Application of MMSE Doppler spectrum estimator to an X-band Phased Array Weather Radar

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Severe weather phenomena such as tornadoes and downbursts are reported more frequently than in the past, there are increasing demands for early detection and warning of severe weather. In Japan, a Phased Array Weather Radar (PAWR) is installed at Osaka University, Suita campus in 2012. The PAWR is an X-band one-dimensional phased array radar which can perform a full volume scan of reflectivity and Doppler velocity at range resolution of 100m in 30 seconds by using an angular imaging technique for elevation [1].

In urban areas, the PAWR measurements at low elevation angles are heavily contaminated by ground clutter due to high concentrations of buildings. The traditional Doppler power spectrum (DPS) estimator, which is basically the Fourier transform, produces high sidelobes due to these ground clutter signals. Although the sidelobes can be reduced by applying a window function, a broadened ground clutter signal mainlobe may overlap a precipitation signal.

This study proposes a DPS estimation method via Minimum Mean Square Error (MMSE) framework. The MMSE framework was proposed in the field of phased array digital beamforming, and realized estimation of precise angle profiles of received power by suppressing antenna sidelobes [2]. Since Doppler spectral processing is governed by the equivalent equation to phased array beamforming, it is expected that a DPS estimator via MMSE can suppress sidelobes and make a precipitation signal detectable. This paper applied the MMSE estimator to an actual received signal of the PAWR and compared it with conventional methods. As a result, compared with the Fourier estimator, the MMSE estimator reduced sidelobes by 20-30 dB and revealed a precipitation signal buried by sidelobes. While a windowed Fourier estimator resulted in spectral broadening of both ground clutter mainlobe and precipitation signals, the MMSE approach estimated ground clutter with narrow mainlobe and low sidelobes, and made a precipitation signals more clearly detectable. Furthermore, the narrowed and sidelobe-reduced ground clutter signal can be removed by a typical Doppler spectral based ground clutter removal method that cuts and fills near-zero velocity components of a DPS. With the MMSE estimator, thus, the PAWR can make its clear observation even in an urban area, and contribute to realize early detection and warning.

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