

Study on adaptive clutter rejection system using external receiving antennas for the MU radar

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Strong clutter echoes from a hard target such as a mountain or building sometimes cause problems of observations with atmospheric radars. In order to reject or suppress ground clutter echoes, it is effective to use NC-DCMP (Norm Constrained- Directionally Constrained Minimum Power) method, which makes null toward the direction of the clutter, if we can receive signals independently from plural antennas [Nishimura et al., JTech., 2012]. It has been demonstrated that the NC-DCMP method is effective to real observation data with the MU (Middle and Upper atmosphere) radar [Hashiguchi et al., Radio Sci., 2018]. Although NC-DCMP method suppresses clutter echoes with almost maintaining the shape of main lobe to add pseudo-noise compared with the conventional DCMP method, the signal-to-noise ratio (S/N) of atmospheric echoes is somewhat degraded. We studied the clutter suppression method with little S/N degradation by using external antennas.

In the NC-DCMP method, the following constrained optimization problem is solved :

$$\text{minimize } P = 1/2 w^H R_{xx} w$$

$$\text{subject to } C^T w^* = N \text{ and } |w^H w| \leq \delta N$$

P is the signal power, w is the weight vector, R_{xx} is the covariance matrix, C is the direction vector of the desired direction, N is the number of array antenna, δ is the norm constraint value, H is a Hermitian operator (complex conjugate transposition), T is a transposition operator, and $*$ denotes a complex conjugate. The gain is different for each sub-array or antenna, the magnitude of the direction vector may be as $C_i = \sqrt{G_i / \|G\|}$. For the special case of $G_1 \gg G_2, G_3, \dots$, $C = [1, 0, 0, \dots]^T$.

Four turnstile antennas were installed in the MU radar site. The signal from the antenna is sent to the MU radar observation room through the coaxial cable after amplified by the LNA with the limiter and BPF. It is further amplified by the LNA in the observation room, and then down-converted to intermediate frequency (5 MHz) signal to input to the multi-channel receiving system of the MU radar.

We compared the NC-DCMP method using the each received data of 25 channels, which is a conventional clutter suppression method, and the NC-DCMP method using the simple combination of 25 channels and 4 channels of external antennas. In the former case, the S/N of the atmospheric echoes is somewhat degraded, but in the latter case the main lobe shape is guaranteed by 25 channel simple synthesis, so the S/N degradation is not observed. In the latter case, the clutter suppression is sometimes insufficient. One cause is considered to be that the range mistakes happen between main and external antennas depending on the external antenna position and the clutter direction. The clutter suppression was improved by optimizing the range in the NC-DCMP processing. Another cause is considered to be that the current positions of external antennas are biased to the north side. Antenna positions should be optimized in the future.

We can apply the achievement of this study to the Equatorial MU radar (EMU), which is proposed to be constructed at West Sumatera, Indonesia. The EMU system is the similar as the MU radar, but its antenna consists of 1045 Yagi antennas with 55 groups and it has 64 receiver channels.

Keywords: Atmospheric radar, Clutter rejection, NC-DCMP method, MU radar