MPAR Data Processing and Data Management

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MPAR Capabilities Drive Complexity of Data

- Phased array radar data management and signal processing requirements are driven by:
  - Bandwidth of the data interface from the radar front end (antenna or receiver)
  - Signal processing algorithms used
  - Latency of signal processing (required throughput rate)

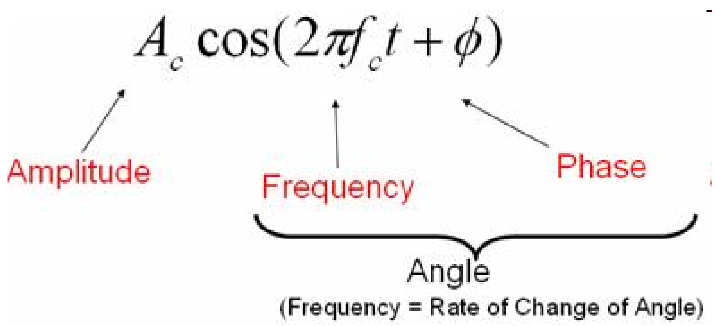
- The radar architecture and mission requirements drive all three concerns above:
  - Multiple-simultaneous beams
  - Dual polarization
  - Air surveillance and weather surveillance

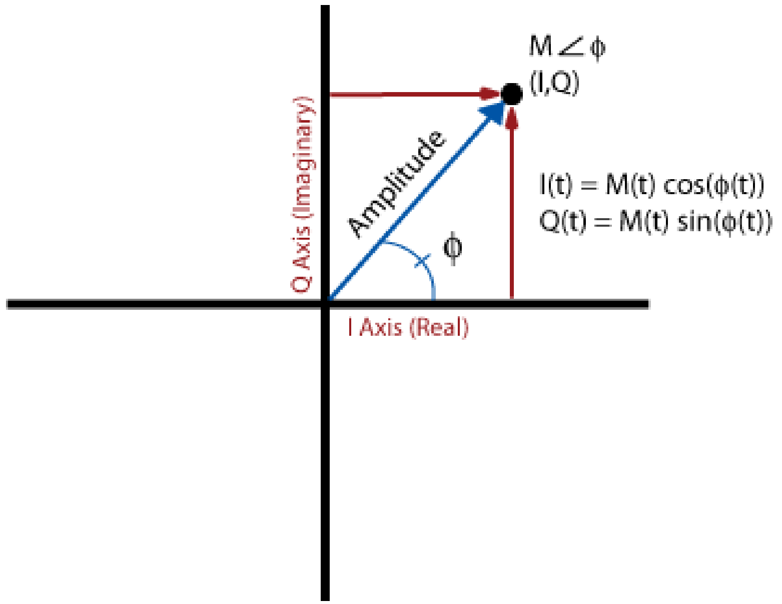
Dual-polarization and Multiple Simultaneous Beams Present a Data Interface, management, and Processing Throughput Challenge for MPAR

Data Management - Sampling and Throughput

- For this exercise, we consider data management to consist of the tasks between radar beamforming and dissemination of measurement products and spectral moments (weather data) and surveillance information

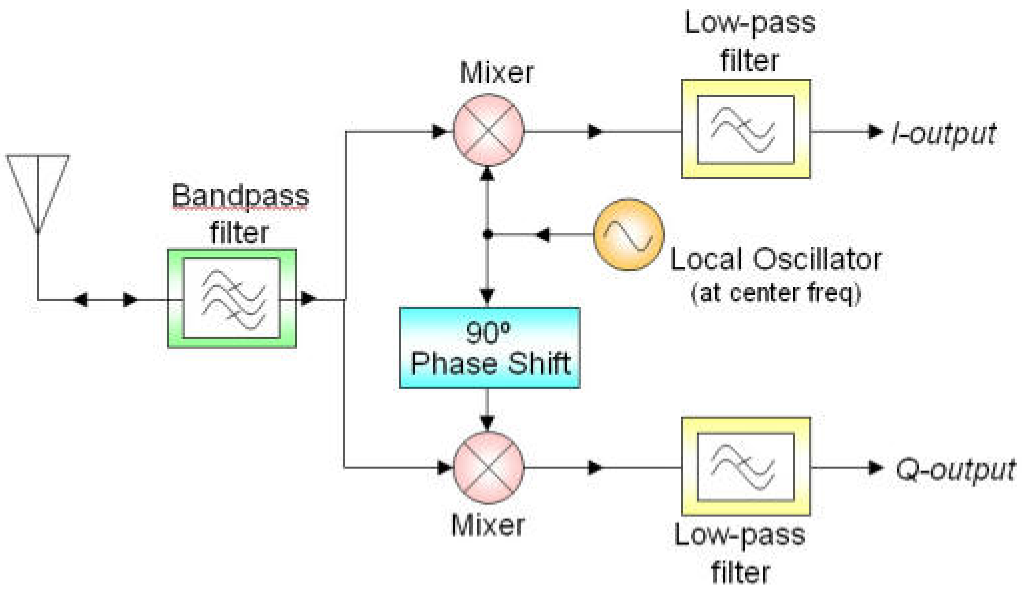
- For each radar beam that is simultaneously received, we digitally sample the returns and generate Inphase and Quadrature samples





Data Management - Sampling and Throughput

- Sampling of RF (radio frequency) or IF (intermediate frequency) signals into I/Q digital samples
  - Can be done on array (digital array radar)
  - Can be done in beamforming network (digital beamformed array)
  - Can be done in radar receiver (active or passive phased array with RF beamforming)



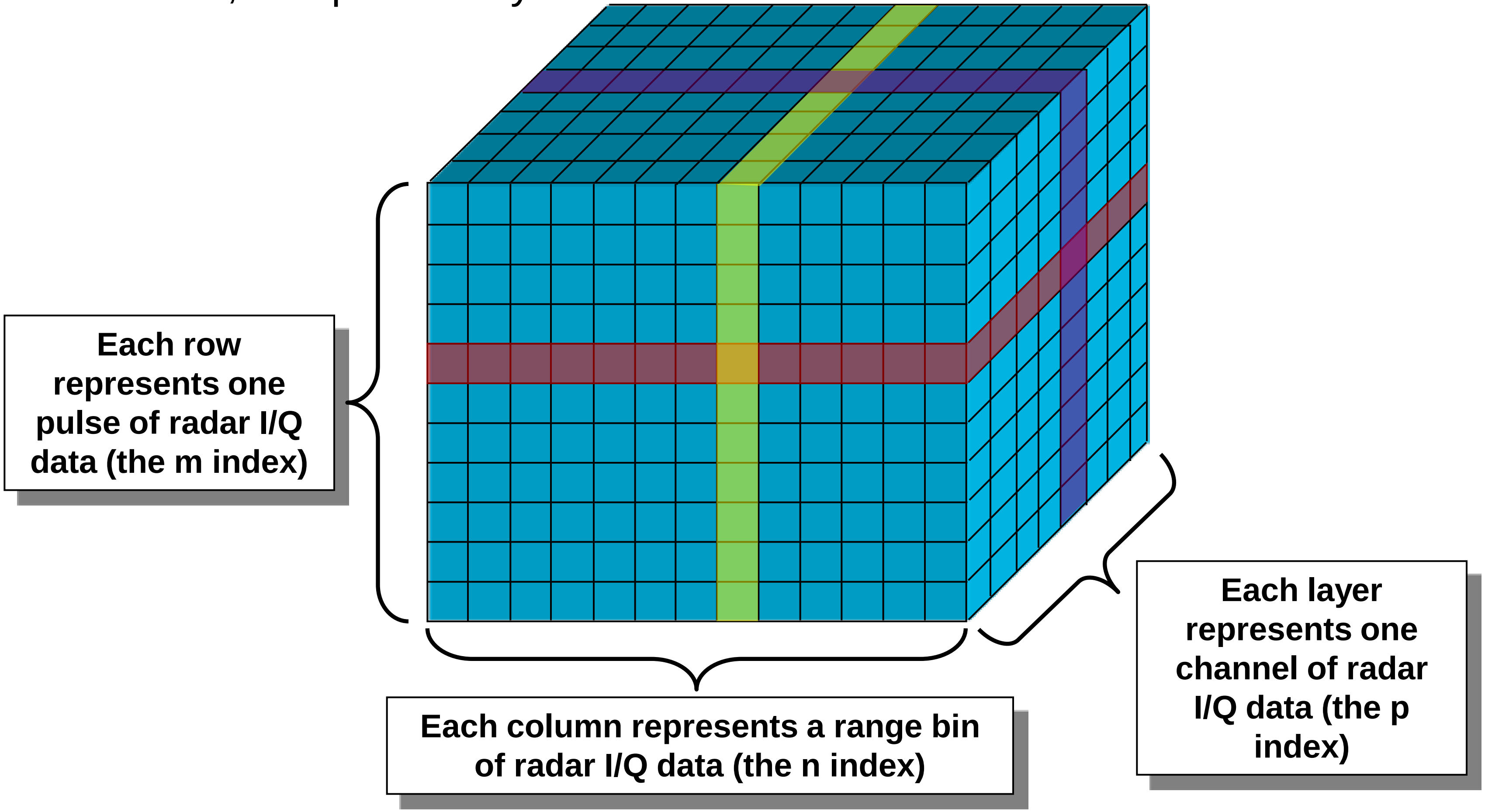
Data Management - Sampling and Throughput

- Amount of I/Q data from the radar front end – an example
  - Two polarization channels (horizontal and vertical)
  - Pulse compressed waveform (10 MHz)
  - Digital sampling of 50 MHz IF at 60 MS/sec (super-Nyquist)
  - 16 bit analog to digital converter on I and Q

  - 2 polarization channels X 60 Msamples/second X 4 bytes (I and Q)
    - 480 MB/sec per beam – each additional simultaneously formed receive beam increases the total bandwidth
    - Raw I/Q samples will be downsampled and/or averaged in range to reduce bandwidth requirements of the signal processing chain
    - Data interfaces between the radar array (or receiver) and the signal processors will need to be wideband

The Radar Datacube

- Suppose we had radar return data (IQ samples) with multiple parameters (pulses, range bins, and frequency/polarization channels)
- The format of the index into the cube is (m,n,p) where m is the row, n is the column, and p is the layer



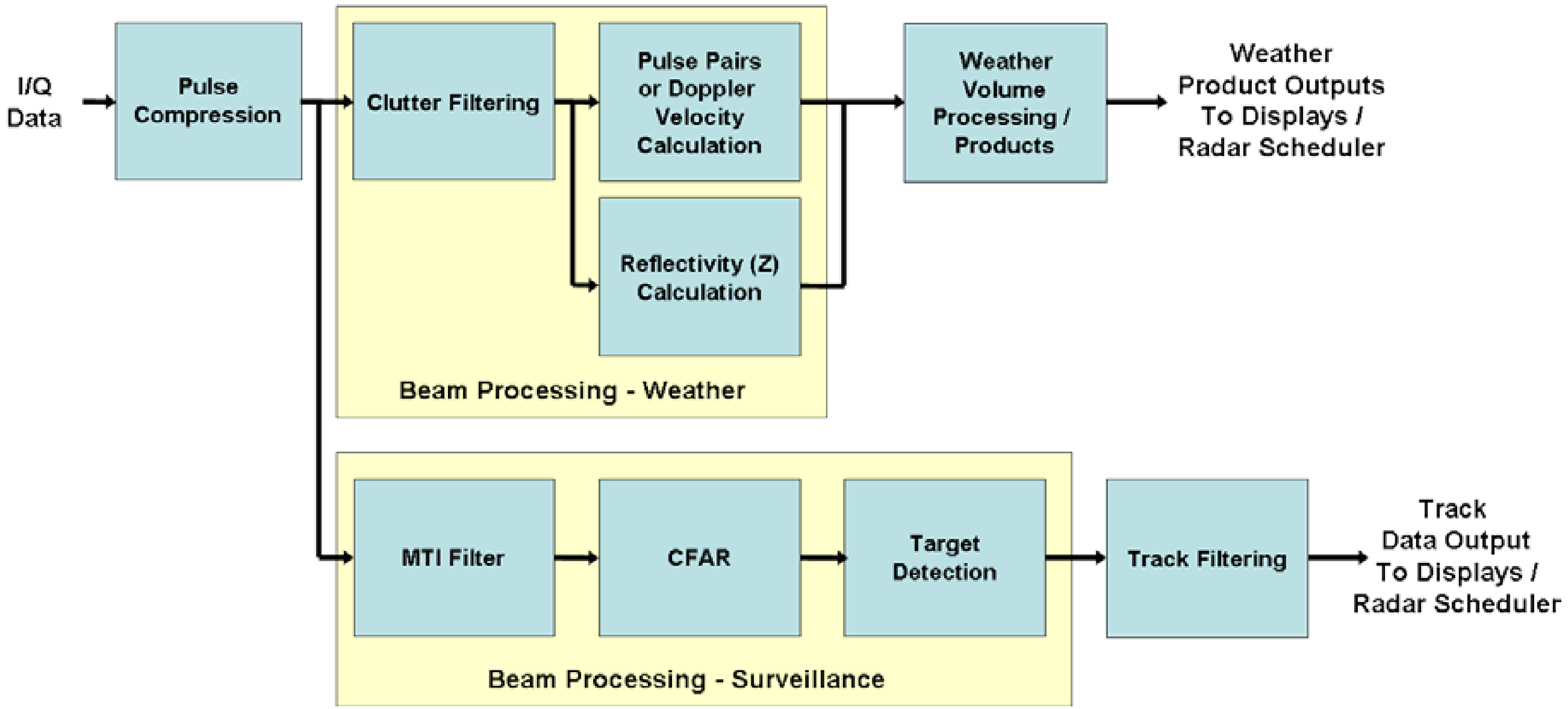
Radar Signal Processing for Weather and Surveillance

- "Partially-parallel" processing chains
  - Same raw I/Q radar data input and intermediate products, but some processing for air surveillance is incompatible with weather processing (Moving Target Indicator filtering, for example)

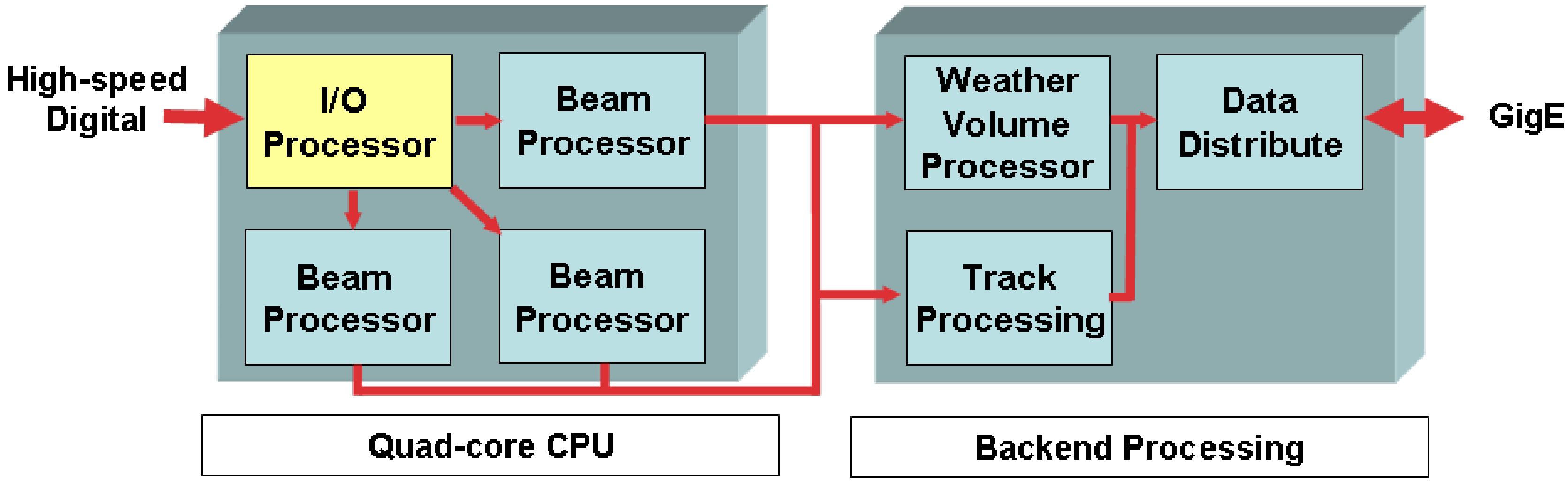
- Latency of Weather Processing vs. Air Surveillance Processing
  - Air surveillance requires 'real-time' processing / Weather can be less time critical
    - Real-time: For a 1ms PRI (1000 Hz PRF) 8 pulse sequence, all processing would need to be completed in 8ms
    - Active Track (Phase Arrays) versus Track While Scan (spinning radars)
      - Active track – slower volume scans with faster interleaved dedicated track dwells (radar must close track loop between track dwells) but may have 10's of seconds for full volume scan
      - Track While Scan – target positions are updated on each revolution (scan) of the antenna, fast volume scan times (e.g. 4 seconds)

Sample Signal Processing Flow

- "Partially-parallel" processing chains

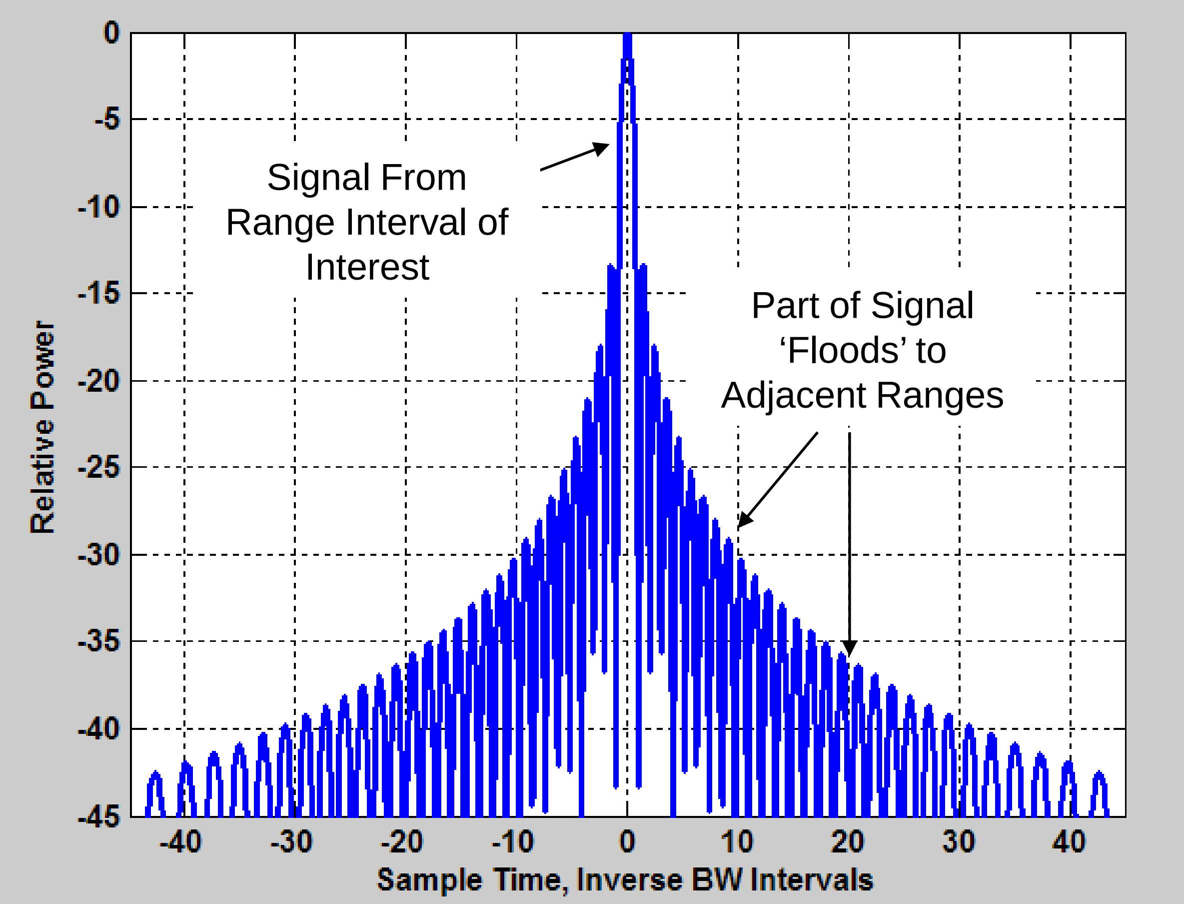


Sample Signal Processing Flow



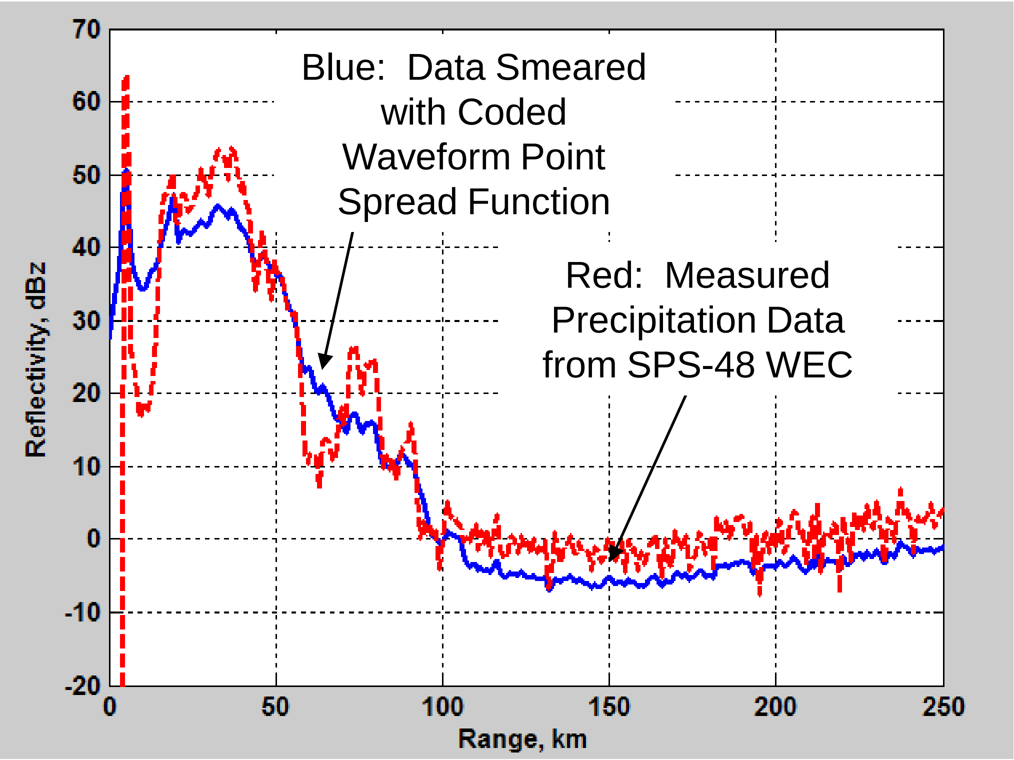
Signal Processing Impacts of Phase Coding

- Phase Coded Waveforms – Sidelobes in Range ‘Flood’ Adjacent Range Intervals



Range Sidelobes Example

- Time Sidelobes Smear Data … Distort Features
- Distortion Will Degrade Hazardous Weather Detection Algorithms



Clutter Filtering Challenges

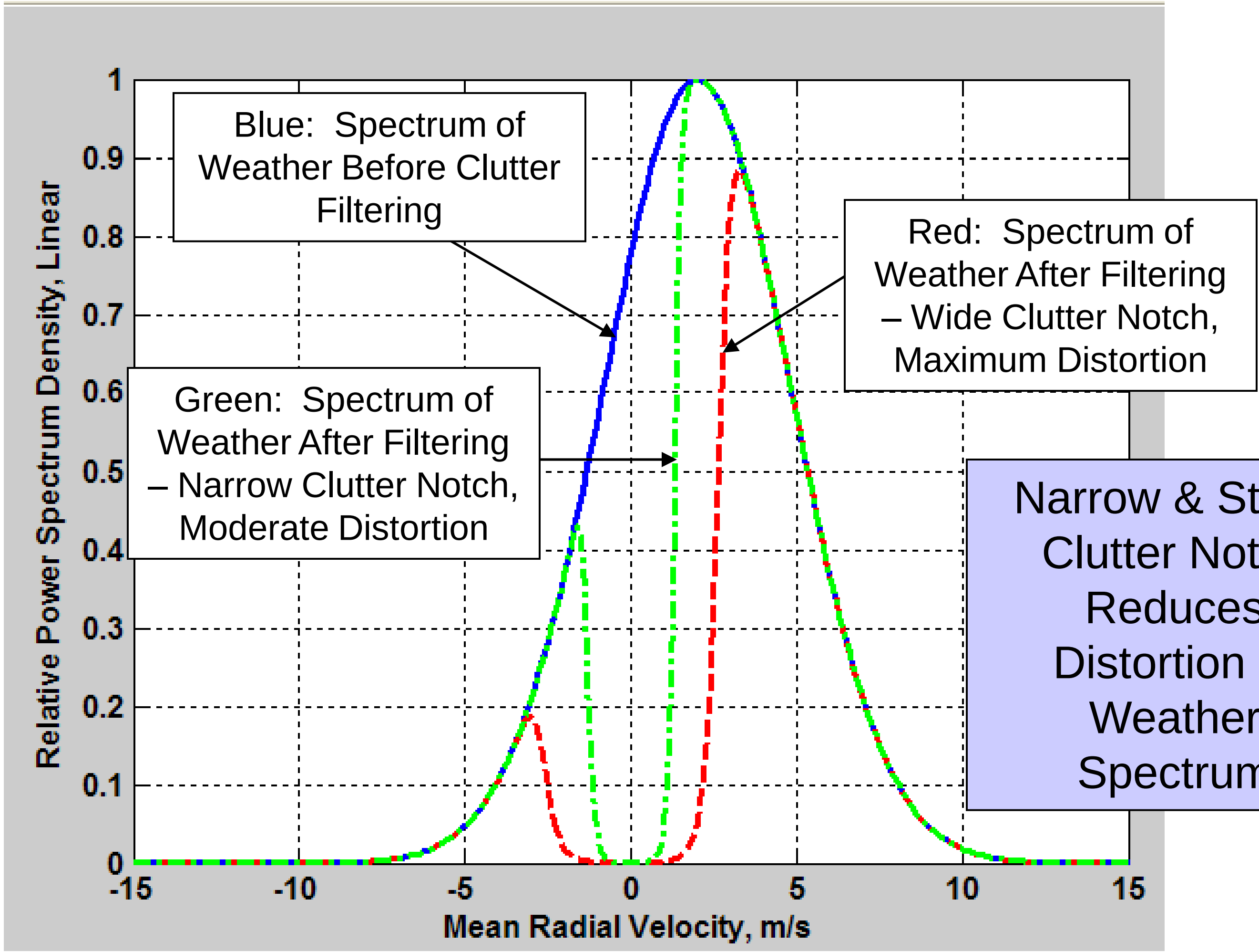
- Pulse Sequence in PAR is Not Continuous
  - One Burst of Pulses Each Azimuth
  - Clutter Filters Have Limited Length Sequence on Which to Operate

- Traditional Filters (TDWR, NEXRAD) Require Certain Number of Pulses to ‘Charge’ Filter
  - TDWR & NEXRAD are Continuously Scanned … Once Charged, Do Not Need to be Charged Again

- Use of Traditional Filters Will Degrade Measurements:
  - Either More ‘Lost’ Data Resulting in Increase in Error for Reflectivity, Mean Radial Velocity, and Spectrum Width OR
  - Less ‘Lost’ Data Resulting in More Contamination to Spectral Moment Measurements from Filter Transient

NEXRAD & TDWR Clutter Filtering Not Appropriate for PAR

Clutter Filtering Challenges



Narrow & Steep Clutter Notch Reduces Distortion of Weather Spectrum

Clutter Filter Bias Example

Clutter Filtering - Previous Solutions

- Finite Impulse Response (FIR) Filters:
  - Advantages: Finite Number of ‘Lost’ Data During Charging
  - Disadvantages: Cannot Achieve Required Clutter Rejection (with Acceptable Bias) with Reasonable Number of Pulses, Typically Amount of ‘Lost’ Data Not Acceptable

- Infinite Impulse Response (IIR) Filters:
  - Advantages: Good Clutter Rejection, Well Tested (NEXRAD, TDWR)
  - Disadvantages: Varying (Non-deterministic) Amount of ‘Lost’ Data During Charging, Typically Amount of ‘Lost’ Data Not Acceptable

- Covariance Matrix Based Filters:
  - Advantages: No Data Lost … Given N Pulses, All N Pulses Available to Estimate Reflectivity, Velocity, and Spectrum Width
  - Disadvantages: To Date, Weather Measurement Errors (Reflectivity, Mean Radial Velocity, Spectrum Width Bias) Desired in TDWR Spec for Ground Clutter Filtering Not Met (Limitations Similar to FIR Filters)