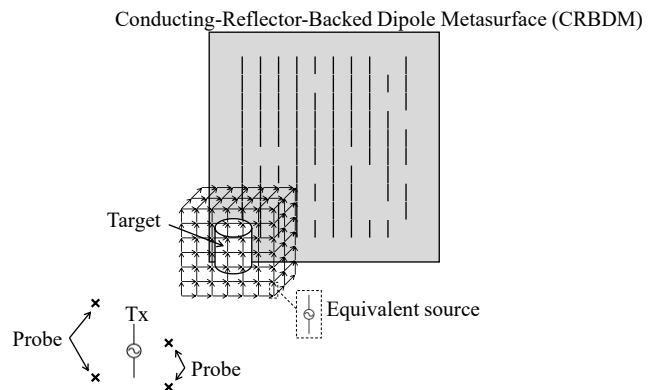


Fig. 1. Concept of the proposed imaging scheme.

II. GEOMETRIES OF DIPOLE ARRAYS

We studied four different dipole arrays shown in Fig.2. Elements with no excitation were removed in this study. Based on a 10x10 dipole array (Full array, Fig.2(a)), a horizontal asymmetric array with elements on the right side removed (right-trimmed array, Fig.2(b)), asymmetric array with elements at the center removed (center-trimmed array, Fig.2(c)) and a vertical and horizontal asymmetric array with elements randomly removed (random-trimmed array, Fig.2(d)) were compared. The number of elements in arrays (b)-(d) is 84.

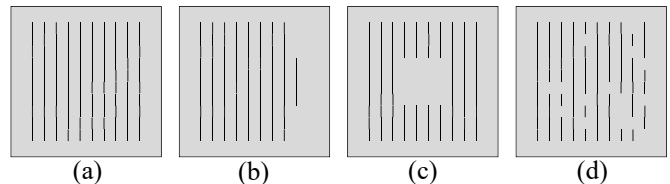


Fig. 2. The studied 10x10 dipole arrays. (a) Full array. (b) Right-trimmed array. (c) Center-trimmed array. (d) Random-trimmed array.

III. SIMULATION RESULTS

The near-field pattern of (a)-(d) when a half-wavelength dipole was used as transmitting antenna (Tx) were compared. The frequencies considered are 18-26 GHz, and the Tx

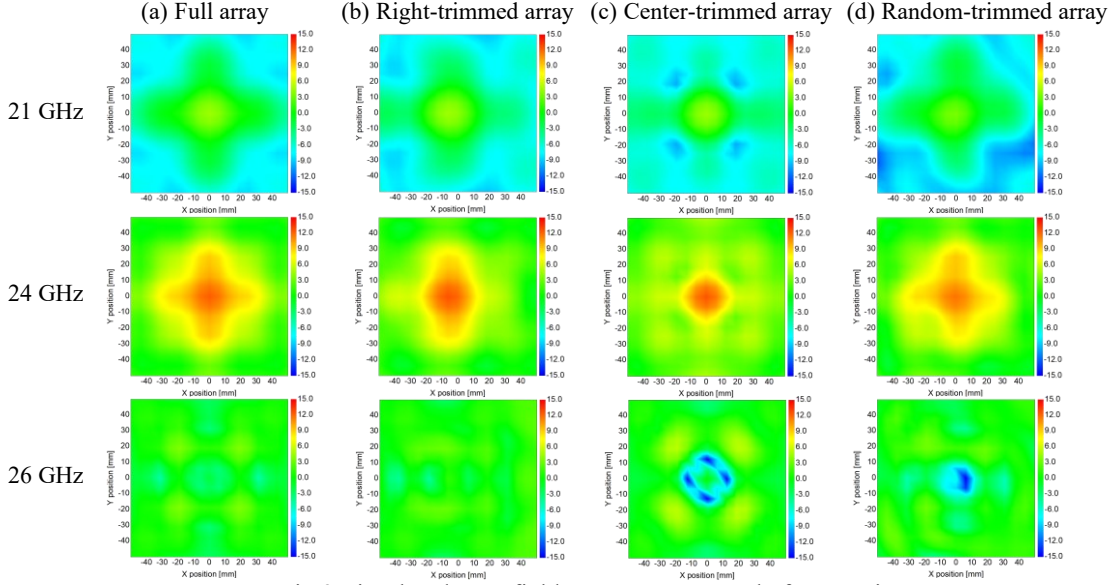


Fig.3 Simulated near-field patterns at example frequencies.

antenna was $50\lambda_0$ away from the CRBDM, where λ_0 is the wavelength at 24 GHz. The reflector was assumed to be infinite, and the field patterns were computed using method of moments (MoM). Fig.3 shows the near-field patterns of $8\lambda_0$ away from the CRBDMs. The field patterns of (a) and (c) are each symmetric due to symmetric dipole arrays, whereas the patterns of (b) and (d) are opposite. The frequency variation of the field patterns of (a) and (b) are relatively similar, whereas those of (c) and (d) are each different.

To evaluate the orthogonality of each measurement modes, SVD analysis was conducted. The SVD patterns of each CRBDM are shown in Fig.4. The flatter SVD curve indicates high orthogonality between indexes of eigen values, resulting in a larger number of effective measurement modes for a given signal-to-noise ratio (SNR). A large difference in the SVD curve indicates low correlation. The SVD patterns of (d) are obviously flat compared to those of (a)-(c) at all frequencies. For example, the effective measurement modes of (a)-(d) for SNR = 30 dB at 24 GHz are 5,6,6 and 10, respectively. In terms of the correlation between frequencies, the SVD patterns of (a) and (b) are similar. In contrast, the SVD patterns differences over frequencies are small in (c) indicating high correlation between frequencies, whereas the SVD pattern differences are large in (d) indicating low correlation between frequencies. These results show that it is possible to enhance the frequency-diversity and orthogonality between measurement modes with vertical and horizontal asymmetric distributions of elements.

IV. CONCLUSION

In this paper, the distributions of elements for CRBDM to enhance frequency-diversity and orthogonality between measurement modes were studied. It was found that the vertical and horizontal asymmetric distributions of elements caused the improved frequency-diversity and orthogonality between measurement modes.

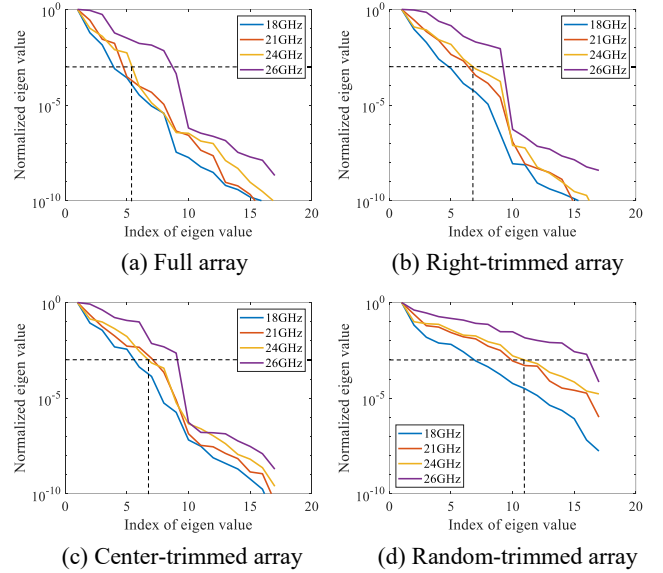


Fig. 4. Comparison of the SVD patterns.

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