Characteristics of Chaff Echoes Observed by X-band Dual Polarization Radar

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Chaff is made of aluminum-coated thin fibers is released by the military to create widespread echoes and confuse tracking radars.

(a) U.S. Air force chaff  (b) U.S. Navy chaff

Diameter: about 28µm
Length: ½ radar wavelength (1.5, 2.5, 5 cm)
Introduction

- Chaff echoes are observed 63.3% days in one year.
- No rain, but the rain rate appears in the radar composite image.
- We should remove chaff echoes for radar quality control.
- So, we research characteristics of chaff echoes observed by NIMR X-band dual polarization radar.

The monthly variation of the number of chaff echo days adapted by 한혜영 외 (2011)

(a) Visible image of MTSAT-1R, (b) 60 minute-accumulated rainfall amount (mm) distribution and (c) radar composite image for the chaff case at 1700 LST 20 May 2010.
### NIMR X-band Dual Polarization Radar

#### Antenna Specifications
- **Type**: Parabolic reflector
- **Diameter**: 2.44 m
- **Beam Width**: 1.0° at 3 dB

#### Transmitter Specifications
- **Type**: Magnetron (PSI)
- **Peak Power**: 180 kW (90 kW simultaneous H/V)
- **Frequency**: 9300 MHz (X-band, λ=3.2 cm)

#### Receiver Specifications
- **Type**: HP Digital Receiver (H/V)
- **Polarization switching**: None (SHV with parallel receiver)

### NIMR Radar

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wavelength</strong></td>
<td>3.2 cm (X-band)</td>
</tr>
<tr>
<td><strong>Bin spacing</strong></td>
<td>150 m</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>60 km</td>
</tr>
<tr>
<td><strong>Nyquist Velocity</strong></td>
<td>320 m/s</td>
</tr>
<tr>
<td><strong># of Elvation</strong></td>
<td>15 (0.5 – 25°)</td>
</tr>
<tr>
<td><strong>Scan interval</strong></td>
<td>10 min</td>
</tr>
</tbody>
</table>
1. Identify each echo case with naked eye.

2. Make table that are expressed azimuth and range for only the identified each echo area (as left figure).

3. Collect dual polarimetric parameters using the tables.

<table>
<thead>
<tr>
<th>Cases</th>
<th>Date</th>
<th>Number of Volume</th>
<th>Number</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaff cases</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20 May 2010 0656 ~ 1015 UTC</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>26 May 2010 0506 ~ 1015 UTC</td>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>02 June 2010 1608 ~ 1746 UTC</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16 June 2010 0056 ~ 0239 UTC</td>
<td>11</td>
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<tr>
<td></td>
<td>22 June 2010 0510 ~ 0630 UTC</td>
<td>9</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>29 June 2010 0320 ~ 0420 UTC</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>05 July 2010 0500 ~ 0650 UTC</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>07 July 2010 0300 ~ 0450 UTC</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precipitation cases</td>
<td>20 July 2009 1500 UTC</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16 August 2010 0156 ~ 0319 UTC</td>
<td>9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Chaff data: total 8 days (111 volumes, 388,189 pixels)
- Precipitation data: total 2 days (10 volumes, 210,523 pixels)
- Chaff echoes are distributed thin and shallow line shape for wind direction.

- **Reflectivity** \((Z)\)
  - chaff echoes : < 10 dBZ
  - precipitation echoes : < 38 dBZ

- **Differential reflectivity** \((Z_{DR})\)
  - chaff echoes : > 5 dB (horizontal oriented)
    or < -2.5 dB (vertical oriented)
  - precipitation echoes : 0 - 2.5 dB

- **Cross correlation coefficient** \((\rho_{HV})\)
  - chaff echoes : < 0.6
  - precipitation echoes : > 0.98
**Frequency distributions**

**Z vs. Z\textsubscript{DR}**

Max frequency distribution: periphery of -5 dBZ, 9 dB
Almost Z\textsubscript{DR} > 0 dB
- chaff filament is horizontal oriented.
Z\textsubscript{DR} < 0 dB: vertical oriented

**Z vs. \(\rho\textsubscript{HV}\)**

Chaff echoes: 0 - 0.75
Mostly \(\rho\textsubscript{HV}\): 0.1 - 0.4

Precipitation echoes: 0.2 - 1.0
Mostly \(\rho\textsubscript{HV}\): > 0.95

Partial ranges of \(\rho\textsubscript{HV}\) overlap.
**Frequency distributions**

**Z vs. STD($Z_{DR}$)**

$Z_{DR}$ of Chaff echoes has wider range.

STD($Z_{DR}$) : large (1 - 8 dB)

- Various spatial distributions

Precipitation echoes : 0 - 3.5 dB

- Homogeneous distributions

**Z vs. $K_{DP}$**

Chaff echoes:

- Symmetrically at -1 °Km$^{-1}$

- Chaff filaments are vertical oriented distribution.

- But, it is different from $Z_{DR}$ distribution.

- So, $K_{DP}$ is unstable.
- There is an overlap of values between Melting layer and chaff echoes.
Overall, the polarimetric parameters for chaff echoes have a wider range of values than those for precipitation echoes.

The chaff filaments tend to be horizontally oriented to radar beams.

It is found that there is a considerable overlap in the cross correlation coefficient range of chaff and precipitation echoes.

It is suggested that care should be taken when using the cross correlation coefficient solely in removing chaff echoes.

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Reference
한혜영 외, 2011, 위성 적외영상 자료를 이용한 현업용 기상레이더 반사도 합성자료의 채프에코 제거. 대기, 21, 285-300.
Thank you for your attention

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