INTRODUCTION TO DUAL-POL WEATHER RADARS: KEY BENEFITS

Radar Workshop 2017

08 / 09 Nov 2017
Monash University - Australia
• Calibration
• Attenuation Correction
• Qualitative Precipitation Estimation
• Hydrometeor Classification
CONTENT

• Calibration

• Attenuation Correction

• Qualitative Precipitation Estimation

• Hydrometeor Classification
BEFORE THE CALIBRATION … CALIBRATION

• Loss Measurement: losses in transmitting and in receiving + Radome

• Antenna Gain in AZ and EL

• Antenna Alignment via sun tracking procedure

• Transmitter calibration: Transmitting power, radar equation

• Zero Check: To determine the noise power of the entire system

• Single-point calibration: to determine the ratio between the real receive signal power and the one calculated by the signal processor (usually through a signal injection)
THE RELATION BETWEEN ZH, ZDR AND KDP

Self Consistency Method

In Rain: Z_H, ZDR and KDP are correlated:

• ZDR is usually well calibrated (or it is easy to calibrate)
• KDP is insensitive to the calibration
• By consequence, Z_H will be calibrated by means of ZDR and KDP.

Gourley et al. 2007
ZDR CALIBRATION

• Birdbath: by looking to the 90°, ZDR should be 0 dB

• Sun calibration: The power received in V channel should be equal to the power in H channel.
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DUAL-POL – $\Phi_{DP}$
ATTENUATION CORRECTION

\[ Z_{\text{corr}}(r) = Z_{\text{ncorr}}(r) + \alpha \cdot \varphi_{DP} \]

\[ ZDR_{\text{corr}}(r) = ZDR_{\text{ncorr}}(r) + \beta \cdot \varphi_{DP} \]

S-Band: \( \alpha = 0.018 \text{ dB/deg} \), \( \beta = 0.0025 \text{ dB/deg} \)
C-Band: \( \alpha = 0.08 \text{ dB/deg} \), \( \beta = 0.02 \text{ dB/deg} \)
X-Band: \( \alpha = 0.25 \text{ dB/deg} \), \( \beta = 0.035 \text{ dB/deg} \)

This is the main base, other methods play:

• By the fact that the attenuation is related to the amount of Rain in the path
• To better adjustment of \( \alpha, \beta \), and the corresponding ratio \( \alpha/\beta \)
• To better estimate the values of \( \varphi_{DP} \)
\[ PIA = \gamma_{H}^{RAIN} \cdot (\phi_1 - \phi_0) + \gamma_{H}^{WS} \cdot (\phi_2 - \phi_1) + \gamma_{H}^{DS} \cdot (\phi_3 - \phi_2) \]

\[ PIDA = \gamma_{DP}^{RAIN} \cdot (\phi_1 - \phi_0) + \gamma_{DP}^{WS} \cdot (\phi_2 - \phi_1) + \gamma_{DP}^{DS} \cdot (\phi_3 - \phi_2) \]
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QPE

• For S-Band: (Ryzhkov et al. 2005)
  - $R = \frac{R(Z)}{0.4 + 5.0 |Z_{DR} - 1|^{1.3}}$ for $R(Z) < 6 \text{ mm/h}$; $R(Z)$ is from $Z = a \cdot R^b$
  - $R = \frac{R(Z)}{0.4 + 3.5 |Z_{DR} - 1|^{1.7}}$ for $6 < R(Z) < 50 \text{ mm/h}$
  - $R = 44.0 |K_{DP}|^{0.822}$ for $R(Z) > 50 \text{ mm/h}$ and $KDP > 0 \, ^\circ/\text{km}$

• For C-Band:
  - $R = 33.5 |K_{DP}|^{0.83}$ for $Z > 38dBZ$ and $KDP > 0 \, ^\circ/\text{km}$
  - Classic $Z = a \cdot R^b$ else

• For X-Band:
  - $R = 19.63 |K_{DP}|^{0.823}$ for $Z > 35dBZ$ and $KDP > 0.3 \, ^\circ/\text{km}$
  - Classic $Z = a \cdot R^b$ else
# Z-R RELATIONSHIP

<table>
<thead>
<tr>
<th>ZH [dBZ]</th>
<th>Marshall-Palmer $Z=200R^{1.6}$ [mm/h]</th>
<th>US relation $Z=300R^{1.4}$ [mm/h]</th>
<th>Tropical $Z=250R^{1.2}$ [mm/h]</th>
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<tr>
<td>10</td>
<td>0,15</td>
<td>0,09</td>
<td>0,07</td>
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<td>15</td>
<td>0,32</td>
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<td>0,46</td>
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<td>2,73</td>
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<td>3,17</td>
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<td>35</td>
<td>5,62</td>
<td>5,38</td>
<td>8,29</td>
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<td>40</td>
<td>11,53</td>
<td>12,24</td>
<td>21,63</td>
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<td>45</td>
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<tr>
<td>50</td>
<td>48,62</td>
<td>63,40</td>
<td>147,36</td>
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<td>55</td>
<td>99,85</td>
<td>144,28</td>
<td>384,64</td>
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<td>60</td>
<td>205,05</td>
<td>328,35</td>
<td>1003,96</td>
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<tr>
<td>65</td>
<td>421,07</td>
<td>747,28</td>
<td>2620,49</td>
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<tr>
<td>70</td>
<td>864,68</td>
<td>1700,70</td>
<td>6839,90</td>
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</table>
Better QPE

QPE study – 5 radars (C) – 30 episodes – Summer 2010

Note: simplified QPE (mono-site, ideal conditions, no rain gauge adjustment, …)

QPE after Attenuation Correction

(« V1 »)

For Raingauge QPE > 5 mm h⁻¹:
Biais Radar/Pluvio = -28 %
CORR = 0.68

QPE without Dual-Pol

For Raingauge QPE > 5 mm/h
Biais Radar/Pluvio = -48 %
CORR = 0.49

Dual-Pol QPE

(« V2 »)

For Raingauge QPE > 5 mm h⁻¹:
Biais Radar/Pluvio = -3 %
CORR = 0.81
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HYDROMETEOR CLASSIFICATION
HYDROMETEOR CLASSIFICATION

X-Band

(a) Membership Function ZDR = f(ZH) for X-Band

(b) Membership Function KDP = f(ZH) for X-Band

(c) Membership Function ROHV = f(ZH) for X-Band

C-Band

(a) Membership Function ZDR = f(ZH) for C-Band

(b) Membership Function KDP = f(ZH) for C-Band

(c) Membership Function ROHV = f(ZH) for C-Band

S-Band

(a) Membership Function ZDR = f(ZH) for S-Band

(b) Membership Function KDP = f(ZH) for S-Band

(c) Membership Function ROHV = f(ZH) for S-Band
NUMERICAL EXAMPLE

\[ P_F^i = F_{BB}^i(Alt) \times F_T^i(T) \times F_Z^i(Z_H) \times [F(Z_H, Z_{DR}) + F(Z_H, K_{DP}) + F(Z_H, \rho_{HV})] \]

<table>
<thead>
<tr>
<th>Type</th>
<th>F(ZH)</th>
<th>F(BB)</th>
<th>F(T)</th>
<th>F(ZH-ZDR)</th>
<th>F(ZH-KDP)</th>
<th>F(ZH-ROHV)</th>
<th>Pi</th>
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<tbody>
<tr>
<td>RAIN</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0,7</td>
<td>1</td>
<td>0,95</td>
<td>2,65</td>
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<tr>
<td>WETSNOW</td>
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<td>0,1</td>
<td>0,5</td>
<td>1</td>
<td>0,9</td>
<td>0,1</td>
<td>0,1</td>
</tr>
<tr>
<td>DRYSNOW</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0,2</td>
<td>0,5</td>
<td>0,9</td>
<td>0</td>
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<tr>
<td>ICE</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0,01</td>
<td>0,3</td>
<td>0,9</td>
<td>0</td>
</tr>
<tr>
<td>HAIL</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

\[ Q = (2.65 - 0.1)/3 \times 100 = 85\% \]
HYDROMETEOR CLASSIFICATION

Same for:

• Meteo – Non Meteo
• Sea Clutters
• Fire
• Volcanic Ashes

It is a matter of behavior
Hassan Al Sakka

h.alsakka@selex-es-gmbh.com

+49 (0) 2137-782-239