Performance improvement of digital beamforming for phased array weather radar

Hiroshi Kikuchi (1), Tomoo Ushio * (1), Fumihiko Mizutani (2) and Masakazu Wada (2)
(1) Osaka University, Suita, Japan
(2) Toshiba Corporation, Kawasaki, Japan

1. Background

The X-band Phased Array Weather Radar (PAWR) at Osaka University has performed three-dimensional precipitation observations in less than 30 seconds [1]. The observation range is 60 km. As a transmitted waves of the radar, a fan-shaped transmission beam is used, with a narrow beamwidth (1.2 [deg]) in azimuth and a wider beamwidth (5.0 [deg]) in elevation. In elevation angles, Fourier beamforming method is used for electronic scanning, with 128 antenna elements. The fan beam is useful to support rapid scanning. However, the received signals tend to be affected by the influence of ground clutter. The PAWR is intended to operate in urban areas, where many tall buildings exist. Consequently, clutter echoes have much influence, even at high elevations.

2. Application of adaptive digital beamforming for the PAWR at Osaka University

The PAWR is developed on the premise of being applied to advanced digital beamforming (DBF) is used for electronic scanning in elevation methods, such as the minimum mean square error (MMSE) beamformers. These adaptive beamformers were expected to suppress the strong clutter echoes. However, phased array radar systems present the difficulty of having to guarantee the output accuracy because the phased array systems have a large amount of antenna elements, amplifiers, and AD converters. We investigated the impact in the PAWR data with some kind of errors of clutter echo suppression using DBF. In addition to Fourier beamforming, MMSE beamformer was used. An adaptive DBF method with correction method is proposed when the received data has errors. The correction method reduces a phase and an amplitude error among each element.

3. RESULTS AND DISCUSSION

The signals received by the 128 channels on July 1, 2016, 13:56:15 (JST) has some errors in the amplitude and phase information. The proposed correction procedure was shown to be capable of handling those errors in both domains (phase and amplitude). From the comparison between the results of the different DBF methods (FR, MMSE, and MMSE with correction method) as shown in Fig. 1, FR overestimated the received power from low elevation angles ($0^\circ – 5^\circ$) to high elevation angles (10°-30°) because the beam pattern has the high sidelobe level. In MMSE, the clutter influence also remained at elevation angles higher than 15°, a range of angles where the results obtained with MMSE were roughly equivalent to the ones obtained with FR. This remaining clutter was caused by the mentioned large errors in the recorded phase and amplitude measurement for some channels. As a result, sidelobe suppression in the clutter direction is not enough to effectively eliminate the clutter at high elevation angles. Finally, the MMSE with the proposed correction method was shown to be very effective in mitigating the clutter at all elevation angles, because of its better suppression of the sidelobes at low elevation angles; it is therefore superior to the other analyzed DBFs as a scheme for clutter reduction.

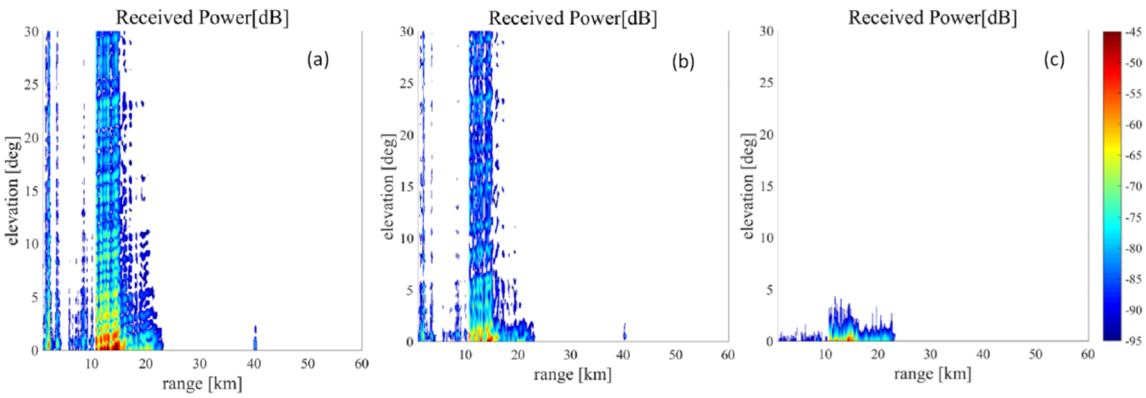

Figure 1. Range-elevation reflectivity cross sections. Panels a), b), and c) are the results of FR, MMSE, and MMSE with the proposed correction method, respectively.

4. References

1. F. Mizutani, M. Wada, T. Ushio, E. Yoshikawa, S. Satoh, and T. Iguchi, “Development of active phased array weather radar,” in *35th Conference on Radar Meteorology*, Sept. 2011.