Sheldon L. Katz, James V. Melody, Timothy Maese, Timothy W. Hodge, Wayne Sabin,
Vladimir Chekalin, Christopher Savcak, John Halenar and William Hock
Lockheed Martin NE&SS-Surface Systems, Moorestown, New Jersey

1. INTRODUCTION

The National Weather Radar Testbed (NWRT) will provide the first phased array radar available on a full time basis to the meteorological research community. As such it is designed to support a variety of applications, as indicated in Table 1.

Table 1 Activities Supported By NWRT	
General Category	Activity Examples
Meteorological Research	Convective Storms Turbulent Flow Rapid update model initialization Dual Doppler
Radar Investigations	Spatial/temporal resolution tradeoffs Clutter mapping and cancellation Phased array design tradeoffs Advanced scan techniques
Automated Algorithm Development	Hazardous weather recognition Forecasting and nowcasting Adaptive scan

NWRT uses a SPY-1A phased array antenna, loaned to NOAA by the U.S. Navy, on a movable pedestal to provide full hemispherical coverage. As a research tool, NWRT is designed to have expandable capabilities. Thus the system includes dual channel analog and digital receivers and provides variable data sampling rates and a programmable digital signal processor. An overview of the NWRT is provided in Forsyth, et. al. (2002).

2. Radar Control Architecture

The radar control structure for NWRT was designed to provide the research community a great deal of flexibility, allowing the user to design the scan pattern, select the coverage region, select the ground clutter filter and optimize the radar dwell for reflectivity or velocity estimation. In addition, the user can program rapid sector scans in any desired sequence and execute scans while the antenna is moving.

The specific radar commands issued to instruct the radar to transmit, receive, steer the radar beam and define the beam processing are included in a radar stimulus command or STIM. A single STIM command can be used to perform some radar functions, such as moving the pedestal or initiating a radar data collection dwell. The single STIM could be repeated[*] sixteen times by proper setting of control fields in the STIM to generate a pulse Doppler data collection sequence. The term "STIM stack" refers to a file with many STIM commands, to be executed in sequence. The result of executing the commands in a STIM stack will generally be the execution of a radar scan over some user-defined volume and generation of the weather spectral moments. Some representative radar parameters controlled by the STIM are given in Table 2.

Table 2 Representative STIM Parameters	
Type Of Parameter	Examples
Radar Dwell Control	Pulse Repetition Interval Waveform (Pulsewidth) Beam Steering Control Number Of Pulses For Tx Data Collection Window
Processing Control	Receive Channel Select I/Q Sampling Rate Processing Mode Matched Filter Range Averaging PRI Stagger Equal/Unequal Subpulses
Pedestal Control	Pedestal Rate Pedestal Position

Using the processing control parameters one can select either 10 MHz, 5 MHz or 2.5 MHz sampling rate, and from among pulse pairs, pulse Doppler or reflectivity only type processing.

User definition of the STIM stack parameters allows the user to construct different scan patterns to meet different data collection objectives, save those scan patterns and use them whenever desired. By combining several STIM stack files together, the user can execute a variety of scan patterns. The control mechanism for executing several STIM stack files in succession is provided via a top-level control file called a SuperSTIM. Each SuperSTIM can control as many as twenty STIM stack files. Figure 1 is an overview of the STIM stack control provided by the SuperSTIM. This control can be repeated up to 20 times per SuperSTIM.

---

* Corresponding author address: Sheldon L. Katz, Lockheed Martin NE&SS, Moorestown, NJ 08057; e-mail: sheldon.l.katz@lmco.com.

As figure 1 indicates, the SuperSTIM contains flags to designate the start and end of a data collection volume. Weather spectral moments estimated from data collected between start and end volume flags constitute a single data volume and are stored as such. The STIM stack repeat count designates the number of times a STIM stack is repeated before the next STIM stack is executed.

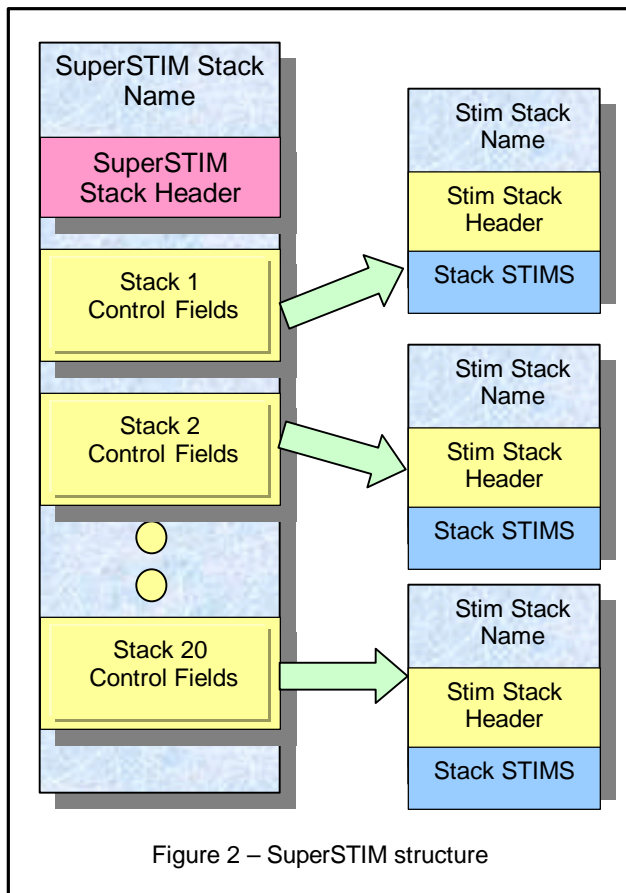| Figure 1 – SuperSTIM Controls |
| --- |
| Start Volume and Volume Count Flags |
| STIM Stack Repeat Count |
| Range Average Control & Processing Change Control |
| Clutter Filter Change Control |
| RF Attenuator Control & Receiver Channel Control |
| Transmission Override & Simulated Target Override |
| Requested STIM Stack Name |
| End Volume Flag |

Figure 2 – SuperSTIM structure

The next four control lines in figure 1 allow the user to tailor STIM stack execution to the current environment, using a STIM stack that could have been created and stored some time previously. For example, each STIM command contains a clutter filter selection parameter. If the user wants to change the clutter filter selected, the STIM stack does not have to

be reconstructed. Instead, the user can select the clutter filter using the clutter filter change control parameters in the SuperSTIM. Clutter filter selection through the SuperSTIM applies to all STIMs in each of three user designated elevation regions. If the user desires to use unique filters at each beam position, he can use the clutter filter selection field in each STIM. In this case no overrides will be used in the SuperSTIM.

Using the SuperSTIM it is also possible to select the receive channel, inhibit RF transmission and inhibit generation of simulated targets defined within the STIM stack. The overall structure of the SuperSTIM is shown notionally in figure 2.

3. STIM Tool

Each radar STIM contains 49 parameters to be defined by the user. In addition a typical sector scan comprised of a 90? azimuth sector with elevation scan to 20? contains over 750 beam locations. Although it is possible to create a STIM stack as an ASCII file manually, the task is difficult. The STIM Tool automates the process of creating a STIM stack. Its output is a file of ASCII STIMs that can be edited to customize the scan.
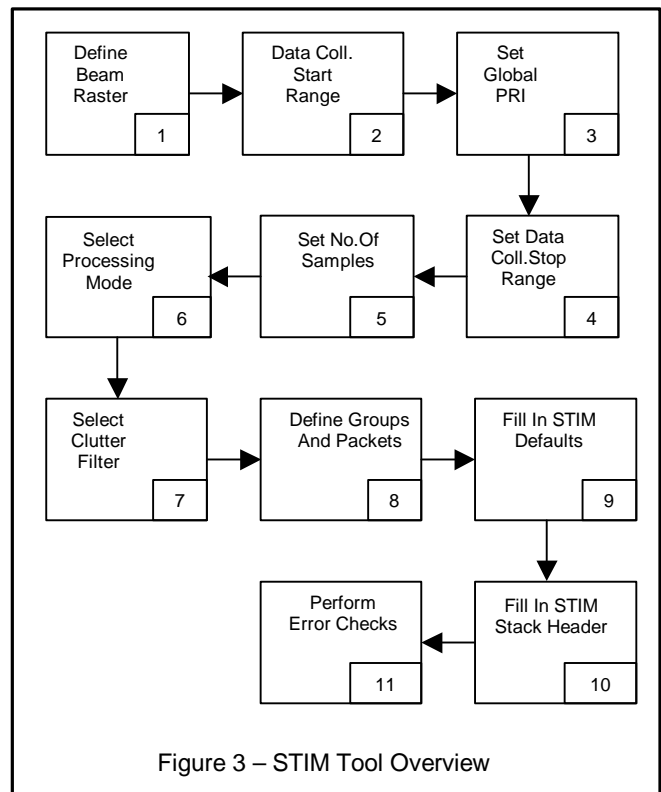

Figure 3 – STIM Tool Overview

Figure 3 is an overview of the STIM Tool that is divided into eleven functions. Function 1 generates the beam raster based on operator selection of angular sector coverage, beam spacing and whether

the raster is to be defined with stable space coordinates or the array steering direction cosines. In addition, the beam steering can be performed relative to the array, or based on a set of azimuth and elevation angles defined in stable space. When stable space steering is used, the beam steering direction cosines are calculated in real time, prior to beam transmission, accounting for the array position and the desired stable space azimuth and elevation beam angles.

Function 2 checks the user defined data collection start range against the system minimum range for the selected pulsewidth and adjusts the data collection start range if so required.

If the user wants to use a single pulse repetition interval (PRI) for the entire raster, function 3 uses the designated PRI to calculate a data collection stop range. If the user does not want to select a global PRI, function 4 calculates the range to a user defined altitude ceiling for each elevation tier and the data collection stop range and then calculates the PRI.

Function 5 determines the number of pulses that must be transmitted at each beam position in the scan raster. The user can select the number of pulses to use for each elevation tier. Alternatively, the user can designate a spectral moment estimation criterion to use as a basis for determining the number of pulses. Using a required reflectivity or velocity estimation error to be achieved for a user defined reflectivity value at a given range, the Tool estimates the number of pulses required to achieve the required spectral moment estimation accuracy. The number of pulses is then adjusted for range averaging.

In function 6, the user designates the processing mode to be either reflectivity only, pulse pairs, 16 pulse Doppler or 32 pulse Doppler. If in function 5, the selection of the number of pulses required was performed by the tool, that number is adjusted in function 6 based on the processing mode selected. For example, if only 9 pulses were required for reflectivity estimation after range averaging, but a 16 pulse Doppler processing mode is requested, function 6 adjusts the number of pulses transmitted to 16. If more than 16 pulses are required, the number of pulses transmitted is adjusted to a multiple of 16.

Clutter filter selection is performed in function 7. NWRT uses a Lockheed Martin patented matrix clutter processor to reduce the effect of ground clutter. A large number of 16 or 32 pulse matrix processors is available to the user. The selection of the clutter processor depends on the value of the design clutter to noise ratio and the normalized clutter spectrum width. The user inputs the clutter spectrum width and the design clutter to noise ratio. The STIM Tool then calculates the normalized spectrum width based on the PRI used and selects the correct matrix clutter processor.

When a radar dwell is to be processed as subsets of pulses, function 8 defines the parameters required by the digital signal processor (DSP) to perform the appropriate processing. For example, if a 32 pulse dwell is to be processed as two 16 pulse Doppler

dwells, function 8 selects the STIM parameters required for the DSP to correctly process the dwell.

Functions 9 and 10 fill in areas of the STIM for which there is no choice of parameters at this time. For example, although the receiver and DSP are designed to handle dual frequency channel input, NWRT is initially configured with the single frequency WSR-88D transmitter. Thus the use of more than one frequency channel is not possible and the STIM Tool selects default parameters corresponding to single frequency operation.

The final function of the STIM tool performs some error checks to insure that system operating parameters are within allowable limits.

The STIM Tool is written in the "C" programming language. The user generally interacts with the tool by selecting parameters in an input file. Execution of the Tool requires about two seconds.

4. Conclusion

The NWRT control structure was designed to provide a great deal of freedom to the user in choosing scan parameters. The user controls the details of the scan and processing through the radar stimulus command file (STIM stack file). The execution of STIM stack files is controlled via a set of high level commands termed a SuperSTIM. Through the SuperSTIM the user can modify the execution of a STIM stack to tailor it to the local environment. For example, the selection of ground clutter filter can be modified through the SuperSTIM, without rewriting the entire STIM stack. To simplify the creation of STIM stacks, we designed a STIM Tool that provides an automated means of generating the STIM stack. This is expected to prove very useful in NWRT operations.

5. References

Forsyth, D. E., J. F. Kimpel, D. S. Zrnic, S. Sandgathe, R. Ferek, J. F. Heimmer, T. McNellis, J. E. Crain, A. M. Shapiro, J. D. Belville and W. Benner, 2002: The National Weather Radar Testbed (Phased-Array). Preprints, 18th International Conference on Interactive Information and Processing Systems (IIPS), Orlando, Fla., Amer. Meteor. Soc., 140-141.