P2.6

COMMON BASEDATA FORMAT SUPPORTS RESEARCH AND OPERATIONAL NEXRAD RADAR REQUIREMENTS

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1. INTRODUCTION

Following the completion of the Open Radar Data Acquisition (ORDA) upgrade to the operational NEXRAD network, the next two phases of system upgrades will be built on the new capabilities provided by the advanced signal processor and digital receiver. One of the first new capabilities will include an ORDA enhancement known as "super-resolution" that provides 0.5 degree (versus 1.0 degree) azimuthal radial sampling at selected lower elevations, extension of Doppler moments from 230 km to 300 km, and 0.25 km reflectivity samples instead of 1 km (Saffle et al. 2006, Torres and Curtis 2006). The more extensive upgrade will be the addition of dual polarization capability that requires major hardware modifications to the antenna subsystem, addition of a second receiver and processor to the ORDA, and software infrastructure changes to the ORDA and Open Radar Product Generator (ORPG) (Saffle et al. 2006, Schuur et al. 2002). Both of these upgrades require changes to the basic basedata format that has been relatively constant since the beginning of the NEXRAD program and is used extensively throughout the community.

2. BASIS FOR GENERIC FORMAT

Initially, minimal changes to the basedata format were envisioned for the addition of super-resolution capability. It was felt the existing basedata format could easily be expanded for adding the required changes for doubling the number of radials and expanding the maximum range. However, for the dual polarization upgrade, it was obvious a major change was required to the basedata format. So, in parallel with the super-resolution prototyping effort, a coordinated tri-agency NEXRAD effort was begun to accelerate the transfer of the dual polarization capability demonstrated at NSSL on their modified prototype NEXRAD radar known as KOUN. One of these planned steps included providing dual polarization data to evaluators and algorithms developers at an early stage before every detail was finalized. An effort was begun to design changes to the NEXRAD basedata format to include the additional dual polarization data information consisting of three new data moments and associated calibration information.

Besides simple expansion of the existing format, several archiving alternatives were examined that included previous efforts by the radar community (Barnes 1980, Lee and Oye 1994, Flanigan et al 2005). Additionally, the Unidata NETCDF system was examined for use as an archive format for NEXRAD (Rew et al. 2006). Besides the obvious required expansion of the format, there were other requirements for maintaining certain compatibility features with the existing baseline format that had to be satisfied.

One of the major requirements was for a flexible yet maintainable and simple format to handle some of the uncertainty during the development phase. Because of the stage of the dual polarization prototyping, there were unknown factors such as required data precision, ranges of data, calibration

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parameters, etc. Another requirement was for an internal data structure for each radial that facilitated high compression of the data. Based on those requirements, a new message type 31 was developed for the super-resolution and dual polarization basedata using past knowledge and the flexibility requirement to handle many of the unplanned changes as they developed. The plan was to freeze the format while the prototyping was still in progress. By doing so, the developers of the ingest product generator computer and the algorithm developers could proceed with their development with any parameter additions or rescaling being handled by the flexible format and the Application Programming Interface (API).

With those requirements set, the WSR-88D generic format was born (ICD Research 2006). For historians, it should be noted the basic structure follows similarities of the exchange format devised by a group committee composed of weather radar community personnel (Barnes et al. 1980). During the development and refinement of the new format, it was observed why the normal best practice for developing an Interface Control Document (ICD) is to simply document the "as built" format. It was very difficult to design and anticipate changes as the prototyping effort progressed and more information was obtained. Undoubtedly, there will be some minor changes in the format as the dual polarization effort reaches a production level but the design should be flexible enough to accommodate these without major API changes.

3. GENERIC FORMAT STRUCTURE

Once the technology issues behind the super-resolution implementation were solved, the Super-Resolution Integrated Working Team decided to use the generic format ICD for inclusion of super resolution data starting in Build 10.0. Because of the flexibility and robustness of the dual polarization generic format, there were no changes required to the basic generic data block descriptors.

In order to facilitate the independent testing of both features and to expedite the transfer of this technology to the production NEXRAD system, a decision was made to formulate an extension to the legacy format to accommodate the increased resolution data and the added moment data. Additionally, it was an opportunity to record additional housekeeping information with the meteorological basedata to facilitate the future real-time and archival value of the data for research and operational use. The advantages of this extra effort to standardize the NEXRAD basedata format for both research and operational use were envisioned to have benefits in several related areas. First, the ability to develop and rapidly implement and test new signal processing and algorithm techniques on NSSL radars could be accelerated by minimizing the effort required by scientists for accessing the new data types. Secondly, a common basedata format could be used within NSSL and by other research laboratories and universities to exchange datasets that have potential NEXRAD use, and thereby, again accelerate the transfer of advanced techniques to the NEXRAD production system. And thirdly, the use of the common format, along with common access software, will lessen development efforts by the community when new radar techniques are implemented and tested.

For a pulsed scanning radar such as the WSR-88D, data are collected in a radial mode with each record having a unique azimuth and elevation angle. Since the WSR-88D operates in a scanning strategy where sweeps are made at constant elevation with changing azimuth, certain constant parameters can be recorded only once per elevation sweep or whenever parameters change. Each volume is expected to have at least one constant Volume block but all other uses of the elevation, sector, or radial constant blocks is totally flexible in the generic research form. Each radial of sampled data contains these basic blocks (see figure 1):

- Message Header Block
- Data Header Block
  - Generic Data Constant Blocks
  - Generic Data Moment Blocks

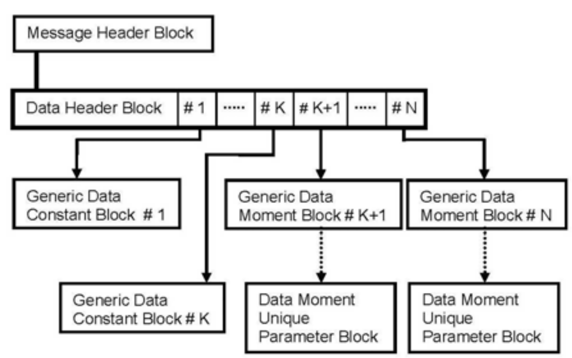

Figure 1. One radial of data using the research version ICD for a generic radar

Message Header Block

Every message type within the WSR-88D is preceded by this block type and contains information about the type of message following as well as the segmentation size and number of segments composing the message. With the increased bandwidths now available and advanced communication protocols, a large segmentation size is used so that each data radial is stored within one segment as large as 65636 halfwords, more than sufficient for any known radar application.

- Message Size
- RDA Redundant Channel
- Message Type
- I.D. Sequence Number
- Julian Date
- Milliseconds of Day
- Number of Message Segments
- Message Segment Number

Data Header Block

Each data header block contains information unique to the radial as well as pointers to data moment blocks and any data constant block information within that message.

- Radar identifier (ICAO)
- Collection time
- Julian date
- Azimuth number
- Azimuth angle
- Azimuth resolution spacing
- Radial status
- Elevation number
- Cut Sector number
- Elevation angle
- Radial spot blanking status
- Azimuth indexing mode
- Data block count

Generic Moment Data Block

The generic moment data block has information describing each data moment characteristics and containing the actual encoded data moment information for one radial:

- Data block type (Data moment designated as "D")
- Data moment name such as "VEL" for velocity [any 3 character string is allowed]
- Number of data moment gates in the radial
- Range to first gate
- Range sample interval
- Signal Noise Threshold used within ORDA
- Size of data field for moment estimate
- Scaling and Offset parameters used to convert from integer to engineering units
- Array containing the same data moment type along one radial (constant elevation and azimuth)

Through knowledge of each data moment's physical range and attainable measured accuracy, the Scaling and Offset values can be determined for encoding data into the optimal number of bits for each range gate estimate. For retrieval efficiency, all data sizes are rounded to 8 bit multiples but in order to improve compression possibilities, only the required number of data bits are encoded to guarantee decoded data meets the required accuracy and range.

The Scale and Offset values are used in these data relationships:

Recorded Value = Scale * True Value - Offset

True Value = (Recorded Value + Offset) / Scale

For example, the velocity moment has a range of -63.5 to +63.0 m/s with Scale set to 2.0 and Offset set to 129.0 using a data field length of 8 bits to map to a value from 2 to 255. All data moments use zero to indicate below SNR threshold and one to indicate range folding.

Generic Data Constant Block

The generic data constant block contains information constant within a specified scanning space:

- Data block type (Data Constant Block designated as "R")
- Data constant block type (Volume, Elevation, Sector, Radial, and future types)
- Size of constant block
- Unique parameters within this data block

4. PRODUCTION DUAL POLARIZATION FORMAT STRUCTURE

For the initial production version of the WSR-88D, a very specific subset of the generic format is implemented (ICD Production 2006) as shown in Figure 2:

For simplicity in implementation, clarity of description, and protection from data transmission record loses, each radial data block will contain a volume, elevation, and radial constant block. Moment data blocks will be those six specified, viz., reflectivity, velocity, spectral width, and the new dual polarization data moments of differential reflectivity, differential phase, and correlation coefficient. If any data moments are not measured for a particular

Volume Coverage Pattern (VCP) for any radial, the data moment pointers can be dropped or set to zero. However, the Volume, Elevation, and Radial constant blocks will always be present along with the recorded data moments.

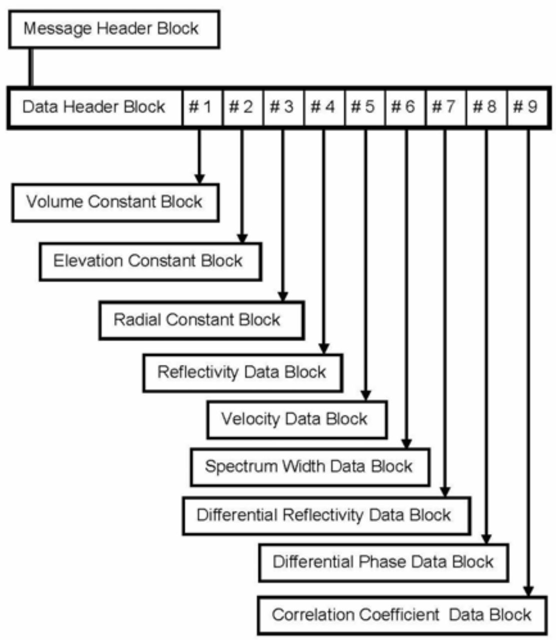

Figure 2. One radial of dual polarization data using the production verision ICD

Volume Constant Data Block

The volume constant data block contains information that is assumed constant over the entire volume scan:

- Version Number
- Latitude and longitude of the radar
- Radar site height above sea level
- Feedhorn height above sea level
- Calibration constant
- Horizontal and vertical transmitter power
- System differential reflectivity
- Initial system differential phase
- Volume Coverage Pattern

Elevation Constant Data Block

The elevation constant data block contains information that is assumed constant over the entire elevation scan:

- Atmospheric attenuation factor

Radial Constant Data Block

The radial constant data block contains information that is assumed constant only over this radial:

- Unambiguous range
- Nyquist velocity
- Noise levels for the horizontal and vertical channels

Because the NEXRAD is a baselined configuration managed system, this new production format will become a permanent part of the Interface Control Document that formally describes the basedata format. As new fields and parameters are added to the format for research or prototyping use, the research version of the ICD will be updated and maintained separately to track and fully document changes for data access by others. Once new techniques targeted for possible implementation into the NEXRAD baseline system are accepted by the NEXRAD tri-agencies, changes to the baseline ICD will be submitted through the standard configuration management process for comment and tri-agency review before becoming part of the baseline.

5. FUTURE USES OF GENERIC FORMAT

The first application of the generic format, beyond the use for the two NEXRAD enhancements, is for transmitting and recording data generated by the phased array radar at the National Weather Radar Testbed located at NSSL. Because of the radar's non-traditional scanning strategies, additional data blocks will be needed to record data accurately and efficiently. The capability of rapid electronic steering will allow data collected in regions of interest in a very short time with the requirement for temporal and spatial grouping in the most efficient manner. New data moment blocks can be defined for spatial grouping of these radar moments as well as new data constant blocks can be defined for grouping common parameters. As described above in Section 3, the generic format allows adding new blocks with minimal changes required to existing data access software.

6. CONCLUSIONS

The benefits of recording radar data in this new flexible generic format will allow more rapid technology transfer from government sponsored research organizations to the operational NEXRAD baseline. Furthermore, since the basic production format will be supported on the operational baseline ORPG by the Radar Operations Center (ROC) and expanded as new features are added, the use of an ORPG clone using the Common Operations and Development Environment (CODE) (Ganger et al. 2002) for algorithm development and testing will further expedite the transfer of new science to real-time baseline operations. The ROC will maintain current Application Programming Interfaces running within the ORPG infrastructure to allow standardized access to the basedata and constant parameters as they are expanded. These updated access routines will be available from the NWS website via the standard CODE package distributed when each new software build is released to the field.

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