Basic study on the Ionospheric Observations of the PANSY radar; Adaptive Sidelobe Cancellation Techniques for the FAI Clutters

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Introduction

- PANSY radar (1)
  - A large VHF active phased array at Syowa Station, Antarctica
  - Can observe Ionospheric incoherent scatterings in addition to the MST radar functionalities
  - Has supplemental antenna array for Field Aligned Irregularities (FAIs)
- Ionosphere observation of the PANSY radar
  - FAIs are assumed to be clutters because of their strong coherent backscattering (Fig. 1)
- Objective
  ⇒ To separate FAI echoes by adaptive beam synthesis utilizing both the main and FAI array

Method

- Norm Constrained Tamed Adaptive (NC-TA) (2)
  - Based on Capon beamformer
  - Has additional constraint about the norm of the optimal weight \( w \) to control the SNR loss
  ⇒ Because the weight norm increase directly connects to the increase of the noise level
  - Norm constraint can be calculated by the desired SNR loss \( L \)
  - Gain weighting
  - Can handle large main array + small sub array
  - The steering vector \( A(\theta, \phi) \) is weighted by the directional gains of each channel to the desired direction

Experiment

- A test observation is made on Feb 15, 2015
  - A Helicopter is targeted assuming FAI clutter
  - Helicopter has GPS track recorder as the “true position” for the phase calibration (Note phases of the main array can be known by self test)
  - 16 channels (8 for main array, 8 for FAI array)

Conclusion and Future Works

- The gain-weighted NC-TA is tested with the FAI array of the PANSY radar
  - The method worked well against the helicopter clutters
  - Further accuracy is needed for the phase calibration
  - Now working on the more plactic observation data

Helicopter Echoes

- Characteristics of the helicopter echoes
  - The target has 3 blades for the main rotor
  - Backscattering from a blade can only be observed when the line of sight becomes perpendicular to the blade
  ⇒ Both the time series and the Doppler spectrum of the rotor signal become series of impulses (Fig. 4)
  - For this case, the rotor has 3 blades and rotates about 400 RPM
- Phase Calibration of the FAI array
  - Applied the low pass filter to extract the signal from the helicopter body (shown in a rectangle of Fig. 4)
  - Performed the least square fitting between the phases of the observed signals and the true phases calculated from the antenna-helicopter distances obtained by GPS
  ⇒ Phase errors are still remaining, and the gradients are different channel-by-channel (Fig. 5)
  ⇒ Caused by inaccuracy of GPS truth?

Results and Discussions

- Two methods are compared on the same data
  - Ordinary 8-channel uniform NC-TA by main array only
  - 9-channel Gain-weighted NC-TA with main and FAI array
  - Main array is nonadaptively synthesized into 1 channel (Fig. 6)
  - FAI array is used separately (8channel)
  ⇒ Permissive SNR loss is set to 0.5 dB for both settings
  ⇒ Desired direction is set to the zenith
- Gain-weighted NC-TA by the FAI array worked fine
  - Showed better performance than the uniform NC-TA against the helicopter clutters in front of the FAI array (Fig. 7)
  - Ground clutters is difficult to suppress because the FAI array does not have the sensitivity to other directions

Other Radar Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Center Frequency</td>
<td>47 MHz</td>
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<tr>
<td>Peak Power</td>
<td>520 kW</td>
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<tr>
<td>Main Array Element</td>
<td>1045 Crossed Yagi (vertical)</td>
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<tr>
<td>FAI Array Element</td>
<td>24 Yagi (30° elevation)</td>
</tr>
<tr>
<td>Sampling Interval</td>
<td>8 ms</td>
</tr>
<tr>
<td>Range Resolution</td>
<td>150 m</td>
</tr>
</tbody>
</table>

Fig. 1 Ionosphere observation of the PANSY radar and FAI clutter

Fig. 2 The model for adaptive signal processing

Fig. 3 Antenna position and beam pattern (Azimuth = 0°) of main and FAI array

Fig. 4 Doppler spectrum of the helicopter echoes for 32 seconds

Fig. 5 Phase errors for each channel after calibration (converted into distance)

Fig. 6 Whole Doppler spectrum obtained by the nonadaptive beamforming method

Fig. 7 The clutter suppression ratio at the range where the helicopter exists obtained by both uniform and gain-weighted NC-TA