# CHAPTER 5

## OPERATIONAL MODES AND VOLUME COVERAGE PATTERNS

**5.1 Introduction.** This chapter describes the WSR-88D operational modes and volume coverage patterns (VCPs). There are two operational modes: Precipitation and Clear Air. Each operational mode uses multiple VCPs.

**5.2 Operational Modes.** The WSR-88D initiates data acquisition and processing in the Clear Air Mode and automatically switches to the Precipitation Mode when Category 1 precipitation is detected (Section 5.4). The Precipitation Mode may also be manually selected at the MSCF.

**5.2.1 Precipitation Mode.** This mode is used when enough significant echoes are present. At times, however, such as early, midlevel formation of convective echoes, the user may choose to enter the Precipitation Mode manually. The initial operating capability included VCPs 11 and VCP 21 (Sections 5.3.1.1 and 5.3.2) for this mode. However, new VCPs, 12 and 121 have been added (Sections 5.3.1.2 and 5.3.3). With these new VCPs, there are now three sub-classifications of the Precipitation mode, those are the Shallow Precipitation Group (VCP 21), Deep Convection Group (VCPs 11 and 12) and the Multiple PRF Dealiasing Algorithm Group (VCP 121).

**5.2.2 Clear Air Mode.** This mode is used when there is no detectable precipitation (Precipitation Category 0) or when precipitation intensity and aerial extent are small (Precipitation Category 2). The initial operating capability includes VCPs 31 and 32 (Sections 5.3.4.1 and 5.3.4.2) for this mode. The two VCPs have identical elevation angles, but vary in the radar pulse width and the pulse repetition time. The long pulse (VCP 31) can be used routinely for maximum signal-to noise ratios and resultant sensitivity: short pulse (VCP 32) can be used when a greater Nyquist velocity is desired for this mode.

**5.3 Volume Coverage Patterns.** During operations, the antenna is controlled by automatic scanning programs. The VCPs are matched to an operational mode to optimize product generation for given meteorological situations. In each operational mode, scanning is continuous to support the needs of the users. Principal Users are informed of the current radar operational mode and the current VCP through the use of system status and error messages.

In 2005 new VCPs were added and a VCP numbering convention was adopted. To accommodate the new and legacy VCPs, the following four groups have been identified.

- Deep Convection Group: Two digits beginning with 1, VCPs 11 and 12.
- Shallow Precipitation Group: Two digits beginning with 2, VCP 21.
- Multiple PRF Dealiasing Algorithm (MPDA) Group: Three digits beginning with 1, VCP 121.

- Clear Air Group: Two digits beginning with 3, VCP 31 and 32.

Within the definition of each VCP, the WSR-88D employs three unique collection techniques to maximize the amount and quality of the data while minimizing the time it takes to collect the data. The following paragraphs describe these data collection techniques.

- **Split Cut** is the term used to describe the technique of scanning a particular elevation slice two or more times, using a different PRF for each full scan. This technique is used to accurately place targets in range using a low PRF and to collect accurate velocity data using a high PRF. For the lowest elevations scans (all elevations below the clutter transition angle of 1.65°) where efficient clutter suppression is required and velocity range folding is likely, all VCPs employ the split cut technique using a Contiguous Surveillance (CS) scan followed by one or more Contiguous Doppler (CD) scans. (For middle elevation scans, the Batch Mode scan can be substituted for the CS scan to achieve the same results.)

    - **Contiguous Surveillance (CS)** is a constant low PRF (long $R_{max}$) employed for the entire 360° scan to determine proper target location and intensity (dBZ). Due to the long Rmax, no range unfolding technique is applied since all target locations are considered to be unambiguous or correct. CS operations are part of the "split cut" mode.

    - **Contiguous Doppler (CD)** is a constant high PRF (short $R_{max}$ and high $V_{max}$) employed for the entire 360° scan to accurately determine "1st guess" velocity and spectrum width information. A result of the high PRF (short $R_{max}$) is that multiple trip echoes can occur and, therefore, a range unfolding technique using data from the CS (or Batch) scan must be applied. CD operations are also part of the "split cut" mode.

- **Batch Mode** is used in the middle angles of most VCPs. The Batch Mode (B) technique uses alternating low and high PRFs on each radial for one full rotation at each elevation angle. Along each radial, the radar starts transmitting pulses using a low PRF (long $R_{max}$) to obtain target intensity and location information. Then, before the antenna completes a 1° sweep, the transmitter quickly switches to high PRF (high $V_{max}$) to obtain more accurate velocity information. This alternating back and forth between a low and a high PRF is done for each radial until a full 360° scan has been completed. The two data sets resulting from the different PRFs are combined to resolve range ambiguity. The Batch Mode is used at elevation slices between 1.8° and 6.5° in VCPs 11, 12, 21, and 32 (not employed in VCP 31) where ground clutter contamination is generally not a problem. Additionally, VCP 121 employs the Batch Mode as part of the "split cut" data collection for middle elevations 2.4°, 3.4°, and 4.3°.

- **Contiguous Doppler X (CDX)** (or contiguous Doppler with no range unfolding) combines a high PRF and a rapid antenna rotation rate to obtain all base data in the higher elevation slices (>7°). Even though a high PRF is used, no range-unfolding algorithm is applied to the data. This is because at these higher elevation angles range folded echoes are highly unlikely. (For example, at 7.5°, the radar beam is already at ~ 50,000 feet at 62 nm range

(the shortest CD $R_{max}$)). CDX is employed at all elevation slices >7° in VCPs 11, 12, 21 and 121, and above 3° in VCP 31 (CDX is not employed in VCP 32).

**5.3.1 Deep Precipitation/Convection Group, VCPs 11 and 12.** The purposes of VCPs 11 and 12 are to: 1) detect and track storms; 2) detect shear, mesocyclones, and other hazardous types of weather associated with deep moist convection; 3) provide precipitation estimates; and 4) obtain wind profiles to supplement soundings.

**5.3.1.1 VCP 11.** The VCP 11 is designed to sample severe and non severe precipitation events. The VCP 11 scans 14 elevation cuts in 5 minutes using Split Cut (CD and CS) for the 0.5° and 1.5° elevation scans, Batch processing from 2.4° through 6.2° and Contiguous Doppler for 7.5° through 19.5°. (See Table 5-1 and Figure 5-1.)

**5.3.1.1.1 Parameters.**

- Short pulse (1.57 μs; PRF 318 to 1304 Hz)
- Unambiguous (Nyquist) velocity range 8 to 32.8 m $s^{-1}$ (15.5 to 63.7 knots)
- Fourteen elevation angles
- Five-minute update rate
- Velocity data within 230 km (124 nm) radius
- Hydrometeorological data within 230 km (124 nm) radius
- Reflectivity data within 460 km (248 nm) radius
- Separate surveillance and Doppler scans are taken at the two lowest elevation angles to improve clutter filter performance, maximize the velocity accuracy and unambiguous interval
- Lowest seven elevation angles are contiguous.

**5.3.1.1.2 Strengths/Applications.**

- More rapid update rate (5 minutes) than VCP 21
- More elevation cuts (14) allowing better operator storm evaluation and producing better algorithm output
- Better for monitoring convection than VCP 21
- Provides better vertical definition of storm structure than VCP 21.

**5.3.1.1.3 Limitations.**

- Slower update rate than VCP 12 (4.2 minutes)
- Lacks the low-level overlapping beams of VCP 12
- More widespread overlaid echo and velocity dealiasing failures as compared to VCP 121
- Cone of silence above 19.5°.

**Table 5-1**
**VCP 11 Characteristics**

| Scan | | | | Surveillance | | Doppler PRF No. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Angle (°) | AZ Rate (°/sec) | Period (sec) | WF Type | PRF No. | # Pulses | 4 #Pulse | 5 #Pulse | 6 #Pulse | 7 #Pulse | 8 #Pulse |
| 0.5 | 18.675 | 19.38 | CS | 1 | 17 | -- | -- | -- | -- | -- |
| 0.5 | 19.224 | 18.83 | CD | -- | -- | 44 | 52 | 56 | 61 | 66 |
| 1.45 | 19.844 | 18.24 | CS | 1 | 16 | -- | -- | -- | -- | -- |
| 1.45 | 19.225 | 18.83 | CD | -- | -- | 44 | 52 | 56 | 61 | 66 |
| 2.4 | 16.166 | 22.46 | B | 1 | 6 | 35 | 41 | 43 | 46 | 50 |
| 3.35 | 17.893 | 20.23 | B | 2 | 6 | 35 | 41 | 43 | 46 | 50 |
| 4.3 | 17.898 | 20.23 | B | 2 | 6 | 35 | 41 | 43 | 46 | 50 |
| 5.25 | 17.459 | 20.73 | B | 3 | 10 | 35 | 41 | 43 | 46 | 50 |
| 6.2 | 17.466 | 20.73 | B | 3 | 10 | 35 | 41 | 43 | 46 | 50 |
| 7.5 | 25.168 | 14.38 | CDX | -- | -- | 34 | 41 | 43 | 46 | 50 |
| 8.7 | 25.398 | 14.25 | CDX | -- | -- | 33 | 41 | 43 | 46 | 50 |
| 10.0 | 25.421 | 14.24 | CDX | -- | -- | 33 | 41 | 43 | 46 | 50 |
| 12.0 | 25.464 | 14.22 | CDX | -- | -- | 33 | 41 | 43 | 46 | 50 |
| 14.0 | 25.515 | 14.19 | CDX | -- | -- | 33 | 41 | 43 | 46 | 50 |
| 16.7 | 25.596 | 14.14 | CDX | -- | -- | 33 | 41 | 43 | 46 | 50 |
| 19.5 | 25.696 | 14.09 | CDX | -- | -- | 33 | 41 | 43 | 46 | 50 |

Notes:

- Default Doppler PRF numbers are underlined; Doppler PRFs are editable <7.0 degrees
- Sum of periods, which is "data collection" time = 279.17 secs / 4.65 mins. Transition times will vary
- Volume scan update time is about 5 minutes
- See Table 5-7 for PRF No. information.

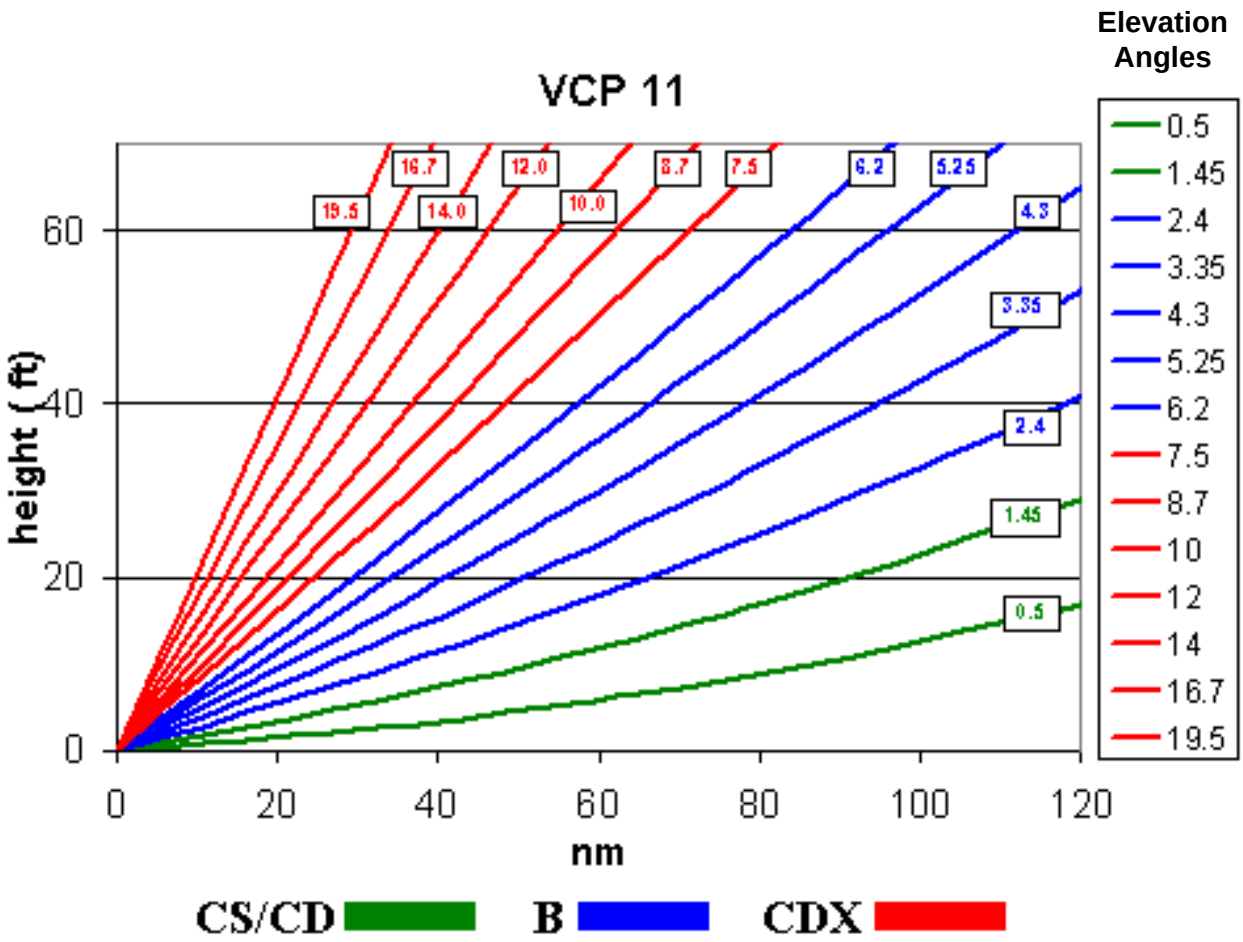


**Figure 5-1**
**VCP 11**

VCP 11 samples fourteen elevation angles in 5 minutes. The lowest two angles use "Split Cut" (CS/CD), middle angles use Batch (B), and higher angles use Contiguous Doppler (CDX) mode. The lines representing the beam elevation with height as a function of range assume standard atmospheric refraction of the beam.

**5.3.1.2 VCP 12.** VCP 12 is designed for deep convection, with better vertical resolution and faster volume scan update than VCP 11. VCP 12 scans 14 elevation cuts in 4.2 minutes using both Split Cut (CD and CS) for the 0.5°, 0.9° and 1.3° elevation scans, Batch processing from 1.8° through 6.4° and Contiguous Doppler for 8.0° through 19.5°. See Table 5-2 and Figure 5-2.

**5.3.1.2.1 Parameters.**

- Short pulse (1.57 μs; PRF 318 to 1304 Hz)
- Unambiguous (Nyquist) velocity range 8 to 32.8 m $s^{-1}$ (15.5 to 63.7 knots)
- Fourteen elevation angles
- 4.2 - minute update rate
- Velocity data within 230 km (124 nm) radius
- Hydrometeorological data within 230 km (124 nm) radius
- Reflectivity data within 460 km (248 nm) radius
- Separate surveillance and Doppler scans are taken at the three lowest elevation angles to improve clutter filtering performance, maximize the velocity accuracy and unambiguous interval
- Lowest seven elevation angles are contiguous or overlap.

**5.3.1.2.2 Strengths/Advantages.**

- Algorithms that depend on low-level data perform better with VCP 12
- Provides superior data in the lowest levels of the atmosphere,
- Fastest update rate of current VCPs, more nearly that of convection and precipitation persistence scales
- Provides better vertical definition of storm structure
- Better rainfall and snowfall estimates than for VCP 11 or 21 due to increased low-level scanning
- Improved storm characterization by algorithms
- Six elevation scans below 4° (overlapping beam sampling).

**5.3.1.2.3 Limitations.**

- Faster antenna rotation rates, especially above the lowest three elevation angles slightly degrades velocity and reflectivity estimates – as compared to VCP11 (fewer pulses in the sample estimate)
- Cone of silence above 19.5°
- Stored only at RPG and not at RDA, it must be downloaded to RDA
- Product availability is limited for some display systems due to communications bandwidth limitations.

**Table 5-2**
**VCP 12 Characteristics**

| Scan | | | | Surveillance | | Doppler PRF No. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Angle (°) | AZ Rate (°/sec) | Period (sec) | WF Type | PRF No. | # Pulses | 4 #Pulse | 5 #Pulse | 6 #Pulse | 7 #Pulse | 8 #Pulse |
| 0.5 | 21.150 | 17.02 | CS | 1 | 15 | -- | -- | -- | -- | -- |
| 0.5 | 25.000 | 14.40 | CD | -- | -- | 34 | 40 | 43 | 46 | 50 |
| 0.9 | 21.150 | 17.02 | CS | 1 | 15 | -- | -- | -- | -- | -- |
| 0.9 | 25.000 | 14.40 | CD | -- | -- | 34 | 40 | 43 | 46 | 50 |
| 1.3 | 21.150 | 17.02 | CS | 1 | 15 | -- | -- | -- | -- | -- |
| 1.3 | 25.000 | 14.40 | CD | -- | -- | 34 | 40 | 43 | 46 | 50 |
| 1.8 | 26.640 | 14.61 | B | 1 | 3 | 25 | 29 | 32 | 34 | 37 |
| 2.4 | 26.400 | 13.64 | B | 2 | 3 | 25 | 30 | 32 | 35 | 38 |
| 3.1 | 26.400 | 13.64 | B | 2 | 3 | 25 | 30 | 32 | 35 | 38 |
| 4.0 | 26.400 | 13.64 | B | 2 | 3 | 25 | 30 | 32 | 35 | 38 |
| 5.1 | 28.010 | 12.86 | B | 3 | 3 | 25 | 30 | 32 | 35 | 38 |
| 6.4 | 28.010 | 12.86 | B | 3 | 3 | 25 | 30 | 32 | 35 | 38 |
| 8.0 | 28.400 | 12.68 | CDX | -- | -- | 30 | 35 | 38 | 41 | 44 |
| 10.0 | 28.884 | 12.46 | CDX | -- | -- | 29 | 34 | 37 | 40 | 44 |
| 12.5 | 28.741 | 12.53 | CDX | -- | -- | 29 | 34 | 37 | 40 | 44 |
| 15.6 | 28.741 | 12.53 | CDX | -- | -- | 29 | 34 | 37 | 40 | 44 |
| 19.5 | 28.741 | 12.53 | CDX | -- | -- | 29 | 34 | 37 | 40 | 44 |

Notes:

- Default Doppler PRF numbers are underlined; Doppler PRFs are editable <7.0 degrees
- Sum of periods, which is "data collection" time = 238.24 secs / 3.97 mins. Transition times will vary
- Volume scan update time is about 4.2 minutes
- See Table 5-7 for PRF No. information.

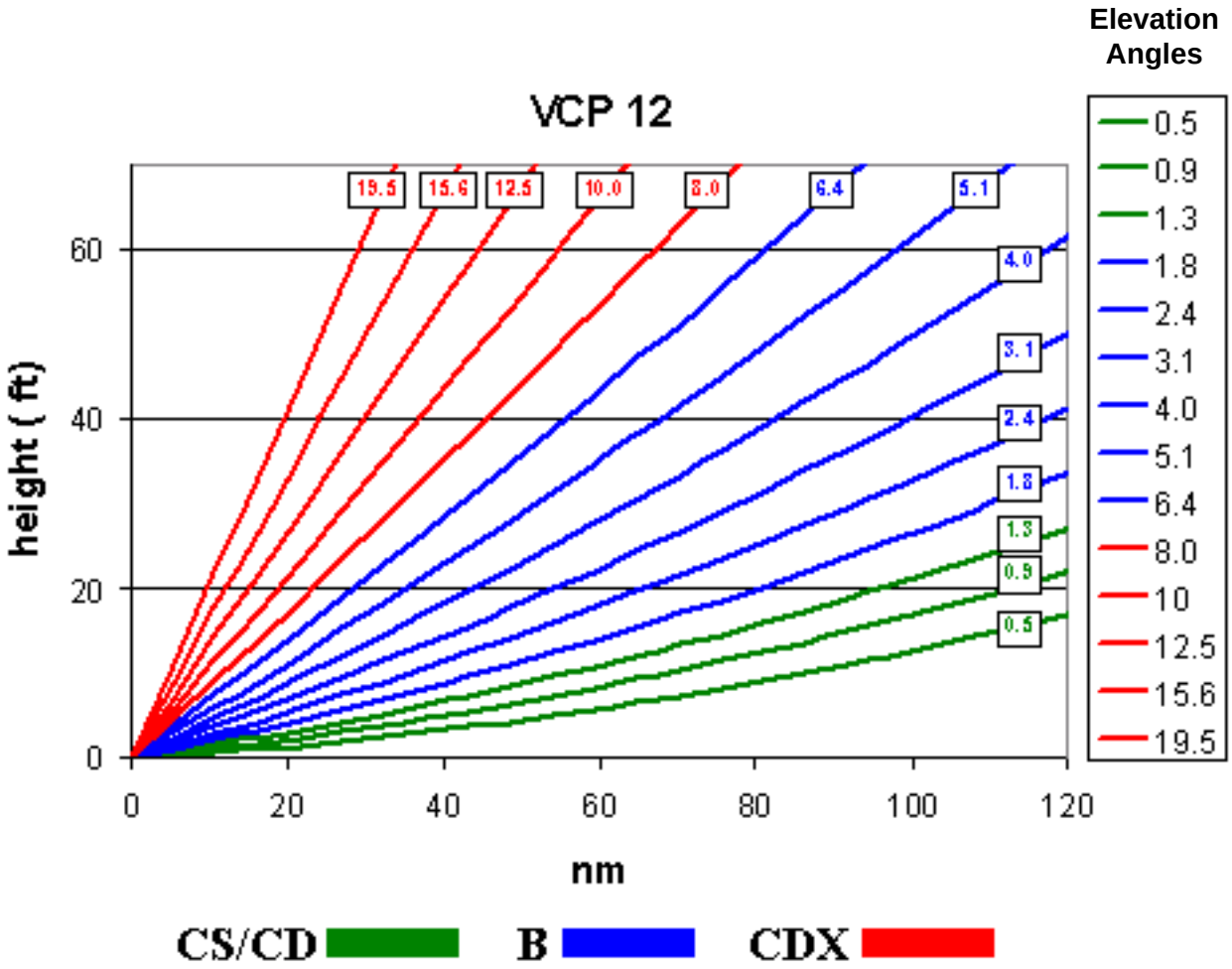


**Figure 5-2**
**VCP 12**

VCP 12 samples fourteen elevation angles in 4.2 minutes. The lowest three angles use "Split Cut" (CS/CD), middle angles use Batch (B), and higher angles use Contiguous Doppler (CDX) mode. The lines representing the beam elevation with height as a function of range assume standard atmospheric refraction of the beam.

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**5.3.2 Shallow Precipitation Group, VCP 21.** The purpose of VCP 21 is to optimize the volume-sampling interval for changing radar echo patterns but its primary application is for shallow precipitation. The VCP 21 scans nine elevation cuts in six minutes. (See Table 5-3 and Figure 5-3). Shallow precipitation is normally not severe, but rather encompasses stratiform rain and snow. Thus the contiguous scans from about 4.3° downward and the slower update rate are appropriate for shallow and slowly changing precipitation situations. If deep convection develops with significant storms, the user may wish to switch from VCP 21 to VCP 11 or VCP 12.

**5.3.2.1 Parameters.**

- Short pulse (1.57 μs PRF 318 to 1304 Hz)
- Unambiguous (Nyquist) velocity range 8 to 32.8 m $s^{-1}$ (15.5 to 63.7 knots)
- Nine elevation angles
- Six-minute update rate
- Velocity data within 230 km (124 nm) radius
- Hydrometeorological data within 230 km (124 nm) radius
- Reflectivity data within 460 km (248 nm) radius
- Separate surveillance and Doppler scans are taken at the three lowest elevation angles to improve clutter filtering performance, maximize the velocity accuracy and unambiguous interval
- Lowest five elevation angles are contiguous.

**5.3.2.2 Strengths/Applications.**

- The default precipitation VCP
- Slightly higher accuracy of estimates for reflectivity and velocity because of a larger number of pulses in the sample estimate.

**5.3.2.3 Limitations.**

- Coarse vertical resolution above the fifth elevation scan
- Degraded performance of algorithms that depend on volumetric information, relative to VCPs 11 and 12
- Pronounced banding of legacy Echo Tops and high layer legacy products
- Small-scale phenomena such as storm initiation may not be detected at the earliest opportunity
- Cone of silence above 19.5°.

**Table 5-3**
**VCP 21 Characteristics**

| Scan | | | | Surveillance | | Doppler PRF No. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Angle (°) | AZ Rate (°/sec) | Period (sec) | WF Type | PRF No. | # Pulses | 4 #Pulse | 5 #Pulse | 6 #Pulse | 7 #Pulse | 8 #Pulse |
| 0.5 | 11.339 | 31.92 | CS | 1 | 28 | -- | -- | -- | -- | -- |
| 0.5 | 11.360 | 31.87 | CD | -- | -- | 75 | 88 | 95 | 103 | 111 |
| 1.45 | 11.339 | 31.92 | CS | 1 | 28 | -- | -- | -- | -- | -- |
| 1.45 | 11.360 | 31.86 | CD | -- | -- | 75 | 88 | 95 | 103 | 111 |
| 2.4 | 11.180 | 32.38 | B | 2 | 8 | 59 | 70 | 76 | 82 | 88 |
| 3.35 | 11.182 | 32.37 | B | 2 | 8 | 59 | 70 | 76 | 82 | 88 |
| 4.3 | 11.185 | 32.36 | B | 2 | 8 | 59 | 70 | 76 | 82 | 88 |
| 6.0 | 11.189 | 32.35 | B | 3 | 12 | 59 | 70 | 76 | 82 | 88 |
| 9.0 | 14.260 | 25.39 | CDX | -- | -- | 59 | 70 | 76 | 82 | 88 |
| 14.6 | 14.322 | 25.27 | CDX | -- | -- | 59 | 41 | 76 | 82 | 88 |
| 19.5 | 14.415 | 25.11 | CDX | -- | -- | 59 | 41 | 76 | 82 | 88 |

Notes:

- Default Doppler PRF numbers are underlined; Doppler PRFs are editable <7.0 degrees
- Elevation Angle is based on antenna beamwidth of 0.95 degrees (i.e., mid-frequency beamwidth
- Sum of periods, which is "data collection" time = 332.80 secs / 5.55 mins. Transition times will vary
- Volume scan update time is about 6 minutes
- See Table 5-7 for PRF No. information.

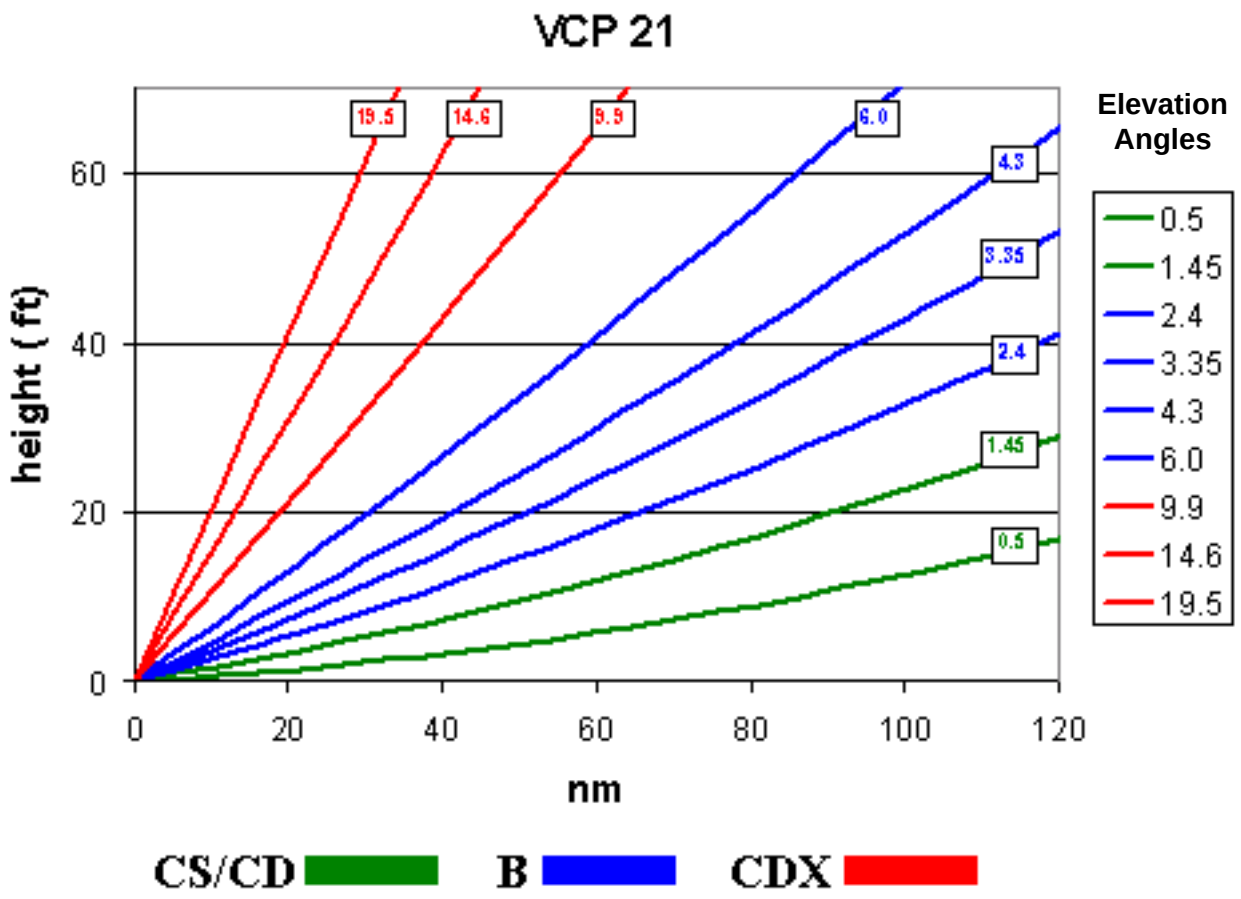


**Figure 5-3**
**VCP 21**

VCP 21 samples nine elevation angles in about 6 minutes. The lowest two angles use "Split Cut" (CS/CD), middle angles use Batch (B), and higher angles use Contiguous Doppler (CDX) mode. The lines representing the beam elevation with height as a function of range assume standard atmospheric refraction of the beam.

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**5.3.3 Multiple PRF Dealiasing Algorithm Group, VCP 121.** The purpose of VCP 121 is to provide rapid volume sampling updates to monitor changing radar echo patterns while at the same time significantly reducing the amount of range folded (50-70% reduction) and incorrectly dealiased velocity data. This VCP is intended to be a short-term solution to the problem of both range and velocity folding. A hardware solution is under development and will be fielded some time after the Open Radar Data Acquisition (ORDA) is deployed.

The VCP 121 is the Multiple PRF Dealiasing Algorithm (MPDA) (see Part C of this handbook) version of VCP 21 (Section 5.3.2). To accomplish the dealiasing goal, VCP 121 uses multiple Contiguous Doppler (CD) rotations at the lower elevation scans. For example, for the 0.5° and 1.5° elevations, the Split Cut technique includes one Contiguous Surveillance (CS) scan and three CD scans (PRFs 8, 6 and 4). The PRF 8 is used first for range unfolding at the RDA. Then data from PRFs 6 and 4 are used at the RPG for additional range unfolding and velocity dealiasing. Similarly, two PRFs (6 and 4) are used at 2.4° and 3.3° to range unfold and velocity dealias the data in the RPG.

VCP 121 can be effective in most meteorological situations. However, due to the increased scanning time required to complete the lower elevations, with respect to VCP 12, VCP 121 may not be appropriate for fast moving or rapidly evolving convective storms, but is espeically useful for widespread precipitation and high wind velocities (e.g., tropical cyclones). (See Table 5-4 and Figure 5-4.)

**5.3.3.1 Parameters.**

- Short pulse (1.57 μs PRF 318 to 1304 Hz)
- Unambiguous (Nyquist) velocity range 8 to 32.8 m $s^{-1}$ (15.5 to 63.7 knots)
- Nine elevation angles
- Five-minute update rate
- Velocity data within 230 km (124 nm) radius
- Hydrometeorological data within 230 km (124 nm) radius
- Reflectivity data within 460 km (248 nm) radius
- Separate surveillance and Doppler scans are taken at the two lowest elevation angles to improve clutter filtering performance, maximize the velocity accuracy and unambiguous interval
- Separate surveillance and Doppler scans are taken at the two lowest elevation angles to improve clutter filtering performance, maximize the velocity accuracy and unambiguous interval.

**5.3.3.2 Strengths/Applications.**

- Provides early implementation of the MPDA thus, providing base data with far less range overlaid echoes and velocity aliased data.
- Recommended for storms with widespread echoes and very strong winds such as hurricanes and intense extratropical cyclones.

**5.3.3.3 Limitations.**

- Lower accuracy of estimates (based on fewer samples) as compared to VCP 21
- May not be appropriate for fast moving or rapidly evolving convective storms
- Cone of silence above $19.5^{o}$
- Should be used with caution for rapidly changing storms or deep convective storms and only when extensive range folding is a problem.

**Table 5-4**
**VCP 121 Characteristics**

| Scan | | | | Surveillance | | Doppler PRF No. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Angle (°) | AZ Rate (°/sec) | Period (sec) | WF Type | PRF No. | # Pulses | 4 #Pulse | 5 #Pulse | 6 #Pulse | 7 #Pulse | 8 #Pulse |
| 0.5 | 29.301 | 12.29 | CS | 1 | 11 | -- | -- | -- | -- | -- |
| 0.5 | 29.795 | 12.08 | CD | 8 | -- | 28 | 33 | 36 | 39 | 43 |
| 0.5 | 27.400 | 13.14 | CD | 6 | -- | 31 | 37 | 40 | 43 | 46 |
| 0.5 | 21.402 | 16.82 | CD | 4 | -- | 40 | 47 | 51 | 55 | 59 |
| 1.45 | 29.300 | 12.29 | CS | 1 | 11 | -- | -- | -- | -- | -- |
| 1.45 | 29.795 | 12.08 | CD | 8 | -- | 28 | 33 | 36 | 39 | 43 |
| 1.45 | 27.400 | 13.14 | CD | 6 | -- | 31 | 37 | 40 | 43 | 46 |
| 1.45 | 21.402 | 16.82 | CD | 4 | -- | 40 | 47 | 51 | 55 | 59 |
| 2.4 | 19.205 | 18.75 | B | 1,8 | 6 | 27 | 32 | 34 | 37 | 40 |
| 2.4 | 27.400 | 13.14 | CD | 6 | -- | 31 | 37 | 40 | 43 | 46 |
| 2.4 | 21.402 | 16.82 | CD | 4 | -- | 40 | 47 | 51 | 55 | 59 |
| 3.35 | 21.600 | 16.67 | B | 2,8 | 6 | 28 | 33 | 35 | 38 | 40 |
| 3.35 | 27.400 | 13.14 | CD | 6 | -- | 31 | 37 | 40 | 43 | 46 |
| 3.35 | 21.402 | 16.82 | CD | 4 | -- | 40 | 47 | 51 | 55 | 59 |
| 4.3 | 16.304 | 22.08 | B | 2,4 | 6 | 40 | 48 | 52 | 56 | 61 |
| 4.3 | 29.499 | 12.20 | CD | 7 | -- | 29 | 34 | 37 | 40 | 44 |
| 6.0 | 20.204 | 17.82 | B | 3,5 | 6 | 34 | 40 | 43 | 47 | 51 |
| 9.9 | 29.499 | 12.20 | CD | 7 | -- | 29 | 34 | 37 | 40 | 43 |
| 14.6 | 29.795 | 12.08 | CD | 8 | -- | 28 | 33 | 36 | 39 | 43 |
| 19.5 | 29.795 | 12.08 | CD | 8 | -- | 28 | 33 | 36 | 39 | 43 |

Notes:

- Default Doppler PRF numbers used for each rotation are underlined; Doppler PRFs are ***not*** editable
- Sum of periods, which is "data collection" time = 292.46 secs / 4.87 mins. Transition times will vary
- Volume scan update time is about 5 minutes
- See Table 5-7 for PRF Number information
- VCP121 has the VCP21 elevation angles with the MPDA.

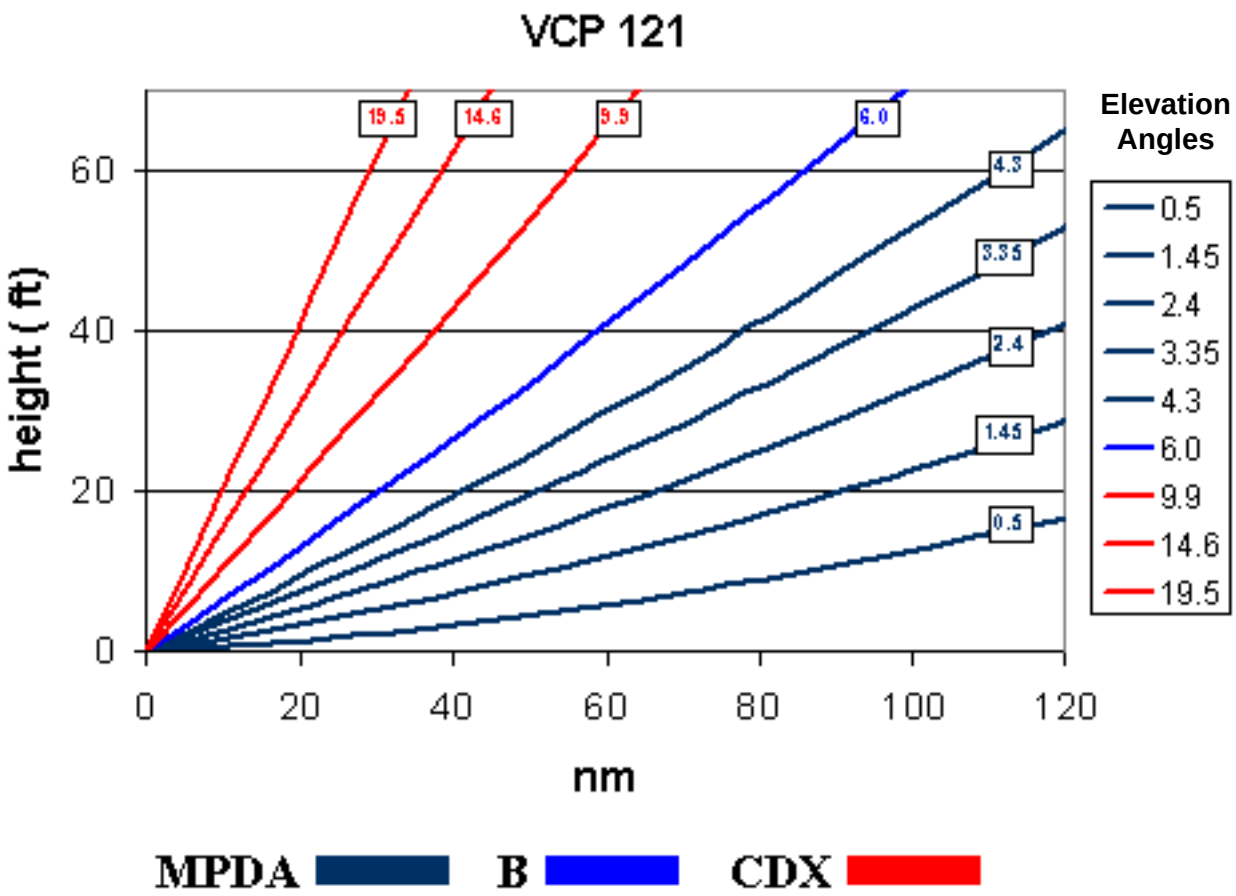


**Figure 5-4**
**VCP 121**

VCP 121 samples nine elevation angles (20 antenna rotations) in 5 minutes. The lowest five angles apply the MPDA technique, while 6.0 uses Batch (B), and the higher angles use Contiguous Doppler (CDX) mode. Multiple CD rotations, one CS and thee each at the lowest two angles, and two at each of the next two elevation angles. Returns from the 3 wave-forms are used in the RPG for range unfolding. The lines representing the beam elevation with height as a function of range assume standard atmospheric refraction of the beam.

**5.3.4 Clear Air Group, VCPs 31 and 32.** The purpose of the VCPs (31 and 32) in this group is to scan the atmosphere with enhanced sensitivity in order to detect low signal echoes (e.g., refractive index gradients, smoke, insects). In practice the VCPs are used when no precipitation is detected or when only snow or very light precipitation is detectable.

**5.3.4.1 Clear Air Group - Long Pulse VCP 31.** The purposes of VCP 31 are to: 1) detect early formation of convective precipitation, 2) detect air mass discontinuities, 3) determine the depth of the mixing layer, 4) monitor precipitation onset, and 5) obtain wind profiles to supplement soundings. (See Table 5-5 and Figure 5-5.)

**5.3.4.2 Parameters.**

- Long pulse (4.7 μs PRF 318 to 452 Hz)
- Unambiguous (Nyquist) velocity range 8 to 12.4 m $s^{-1}$ (15.5 to 24.1 knots)
- Five elevation angles
- Ten-minute update rate
- Surveillance coverage of the lowest elevation angle within 460 km (248 nm) radius
- Hydrometeorological data within 230 km (124 nm) radius
- Separate surveillance and Doppler PRF on lowest three elevation angles.

**5.3.4.3 Strengths/Applications.**

- Long pulse provides maximum sensitivity to low signals because of the larger number of sample estimates per volume sample
- Excellent for detection of weak returns such as boundaries, fronts, ice crystals and non-meteorological returns such as smoke and insects and birds
- Algorithms can function in clear air mode
- Often used effectively for dry snow situations.

**5.3.4.4 Limitations.**

- May not provide unambiguous estimates of the velocity within a low-level jet due to bird contamination
- Lack of vertical resolution will restrict usefulness in sampling storms or in supplementing upper air soundings
- Velocity dealiasing failures occur more frequently, except during weak wind conditions because of the large percentage of velocity dealiasing errors due to a small Nyquist co-interval
- Cone of silence above $4.5^{o}$
- Lower spatial resolution (750 m pulse width vs. 250 m pulse width for short pulse)
- Volume scan algorithms requiring the full volume data will not function well.

**Table 5-5**
**VCP 31 Characteristics, Long Pulse**

| Scan | | | | | |
|---|---|---|---|---|---|
| Angle (°) | AZ Rate (°/sec) | Period (sec) | WF Type | PRF No. | # Pulses |
| 0.5 | 5.039 | 71.83 | CS | 1 | 63 |
| 0.5 | 5.039 | 71.52 | CD | 2 | 87 |
| 1.50 | 5.040 | 71.82 | CS | 1 | 63 |
| 1.50 | 5.062 | 71.52 | CD | 2 | 87 |
| 2.50 | 5.041 | 71.81 | CS | 1 | 63 |
| 2.50 | 5.062 | 71.50 | CD | 2 | 87 |
| 3.50 | 5.063 | 71.49 | CDX | 2 | 87 |
| 4.50 | 5.065 | 71.47 | CDX | 2 | 87 |

Notes:

- PRF #2 is used for CD mode throughout this VCP and is ***not*** editable
- Sum of periods, which is "data collection" time = 572.96 secs / 9.55 mins. Transition times will vary
- Volume scan update time is about 10 minutes
- See Table 5-7 for PRF No. information.

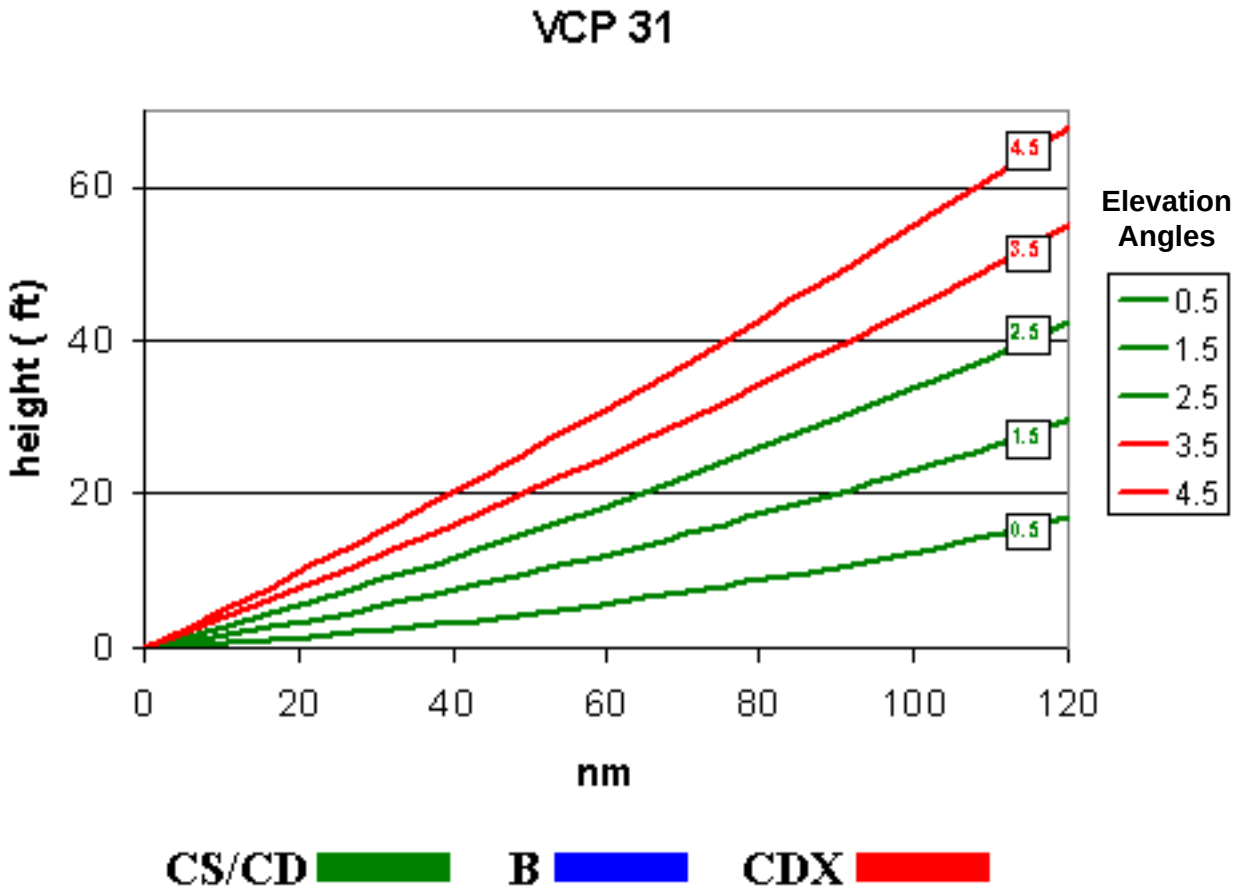


**Figure 5-5**
**VCP 31**

VCP 31 samples five elevation angles (0.5, 1.5, 2.5, 3.5, and 4.5 degrees) in 10 minutes. The lowest two angles use "Split Cut" (CS/CD), and highest two angles use Contiguous Doppler (CDX) mode. The lines representing the beam elevation with height as a function of range assume standard atmospheric refraction of the beam.

**5.3.4.2 Clear Air Scan Short Pulse VCP 32.** The purpose of VCP 32 is the same as that described for VCP 31 in Section 5.3.4.1. (See Table 5-6 and Figure 5-6.)

**5.3.4.2.1 Parameters.**

- Short pulse (1.57 μs; PRF 318 to 1304 Hz)
- Unambiguous (Nyquist) velocity range 8 to 28.2 m $s^{-1}$ (15.5 to 54.8 knots)
- Five elevation angles
- Ten-minute update rate
- Surveillance coverage of the lowest elevation angle within 460 km (248 nm) radius
- Hydrometeorological data within 230 km (124 nm) radius
- Separate surveillance and Doppler PRF on the two lowest elevation angles.

**5.3.4.2.2 Strengths/Applications.**

- Clear air sampling as with VCP 31 but with short pulse
- Fewer velocity dealiasing failures than with VCP 31
- Almost as many phenomena detected as detected with VCP 31.

**5.3.4.2.3 Limitations.**

- Somewhat less sensitive than VCP 31
- Lack of vertical resolution will restrict usefulness in sampling storms or in supplementing upper air soundings
- Cone of silence above $4.5^{o}$ elevation
- Algorithms requiring the full volume data will not function well.

**Table 5-6**
**VCP 32 Characteristics, Short Pulse**

| Scan | | | | Surveillance | | Doppler PRF No. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Angle (°) | AZ Rate (°/sec) | Period (sec) | WF Type | PRF No. | # Pulses | 4 #Pulse | 5 #Pulse | 6 #Pulse | 7 #Pulse | 8 #Pulse |
| 0.5 | 4.961 | 72.97 | CS | 1 | 64 | -- | -- | -- | -- | -- |
| 0.5 | 4.544 | 79.66 | CD | -- | -- | 188 | 220 | 238 | 256 | 278 |
| 1.50 | 4.961 | 72.96 | CS | 1 | 64 | -- | -- | -- | -- | -- |
| 1.50 | 4.544 | 79.66 | CD | -- | -- | 188 | 220 | 238 | 256 | 278 |
| 2.50 | 4.060 | 89.15 | B | 2 | 11 | 188 | 220 | 238 | 256 | 278 |
| 3.50 | 4.061 | 89.13 | B | 2 | 11 | 188 | 220 | 238 | 256 | 278 |
| 4.50 | 4.063 | 89.10 | B | 2 | 11 | 188 | 220 | 238 | 256 | 278 |

Notes:

- Default Doppler PRF numbers are underlined; Doppler PRFs are editable
- Sum of periods, which is "data collection" time = 572.63 secs / 9.54 mins. Transition times will vary
- Volume scan update time is about 10 minutes
- See Table 5-7 for PRF No. information.

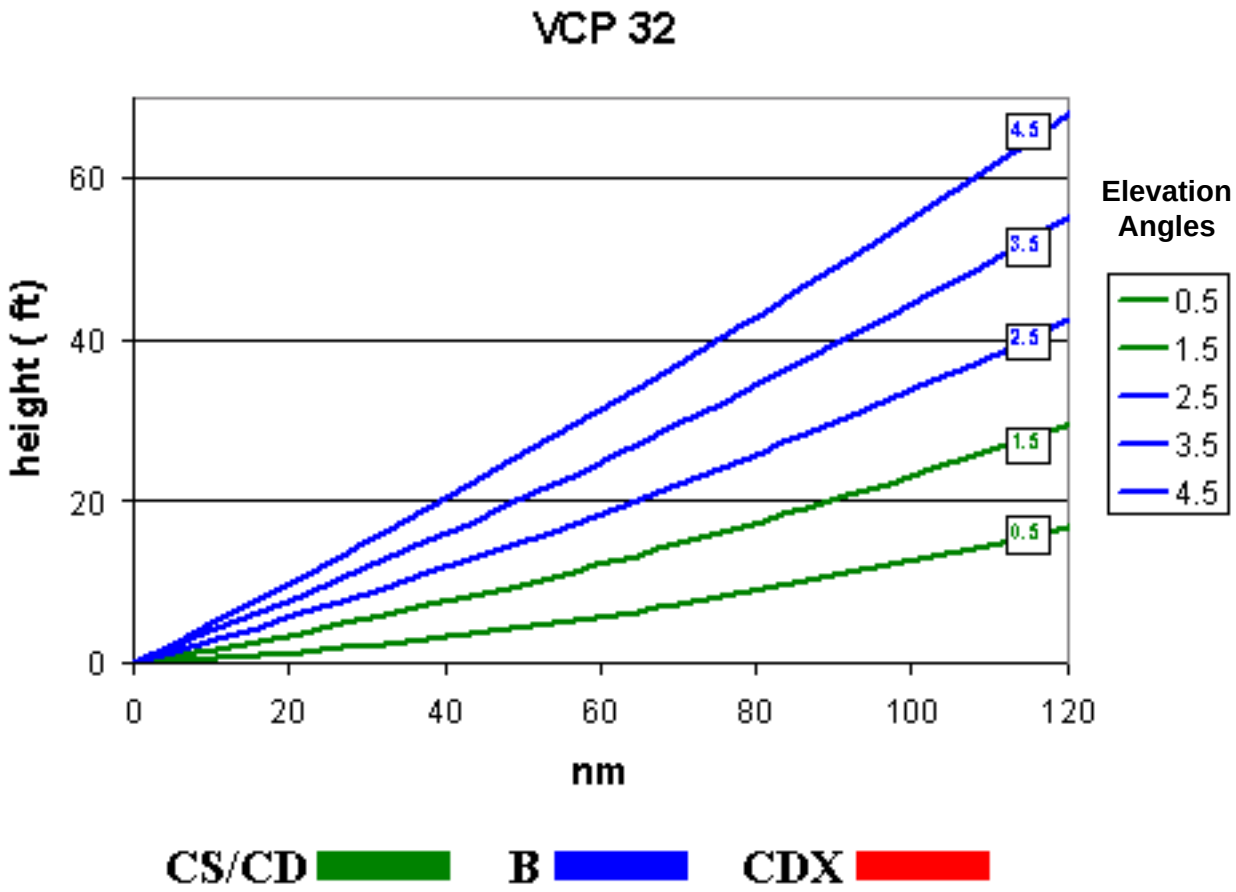


**Figure 5-6**
**VCP 32**

VCP 32 samples five elevation angles (0.5, 1.5, 2.5, 3.5, and 4.5 degrees) in 10 minutes. The lowest two angles use "Split Cut" (CS/CD), and highest three angles use Batch (B) mode. The lines representing the beam elevation with height as a function of range assume standard atmospheric refraction of the beam.

**5.4 Mode Selection and Deselection Criteria.** Selection of operational modes is no longer related to WSR-88D precipitation estimation procedures since a new precipitation algorithm was deployed with RPG Build 5 (Section 3.3.1). The Precipitation Detection Function (PDF) is designed to automatically determine if precipitation is occurring within 124 nm of the radar. The PDF examines reflectivity returns from the elevation angles up to $4^{o}$, and compares them to the Precipitation Rate Threshold and an Area Threshold, which is the sum of the Precipitation Area and Nominal Clutter Area Thresholds. One of the following three Precipitation Categories is assigned each volume scan depending on which combination of thresholds are met or exceeded:

Category 0 – No precipitation detected in the past hour.
Category 1 – Significant precipitation detected in the past hour.
Category 2 – Light precipitation detected in the past hour.

When the Precipitation Category is 0 or 2, any VCP can be selected. When the Precipitation Category is 1, the radar can only be operated in a Precipitation Mode.

**5.4.1 Clear Air Mode to Precipitation Mode.** The radar initiates processing in the Clear Air Mode. The mode is automatically switched to the Precipitation Mode when Category 1 precipitation is detected. At times, however, such as early, midlevel formation of convective echoes, the user may choose to enter the Precipitation Mode manually.

**5.4.2 Precipitation Mode to Clear Air Mode.** A return to the Clear Air Mode must be manually selected at the MSCF. Typically, is done after one hour or more of no significant precipitation echoes.

**5.5 Volume Coverage Pattern Adaptable Parameters.**

Most characteristics of operational VCPs are fixed; however, operators are able to make some parameter changes. One changeable parameter is the Doppler PRF for a selectable range of elevation cuts. An exception exists for VCP 31 and VCP 121 whose Doppler PRFs are set, and not modifiable, to ensure proper processing. For all other VCPs, users can control three sector boundaries to allow localized PRF changes. Another changeable VCP parameter is the velocity increment. A rarely used option is the parameter change of Signal to Noise Ratio (SNR). Each type of change is discussed below as well as the fixed characteristics of selectable PRFs.

**5.5.1 Doppler PRF Changes**. Users can select the best PRF in order to minimize the amount of obscuration for a specific meteorological target (e.g., the maximum unambiguous range can be modified to a limited extent by changing the Doppler PRF). Normally, the Auto PRF function will minimize the amount of obscuration for an entire elevation cut, however, velocity values within a particular storm or region of interest might be range folded. In those instances, an operator can change the PRF to alter the unambiguous range and thus reveal velocity values that were previously overlaid.

**5.5.2 Velocity Increment Changes**. The Velocity (Measurement) Increment (VMI) selection defines the resolution of the available base velocity data. Velocity measurement

increments are available for resolutions of 0.97 knots (0.5 m/s) and 1.94 knots (1.0 m/s). Radial wind velocities can be viewed ranging from ±123 knots using the default VMI resolution of 0.97 knots. In order to view radial wind speeds ranging from ±246 knots, the VMI resolution may be changed to 1.94 kt resolution. This is usually done when a tropical storm approaches or when very strong divergence at the summit of convective storms occurs where the flow is sometimes greater than 200 knots. When 1.94 knots is selected as the VMI, the velocity resolution reduces from a 1 knot increment to a 2 knot increment. The selection of a velocity increment also dictates which velocity display threshold table will be used to quantize the velocity data for display.

**5.5.3 Signal to Noise Ratio (SNR) Changes.** The SNR is the signal power divided by the noise power as expressed in decibels (dB). Users can increase the effectual SNR of surveillance cuts to temporarily remove noise from displays if performance is degraded. In unusual circumstances, users can lower the effectual SNR to observe weak target signals such as plumes of smoke or dust. Changing the effectual SNR does not actually change radar signal processor characteristics or the true SNR but does affect display properties.

**5.5.4 PRF Characteristics.** Available PRFs are coded with PRF numbers ranging from 1 through 8 (Table 5-7). In addition, each WSR-88D uses one of five sets known as Delta PRF Indices (PRI) A through E that supply small shifts to numbered PRFs. Small shifts in PRF avoid interference with neighboring radars. Over 90 percent of operational WSR-88D sites use Delta PRI Set C. The unambiguous range and Nyquist Velocity for each PRF of Delta PRI C are shown in the following table.

**Table 5-7**
**An Example Of Typical WSR-88D PRF Characteristics Used Operationally**
**(Delta PRI Set C)**

| PRF No. | PRF ($s^{-1}$) | $R_{max}$ (nm/km) | $V_{max}$ (kts/$ms^{-1}$) |
|---|---|---|---|
| 1 | 322 | 252/467 | 16/8 |
| 2 | 446 | 181/336 | 22/11 |
| 3 | 644 | 126/233 | 32/16 |
| 4 | 857 | 95/176 | 43/22 |
| 5 | 1014 | 80/148 | 51/26 |
| 6 | 1095 | 74/137 | 55/28 |
| 7 | 1181 | 69/128 | 59/30 |
| 8 | 1282 | 63/117 | 64/33 |