Mitigation of Range Velocity Ambiguities

Analysis and Evaluation

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Simulation Studies
Simulation studies using synthetic data

- Statistical performance
- Sub-function tests (e.g., study of GMAP)
Studies using time-series data (I)

- **Real-time**
  - Phase coding
    - Uses WSR-88D phase shifter
    - 1\textsuperscript{st} trip decoding
  - Staggered PRT
    - Complete processing except for GCF
  - Implemented on the RRDA for
    - General quality assessment
    - Aid in data collection
    - Immediate comparison
Studies using time-series data (II)

• Off-line
  ▪ Playback through RRDA
  ▪ Playback through SimSPS: 
    Simulator of the Signal Processing Subsystem
    • Exact replica of RRDA’s SPS implemented in MATLAB
    • Functionality matches legacy WSR-88D
    • Easy implementation of evolutionary requirements
    • Allows for both qualitative and quantitative analyses
R/V Ambiguity Mitigation Algorithms

Staggered PRT Phase Coding
The Staggered PRT Algorithm

- Transmitter alternates two PRTs
  - PRT ratio: $\kappa = T_1/T_2 = m/n$

- Maximum unambiguous range
  - $r_{a2}$ for reflectivity
  - $r_{a1}$ for Doppler velocity and spectrum width

- Maximum unambiguous velocity
  - $v_a = m \, v_{a1} = n \, v_{a2}$ (Velocity dealiasing algorithm)
The Staggered PRT Algorithm

KTLX
VCP 11 – Batch Mode
04/06/03 4:42 GMT
EL = 2.5 deg

KOUN
Staggered PRT (184 km/276 km)

\( v_a = 25.4 \text{ m s}^{-1} \)

\( v_a = 45.2 \text{ m s}^{-1} \)
Velocity Computation
Algorithm Performance

KOUN
Staggered PRT (240 km/360 km)
EL = 2.5 deg
Staggered PRT (184 km/276 km)

04/06/03 4:50 GMT

$v_a = 34.6 \text{ m s}^{-1}$

$v_a = 45.2 \text{ m s}^{-1}$
Censoring

03/18/03 3:28 GMT

Reflectivity
Staggered PRT (184 km/276 km)

EL = 1.5 deg

Velocity
Staggered PRT (184 km/276 km)

\[ v_a = 45.2 \text{ m s}^{-1} \]
PRT Trade-Off

Long PRTs
Staggered 336/466
\(v_a = 26.8 \text{ m s}^{-1}\)

Medium PRTs
Staggered 240/360
\(v_a = 34.6 \text{ m s}^{-1}\)

Short PRTs
Staggered 184/276
\(v_a = 45.2 \text{ m s}^{-1}\)

04/06/03  3:14 GMT
EL = 1.5 deg
\(\kappa = \frac{2}{3}\)
The SZ-2 Algorithm

• Transmitted pulses are phase-modulated with SZ(8/64) switching code

• Phase-coded scan is preceded by long-PRT surveillance scan
  ▪ Surveillance scan is not phase coded
  ▪ Powers from the surveillance scan are used to determine overlaid trips in the phase-coded scan
  ▪ Spectrum widths from the surveillance scan are used for censoring
SZ-2 Algorithm Performance

Reflectivity
Long PRT

EL = 0.5 deg

Velocity
SZ-2 with short PRT

04/06/03 4:26 GMT

$v_a = 35.5 \text{ m s}^{-1}$
SZ-2 Algorithm Performance

Velocity
Legacy “Split cut”
EL = 0.5 deg

04/06/03 4:28 GMT

Velocity
SZ-2 with medium PRT

$v_a = 23.7 \text{ m s}^{-1}$
Staggered PRT vs. SZ-2

Velocity
Staggered 240/360
EL = 0.5 deg

04/06/03  4:30 GMT

Velocity
SZ-2 with medium PRT

$v_a = 34.6$ m s$^{-1}$

$v_a = 23.7$ m s$^{-1}$
Performance of R/V Ambiguity Mitigation Algorithms

KOUN Cases
Stratiform Precipitation
Phase Coding

Reflectivity
Long PRT

10/08/02  15:11 GMT
EL = 0.5 deg

Velocity
Legacy short PRT

\[ v_a = 8.9 \text{ m s}^{-1}, r_a = 466 \text{ km} \]

\[ v_a = 35.5 \text{ m s}^{-1}, r_a = 117 \text{ km} \]
Stratiform Precipitation
Phase Coding

Velocity
SZ-2 with short PRT
EL = 0.5 deg

10/08/02  15:11 GMT

Velocity
Legacy short PRT

\[ v_a = 35.5 \text{ m s}^{-1}, \quad r_a = 117 \text{ km} \]

\[ v_a = 35.5 \text{ m s}^{-1}, \quad r_a = 117 \text{ km} \]
Stratiform Precipitation
Phase Coding

10/08/02 15:11 GMT
EL = 0.5 deg

Velocity
SZ-2 with medium PRT

\[ v_a = 23.7 \text{ m s}^{-1}, \quad r_a = 175 \text{ km} \]

Velocity
Legacy medium PRT

\[ v_a = 23.7 \text{ m s}^{-1}, \quad r_a = 175 \text{ km} \]
Stratiform Precipitation
Staggered PRT

02/13/03  20:57 GMT
EL = 1.5 deg

$\nu_a = 26.8 \text{ m s}^{-1}$, $r_{a1} = 336 \text{ km}$, $r_{a2} = 466 \text{ km}$
Stratiform Precipitation
Staggered PRT

Velocity
Short Staggered PRT
EL = 1.5 deg

Velocity
Long Staggered PRT

$\nu_a = 71.2 \text{ m s}^{-1}, \ r_{a1} = 117 \text{ km}, \ r_{a2} = 175 \text{ km}$

$\nu_a = 26.8 \text{ m s}^{-1}, \ r_{a1} = 336 \text{ km}, \ r_{a2} = 466 \text{ km}$
Convective Precipitation
Staggered PRT

05/17/03  0:39 GMT
EL = 2.5 deg

\[ v_a = 34.6 \text{ m s}^{-1}, \quad r_{a1} = 240 \text{ km}, \quad r_{a2} = 360 \text{ km} \]
Convective Precipitation
Staggered PRT

05/17/03  0:39 GMT
EL = 2.5 deg

Velocity
Legacy short PRT

\( v_a = 35.5 \text{ m s}^{-1}, r_a = 117 \text{ km} \)

Velocity
Staggered PRT

\( v_a = 34.6 \text{ m s}^{-1}, r_{a1} = 240 \text{ km}, r_{a2} = 360 \text{ km} \)
Squall Line
Staggered PRT

06/11/03  6:27 GMT

Reflectivity
Long Staggered PRT
EL = 1.5 deg

Velocity
Long Staggered PRT

\( v_a = 26.7 \text{ m s}^{-1}, \ r_{a1} = 336 \text{ km}, \ r_{a2} = 466 \text{ km} \)
Squall Line
Staggered PRT

06/11/03  6:27 GMT
EL = 1.5 deg

Long PRTs
Staggered 336 km/466 km
\( v_a = 26.8 \text{ m s}^{-1} \)

Medium PRTs
Staggered 240 km/360 km
\( v_a = 34.6 \text{ m s}^{-1} \)

Short PRTs
Staggered 184 km/276 km
\( v_a = 45.2 \text{ m s}^{-1} \)
\[ v_a = 35.5 \text{ m s}^{-1}, \ r_a = 117 \text{ km} \]
Squall Line
Phase Coding

06/11/02  6:44 GMT
EL = 0.5 deg

Velocity
Legacy medium PRT

\( v_a = 23.7 \text{ m s}^{-1}, \ r_a = 175 \text{ km} \)

Velocity
SZ-2 with medium PRT

\( v_a = 23.7 \text{ m s}^{-1}, \ r_a = 175 \text{ km} \)
MCS-Squall Line
Phase Coding

Reflectivity
Long PRT

06/26/03 3:14 GMT
EL = 1.5 deg

Velocity
Legacy short PRT

\[ v_a = 8.9 \text{ m s}^{-1}, \quad r_a = 466 \text{ km} \]

\[ v_a = 35.5 \text{ m s}^{-1}, \quad r_a = 117 \text{ km} \]
MCS-Squall Line
Phase Coding

Velocity
SZ-2 with short PRT
EL = 1.5 deg

06/26/03  3:14 GMT

Velocity
Legacy short PRT

\[ v_a = 35.5 \text{ m s}^{-1}, \ r_a = 117 \text{ km} \]
MCS-Squall Line
Phase Coding

Velocity
SZ-2 with short PRT

04/06/03  3:14 GMT
EL = 1.5 deg

Velocity
Staggered PRT (240 km/360 km)

\[ v_a = 34.6 \text{ m s}^{-1}, \quad r_a = 240 \text{ km} \]
\[ v_a = 35.5 \text{ m s}^{-1}, \quad r_a = 117 \text{ km} \]
Summary

- At lower elevations and in MCS and widespread convective systems, the medium PRT gives best compromise in both techniques.
- In shallow stratiform convective systems, the medium Staggered PRT gives good results even at the lowest elevations.
- At elevations of 1.5 deg and higher, the staggered PRT has an advantage in clear area coverage.
- Both techniques significantly reduce obscuration with respect to legacy processing.
The End
Backup Slides
Simulation studies using synthetic data

- Statistical performance

SZ-2 Algorithm - Clutter in 1st trip, C/S₁ = 0 dB, GMAP GCF, PNF @ adj. vs

\[ \text{sd}(v_1) - \sigma_2 = 4 \text{ m/s} \]

\[ \text{bias}(v_1) - \sigma_2 = 4 \text{ m/s} \]

\[ \text{sd}(v_2) - \sigma_2 = 4 \text{ m/s} \]

\[ \text{bias}(v_2) - \sigma_2 = 4 \text{ m/s} \]
Summary of Staggered PRT Technique

- **Range coverage**
  - $Z$ to $r_{a2}$ and $v$ to $r_{a1}$, where $r_{a1}/r_{a2} = m/n = K$
  - Natural “match” for WSR-88D VCPs

- **Extension of maximum unambiguous velocity**
  - $v_a = m \, v_{a1} = n \, v_{a2}$

- **Range-velocity ambiguities**
  - Uniform PRT
    - $r_{a}v_a = c\lambda/8 \rightarrow$ Inadequate for $\lambda = 10$ cm
  - Staggered PRT
    - $r_{a1}v_a = m(c\lambda/8)$
    - $r_{a1}$ vs. $v_a$ trade-off controlled by PRTs
SZ-2 Censoring

With censoring

Without censoring