Dual Polarization
the Challenge

Dusan Zrnic (NSSL)
Two Dual Polarization Modes

Simultaneous SHV (it is not fully polarimetric)
H and V are transmitted simultaneously, both copolar components are received

\[
\begin{array}{ccccccccc}
H & H & H & H & H & H & H & H & H \\
\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
\end{array}
\]

H receiver

\[
\begin{array}{cccccccc}
V & V & V & V & V & V & V & V & V \\
\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
\end{array}
\]

V receiver

Alternate AHV (it is fully polarimetric)
H and V are transmitted alternatively

\[
\begin{array}{ccccccccc}
H & V & H & V & H & V & H & V \\
\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
\end{array}
\]
Challenge: DualPol-PAR to have Same Data Quality as DualPol-WSR-88D

Polarimetric Data Quality Achieved on Conventional Radars:

- High cross-correlation coefficient $\rho_{hv}$, small bias in differential reflectivity $Z_{DR}$, and low linear depolarization ratio $L_{DR}$, characterize a well designed polarimetric radar
  - EEC recent Polarimetric Radars (Sigmet Processor, Gamic Processor): $\rho_{hv} \approx 0.996$ to 0.998
  - KOUN (WSR-88D, NSSL design) $\rho_{hv} \approx 0.998$, $L_{DR} < -33$ dB
  - $Z_{DR}$ bias should be $< 0.15$ dB
ISSUES affecting dual polarization data

- **COUPLING** between the horizontal and vertical components (inherent to Planar PAR for measurements away from the two principal planes)

- CROSS-POLAR PATTERN (present in PAR and Conventional Radar)

- MATCHING OF BEAMS at vertical and horizontal polarizations (present in PAR and Conventional Radar)
Transmitted Linearly Polarized Waves from a

- Parabolic Dish are orthogonal throughout the whole field of view

- Planar Phased Array are not orthogonal through most of the field of view
COUPLING - Planar Array}
Alternate (AHV) Mode

- Tested extensively on parabolic antennas
- Planar Phased Array
  - Performs well if corrected over the field of view
  - Correction to mimic conventional radar can be done over most of the field of view
  - Correction is multiplicative and is a function of pointing direction

COUPLING, Ref: Guifu et al 2009
IEEE Tr., GRS-47
Simultaneous (SHV) Mode

- Accepted for the WSR-88D
- Planar Phased Array
  - Performs with multiplicative correction only over a limited field of view
  - Corrections* over the remaining field of view are not practical
  - Therefore alternatives are needed for most of the field of view:
    - Orthogonal coding
    - Alternate HV
    - Other?
Field of View SHV mode

$Z_{DR} = 0 \text{ dB}, \rho_{hv} = 1; \beta = 0 \text{ deg}, \Phi_{DP} = 180 \text{ deg}$

Bias in $Z_{DR} < 0.1 \text{ dB}$
Field of View AHV mode

\[ Z_{DR} = 0 \text{ dB}, \rho_{hv} = 1; \beta = 0 \text{ deg} \]

Bias in \( Z_{DR} < 0.1 \text{ dB} \)
Decoupling Doppler from Differential Phase (AHV - mode)

• Scanning strategy and transmission sequence should be designed to optimize overall performance. This is a System Design Problem

• The following Transmitted Sequence Triplet decouples Doppler from Diff Phase
• There is no inherent coupling so CPA is equivalent to a conventional radar (Ref: Guifu 2009 – *OU-NSSL Patent pending*)

• System Study is in Order – scanning strategy, multiple beams, frequencies, beamwidth, waveforms, ......
CPAs
Single Pol
Advantages of CPA

• No beamwidth increase if AZ scans are at constant Elevation. That is: Quality of measurements is isotropic in each conical scan.

• Effects of precipitation on the radome is expected to be smaller.

• Polarimetric issues are equivalent to the issues concerning the conventional radar.
CROSS-POLAR PATTERN

- This issue affects both the PAR and the Parabolic dish antenna

- Two types of cross polar pattern have profound effect on biases of the polarimetric variables
Two Antenna Types

1) SINGLE CROSS-POLAR MAIN LOBE:
Principal cross-polar LOBE centered on the copolar main lobe

(2) MULTIPLE CROSS-POLAR MAIN LOBES: symmetric with respect to beam axis and IN PHASE OPOSITION TO EACH OTHER:

CROSS-POLAR PATTERN
Comparison

• Type I (single lobe) pattern is much more detrimental than type II.

• To achieve the same reduction of bias in polarimetric variables the integrated cross-polar single lobe pattern to integrated main lobe pattern must be 10 dB lower than the value for multiple lobe (type II) pattern.
A Cylindrical PAR on every Water Tower
Envelope of $Z_{DR}$ bias < 0.15 dB in the Az – El from boresight (SHV mode)

![Graph showing the envelope of $Z_{DR}$ bias]

- $Z_{DR}$ bias > 0.15 dB
- $Z_{DR}$ bias = 0.15 dB

Azimuth from boresight (deg) vs. Elevation from boresight (deg)
COUPLING - Planar Array

Alternate (AHV) Mode

- The differential phase and Doppler are coupled
- Tested extensively on parabolic antennas
- Planar Phased Array
  - Performs well if corrected over the field of view
  - Correction to mimic conventional radar can be done over most of the field of view
  - Correction is multiplicative and is a function of pointing direction

COUPLING, Ref: Guifu et al 2009 IEEE Tr., GRS-47
MATCHING BEAMWIDTHS

• At 20 dB below the peak the beam patterns for H and V polarizations should be within 1.85 dB of each other