Contributors to Measurement Errors (Chap. 7)

- *1) Widespread spatial distribution of scatterers (range ambiguities)
- *2) Large velocity distribution (velocity ambiguities)
- *3) Antenna sidelobes
- *4) Antenna motion
- *5) Ground clutter (regular and anomalous propagation)
- *6) Interference from other weather radars (next slide)
- *7) Airborne scatterers (birds, etc.)
- *8) Returns from strong point scatterers
- *9) Solar radiation
- 10) Time window effect
- 11) Receiver noise
- 12) Receiver non-linearity
- 13) Quantization and saturation noise
- 14) Many more contributors that are too numerous to list
INTERFERENCE FROM NEARBY RADARS

Often 1\textsuperscript{st} seen by Operational radar Meteorologists

Fig. 11.3
Interference from weather radars at Dodge City, Kansas and Enid, OK

Dodge City

Enid

250 km

10/29 - 11/11/2013

METR 5004
Enid weather radar display. Interference from Dodge City Transmissions
Range and Velocity Ambiguities

- Short PRTs are needed to maintain signal coherency, to provide acceptable velocity aliasing, & low estimate variance.

- Dilemma: \( r_a v_a = c\lambda/8 \)
  - Given \( \lambda \), we can pick \( v_a \) to satisfy our needs. Then, \( r_a \) is fixed, and it is usually so small that there can be 2\(^{nd}\) and even 3\(^{rd}\) trip overlaid echoes.

- **Goal**: Reduce obscuration from overlaid echoes (a.k.a. “purple haze syndrome”).

From Dr. Torres?
Range/Velocity Ambiguity Mitigation in the WSR-88D network

- Long PRTs are used to estimate powers (reflectivity) and short PRTs to estimate velocity
- Long-PRT powers are used to unfold short-PRT velocities
  - Range unambiguous powers from the long PRT tell us where the echoes come from in the short PRT
  - Overlaid echoes with comparable strengths cannot be resolved!
Performance of range velocity Ambiguity Mitigation in the WSR-88D network

- Velocity field is obscured by range-overlay censoring ("purple haze" syndrome)
- In case of overlaid echoes, only strong-trip velocities are recovered
  - Strong-trip power must exceed weaker-trips powers by ~10 dB
- Velocities from weaker echoes cannot be recovered!

Can we do better?
Mitigation Techniques for range and velocity ambiguities

• 1) To avoid range ambiguities of Z measurements:
   -- Long PRTs

• 2) To mitigate range ambiguities for Doppler measurements:
   – Phase coding (Random)
   – Phase coding (Systematic → WSR-88D)

• 3) To mitigate velocity ambiguities:
   -- Continuity (not a signal processing approach)
   -- Staggered PRT (future for WSR-88D); also mitigates range ambiguities
Range Ambiguities

- Simultaneous H,V (SHV mode; used by the WSR-88D)
  - Polarimetric variables $Z_h, Z_v, \rho_{hv}(0)$, and $\phi_{DP} = \phi_{hh} - \phi_{vv}$ are affected in the same manner as reflectivity factors.
  - Range ambiguities (i.e., overlaid echoes) need not appear if Doppler velocity measurement is not required (only long PRT could be used!)
  - Sophisticated mitigation of ambiguities is needed if mean velocity must be estimated along with polarimetric variables.

- Alternately transmit H,V (AHV mode)
  - Differential Phase and Doppler velocity are coupled.
Range/velocity Ambiguity Mitigation in the WSR-88D network

- **Split cut** at low elevation angles
  - Collect two scans at the same elevation angle (one using a long PRT and one using a short PRT)
  - The long-PRT scan is used to retrieve unambiguous powers and polarimetric parameters, whereas the short-PRT scan is used to retrieve (range-folded) velocities
  - Good ground clutter suppression but antenna scans twice at the same elevation

- **Batch mode** at intermediate elevation angles
  - Collect one scan with interlaced batches of short and long PRTs
  - The long-PRT scan is used to retrieve unambiguous powers and the short-PRT scan to retrieve (range-folded) velocities and polarimetric parameters
  - Reduced ground clutter suppression but antenna scans once at each elevation
Batch mode of data collection

\[ T_s(Z) = \text{long PRT, for reflectivity measurements } \approx 2 \text{ ms}; \]
\[ T_s(v) = \text{short PRT for Doppler and polarimetric measurements } \approx 0.9 \text{ ms} \]
\[ r_a(Z) = \text{Unambiguous range for reflectivity measurements } (Z_h) \approx 300 \text{ km} \]
\[ r_a(v) = \text{Unambiguous range for Doppler and Polarimetric measurements } \approx 135 \text{ km} \]
\[ M(Z) = \text{number of samples for reflectivity measurements } \approx 6 \]
\[ M(v) = \text{number of samples for Doppler and polarimetric measurements } \approx 36 \text{ to } 40 \]
Mitigation of Range Ambiguities (Table 7.1; p.176) (VCP 11)

Uniform PRTs

Alternate batches of long (for Z) and short (for velocity) PRTS.

Long PRTs (first PPI scan) for reflectivity $r_a > 460$ km;
Short PRTs (second PPI scan) for velocity, $r_a < 200$ km; typically 150 km

$E_l = 19.5^\circ$

$= 5.25$

$= 4.3$

$= 2.4$

$= 1.45$

$= 0.5$

10/29- 11/11/2013

METR 5004

12
Phase Coding
(First scan long PRT as shown)
10/08/02 15:11 GMT
EL = 0.5 deg
Phase Coding

Doppler Velocity
Phase coding, medium PRT

EL = 0.5 deg

10/08/02  15:11 GMT

Doppler Velocity  Processing
as on earlier WSR-88Ds

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

$v_a = 23.7 \text{ m s}^{-1}, r_a = 175 \text{ km}$
Phase Coding Performance (I)

03/03/04  20:28 GMT

Reflectivity
“Split cut”

EL = 0.5°

Legacy Velocity
“Split cut”

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

\( v_a = 28.1 \text{ m s}^{-1}, r_a = 148 \text{ km} \)
Phase Coding Performance II)

03/03/04 20:28 GMT

SZ-2 Velocity
Short PRT

EL = 0.5°

Legacy Velocity
“Split cut”

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

$v_a = 28.1 \text{ m s}^{-1}, r_a = 148 \text{ km}$
Mitigation of Velocity Aliases

(Based on continuity of the velocity field)
Distributions of Velocities in Tornadic Storms

(Fig. 7.4)
Multiple Doppler Aliases (long PRT)
Velocity Field after Dealiasing (i.e., spatial continuity had been applied)
Weather and Ground Signals

If time is short skip the remaining slides on GCF;

1. Original time series:

   ![Original Time Series](image)

2. Doppler Spectrum:

   ![Doppler Spectrum](image)

10/29-11/11/2013 METR 5004
Weather Signal after Clutter Filter
Clutter Filter Map

GROUND CLUTTER FILTER ON/OFF
VCP48, DATE: 04:03:04, TIME: 20:39:18, CUT # 4 (0.44°)

regions of clutter filter and pulse pair

GCF to be applied

No GCF

<th
Reflectivity Field no GCF

REFLECTIVITY: Z (dBZ)
VCP48, DATE:04:03:04, TIME:20:39:18 , CUT # 4 (0.44°)

30 km
20 km
10 km

pulse pair - no clutter filter

95 dB
86.5
78.1
69.6
61.1
52.7
44.2
35.7
27.3
18.8
10.3
1.87
-6.6
-15.1
-23.5
-32
<th

10/29-11/11/2013
Reflectivity Field after GCF
Velocity Field no GCF
Velocity Field after GCF