Preliminary analysis to design C-band polarimetric phased array weather radar

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Most of the severe phenomena, such as a tornado and a downburst, are caused by locally generated cumulonimbus cloud in a short time (i.e. 10 min). In order to observe the evolution of the inner structure of the cloud that changes on a scale of several minutes, a weather radar with higher spatiotemporal resolution is needed.

The X-band (9.4 GHz) phased array weather radar (PAWR) at Osaka University, which has been operated from 2012, that has high temporal resolution (30[sec]) and high spatial resolution (100[m]) has been already under operation in Osaka area, Japan. The PAWR is a single polarization radar. Therefore, the accuracy of rainfall estimates of the PAWR is lower than that of the parabolic shape radar using dual polarized wave, which is generally called a polarimetric weather radar, although the PAWR is far superior in spatiotemporal resolution.

A weather radar with polarimetric observations can provide multi-parameter measurements that reveal detailed microphysics of storms in addition to accurate precipitation estimation, and improve weather forecasts. As a next radar development project, we plan to develop a polarimetric phased array weather radar. It is expected that the future phased array radar will achieve a polarimetric capability. In 2018, a X-band polarimetric phased array weather, which is termd by a multi-parameter phased array weather radar; MP-PAWR, has been operated in Tokyo, Japan. In this study, the transmitted frequency of the under consideration radar is C-band (5GHz). The C band weather radar, which has the observation range of several kilometers, is effective to cover the whole of Japan's land area. The goal of this study is to design the C-band polarimetric phased array weather radar, which is capable of measuring the 3-D rainfall distribution in less than 1 min in a range of several hundred kilometers, respectively.

However, it is difficult to maintain high accuracy of observation of polarimetric phased array weather radar because of the following topics. 1) the effect of deterioration of the antenna characteristics, which are formed by the digital beam forming, in oblique direction are deteriorated. 2) the performance of the cross polarization discrimination, which is performance to distinguish between horizontal waves and vertical waves, are reduced in oblique direction. These problems caused the ununiformity of the accuracy of rainfall estimates.

In this paper, we proposed the C-band dual polarized antenna elements and array antennas. We designed the antenna element in consideration of high cross polarization discrimination (XPD). The proposed radar is a fixed type radar. We designed the three types of the array antenna, which are a

planar, cylinder, and semi-spherical shapes. The antenna pattern of the cylinder shape antenna is characterized to be constant in the azimuth direction. The semi-spherical shape is characterized in that the antenna pattern is constant in the azimuth and elevation directions. In this study, numerical simulations was carried to evaluate the estimation accuracy of radar parameters using different arrays. In the numerical simulations, realistic targets using the data of the X-band MP-PAWR were used. As a result, the radar reflectivity factor with the planar shape antenna was highly overestimated by comparing with the cylinder and semi-spherical shape antennas because of the wide beam width and high sidelobes for oblique directions. The Mean Absolute Error (MAE) between the truth and the estimated value is about 3.0 dBZ in the horizontal direction (e.g. azimuth angles). In the case of cylinder shape antenna, it was overestimated in only the vertical direction (e.g. elevation angles). The MAE is 1.4 dBZ. The estimation accuracy with semi-spherical shape antenna was equivalent to that with the parabolic antenna. The MAE is 1.0 dBZ. In this presentation, we will present the numerical simulation results of the polarimetric parameters, such as differential reflectivity, specific differential phase, correlation coefficient, and discuss the advantage and disadvantage of the three types of array antennas.