概要

Inflation theory predicts that primordial gravitational waves generate B-mode polarization pattern of the cosmic microwave background (CMB). *LiteBIRD* is a space-born telescope mission to observe CMB polarization with the goal of detecting B-mode polarization. *LiteBIRD* employs a crossed Dragone antenna cooled to 5 K to reduce thermal noise. It is also equipped with thousands of transition edge sensor bolometers, enabling wide-field (9×18 deg) and broad-frequency ($34 - 448$ GHz) observations. Previous observations by Planck have shown that stray light caused by radiation from the Galactic plane entering the telescope from outside the field of view constitutes a significant source of systematic error in CMB polarization observations. It is because that characterization of telescope antenna patterns for each detector, including far sidelobes at -60 dB level, is required.

Vector near-field measurements are effective for evaluating antenna patterns inside the cryogenic chamber, taking advantage of the compact configuration and the absence of a vacuum window. This method requires measurement of both the phase and amplitude of the electric field on the aperture plane. To use the near-field measurement technique, bolometers, which are insensitive to phases, have been replaced with heterodyne receivers. However, when bolometers are replaced, the measured antenna patterns differ from that of the whole telescope system, because the effects of the orthomode transducer and impedance mismatches between heterodyne receivers and bolometers are not included. Moreover, replacing all detectors in a bolometer array is impractical due to constraints on space and thermal load.

To perform near-field measurements for all bolometers we have developed a phase-retrieval method, referred to as "Phase Steps Holography with Integrated Detectors (PSH-id)". which uses three holograms, which are interference fringes, with a reference wave emitter that is positionally fixed relative to the detector (i.e., path-invariant). The proposed method enables near-field measurements of antenna patterns for telescopes equipped with detector arrays that are insensitive to phases, such as bolometers and kinetic inductance detectors.

We demonstrated that no adjustment is necessary for the phase steps, and that the phase combination is robust, which is crucial for broadband applications. In our experiments conducted at $140 - 220$ GHz with a crossed Dragone antenna, we compared the antenna patterns obtained from retrieved complex electric field of the aperture plane with those from vector near-field measurements. These antenna patterns in the sidelobes were consistent at the -60 dB levels in the far field. These experiments were also performed for three cases of different detector locations on the focal plane to demonstrate the wide-field capability. We also compared our results with those of the previous holography work based on time-domain filtering instead of phase steps.