# P12.172 A Novel Real-Scene Echo Signals Physical Simulator of Doppler Weather Radar

Jianxin He Chao Wei Xuehua Li Haijiang Wang Zhao Shi
Key Laboratory of Atmospheric Sounding .Chengdu University of Information technology .Chengdu, China

## 1. Introduction

The calibration and quantitative performance test of receiver system is indispensable and the echo signals are needed during the development, debugging, routine maintenance and repair of the Doppler weather radar. Traditionally, the real meteorological target echo is used for the receiver as a test signals in the field test. But this method is high cost, complicated process and long period. And it is difficult for quantitative test because the parameters of meteorological target are uncontrollable. Currently， a signal frequency signal which does not have the characteristics of the weather rather than a spectrum signal was generated from the universal signal generators or from the special test instruments manufactured by some manufacturers. This signal could be used for the system hardware technical performance calibration through measuring the technical parameters of the system channel, but could not be applied to the terminal algorithm verification.

To avoid these defects, this paper presents a simple, quick and economic method for developing the hardware and software of the meteorological target echo signals and environment signals simulator system.

The study of simulation theory and approaches for different radar system and different weather phenomenon has been applied in the software emulator. Ryan m. May and Michael i. Biggerstaff (2007) have summarized many approaches that have been taken previously in the simulation of weather radar data, varying in sophistication from simple time series simulation (Zrnic 1975) to reflectivity calculation (Chandrasekar and Bringi 1987; Krajewski et al. 1993) to full simulation of radar returns from each pulse (Capsoni and D'Amico 1998; Capsoni et al.2001). Zrnic (1975) generated time series simulation data of weather radar using the Doppler velocity spectra of an assumed Gaussian distribution within one resolution volume. Chandrasekar and Bringi (1987) looked at the variation of simulated reflectivity values as a function of raindrop size distribution parameters. However, none of these studies has concerned to generate a real-scene echo signal of real weather target.

Based on the real base data and the function of Doppler Gaussian velocity spectra, this work not only could provide the simulation of IQ data but also generate the analog simulation signal of video signal, IF signal and RF signal.

## 2. System implementation

### 2.1. System Components

The Figure 1 shows a block diagram of the Doppler Weather Radar Real-Scene Echo Signals Physical Simulator system. The simulator is composed of User Interface (UI), Simulation Data Module, Data Interface, Analog and Microwave Module and the Antenna Simulation Module.

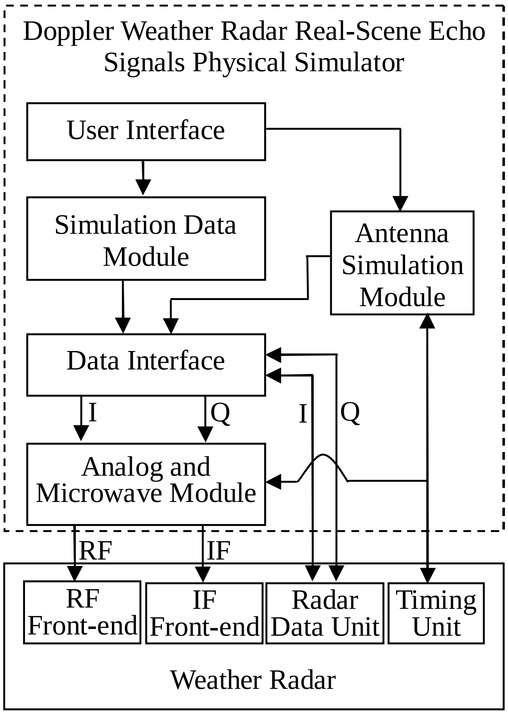



Fig.1. Block diagram of the schematic of the Doppler Weather Radar Real-Scene Echo Signals Physical Simulator system

The simulator configuration parameters shown in Table 1, such as the weather radar parameters, simulator control parameters, etc, are set through the User Interface (UI) in PC platform. The real-scene echo data is generated in the Simulation Data Module according to the simulation algorithm. Both of the components complete in the computer as software.

The Data Interface is used to communicate with the computer through the Peripheral Component Interconnect (PCI) bus and transfer the simulation data to the Analog and Microwave Module. And the implementation of the bidirectional data transmission between the Radar Data Unit and the Data Interface is directly depended on the simulator configurations and parameters.

The Analog and Microwave Module is composed of Digital-to-Analog Converter, IQ modulator and Up Converter. This component is based on the Agilent E4438C ESG Vector Signal Generator (Agilent Technologies 2005) and the N5102A Baseband Studio Digital Signal Interface Module (Agilent Technologies 2005).

The Antenna Simulation Module is mainly used to simulate the Azimuth and Elevation information and the Antenna status. The Data Interface transfers the simulation data to the Analog and Microwave Module is directly related to this components.

Table 1: Simulator configuration parameters

| Weather radar parameters | |
|---|---|
| Wavelength | Pulse width |
| Calibration value | NO of radial |
| Scanning strategy | NO of range |
| Range resolution | |
| Intermediate frequency | PRF |
| Signal-to-noise ratios | |
| No. of pulses per radial (M) | |
| **Simulator control parameters** | |
| Input type | Output type |
| Output frequency | |

## 2.2. Simulation methods of real-scene echo

Figure 1 shows that the input data to the simulator is from two resources. One is the real base data and IQ data that collected by the other radar or itself. Replaying the base data can combine the weather radar simulation echo close to the real weather target; replaying the IQ data does not depend on the simulation algorithms to generate the echo signals and the echo would be real.

The other is generated from the simulation algorithm (Zrnic 1975; RYAN M. MAY AND MICHAEL I. BIGGERSTAFF 2007). For each gate or sample point there is a resolution volume in space within which hydrometeors contribute significantly to the sample (Doviak and Zrnic, 1984). Randomly draw an echo region. And set an equal value for reflectivity(R) of the each resolution volume in the region as well as velocity (V), spectrum width (SW), etc. Then the target data and clutter data are calculated. As mentioned previously, the echo signal would be generated and processed. Compare the product with the R, V, W parameters to evaluate the receiver's performance. This can be used for weather radar quantitative performance test, analysis, calibration and the terminal algorithm verification.

2.3. Simulation data and output signal

Figure 2 is the flow chart of the software. The weather target echo data are simulated and calculated to obtain a complex spectrum that was composed by the random phase spectrum and the random Doppler power spectrum which is Gaussian distribution and contains Gaussian White noise. To generate the clutter signals are directly related to the type of the clutter that will simulate. The weather target signals combined with the clutter signals to form a weather radar echo signals in the echo synthesizer. The IQ signals that correspond to the signals of the receiver's I channel and Q channel are produced from complex spectrum of the weather radar echo signals by Inverse Fast Fourier Transform (IFFT), respectively. Through IQ modulation and up-conversion, an analog video signal, intermediate frequency (IF) or radio frequency (RF) signal was generated from the IQ signals.

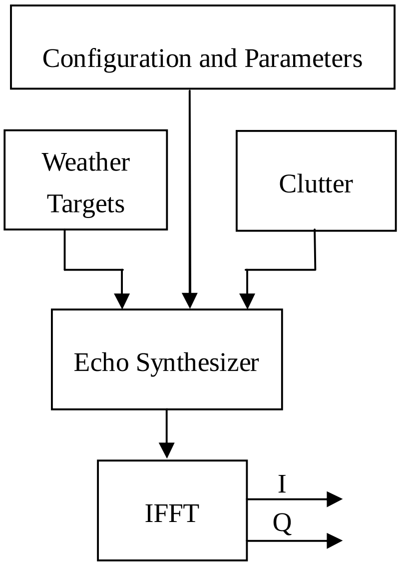



Fig.2 The flow chart of the software

For the output, along with the options required for its operation, the simulator provided a digital interface delivering digital baseband (IQ) as well as a flexible connector for video signal, IF signal and the RF signal for different parts of the radar receiver, respectively. The IF signal can be directly added to the IF receiver front-end, or connected to RF front-end by up-conversion to RF signal for the weather radar receiver system quantitative test and the terminal algorithm verification.

2.4. Data synchronization

The coherency and synchronization for the radar and the simulator are very important. There are numerous ways to provide a common frequency reference to the system components. Figure 3 shows a simple setup where the signal generator radar supplies the common frequency reference to the E4438C and the N5102A and the PCI card is providing data clock to the N5102A module.

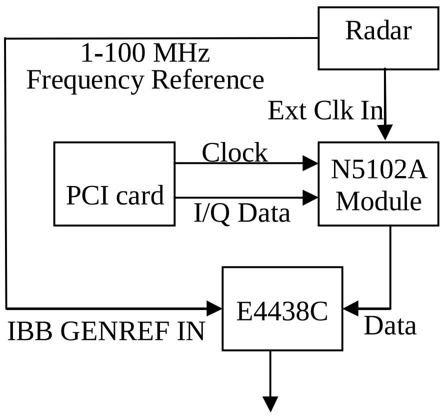
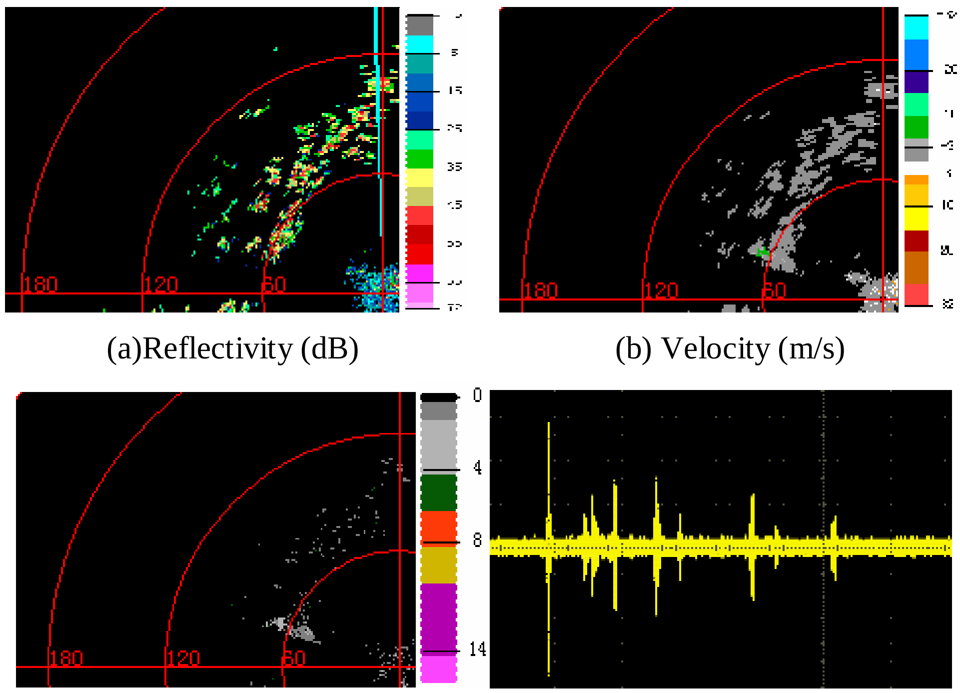



Fig.3. Frequency Reference Setup Diagrams for the N5102A Module Clock Signal, Radar and E4438C

## 3. Result

Currently, the base product and IQ data replaying function has been applied to the radar receiver system repair and test. The base product of the ground clutter IQ data replaying for WSR-98Dis sketched in Figure 4. The WSR-98D works at wavelength of 10 centimeters with a pulse width of 0.833us. The current operational scanning strategy is plan position indicator PPI with range resolution of 250 meters apart. The simulator output signal is 60MHz IF signal.




(a)Reflectivity (dB)    (b) Velocity (m/s)

(c) Spectrum Width (m/s)    (d) IF signal

Fig.4. The IQ data replaying for ground clutter

The IF signal (Fig.4d) is corresponded to echo of the radial (Azimuth 298° and Elevation 0.5° )that indicated by the Scan-Line in Figure 4a. The largest amplitude of the IF signal simulated the ground clutter that echo returned from the buildings at ranges 30 kilometers (km) around the radar center. Between 60km and 120km there was a mountain. The calibration effect was considered for the echo signal power.

During the calculation of the IFFT,

overflow problems had a conspicuous effect to the accuracy of the reflectivity. And the effect to the reflectivity value is a constant. Based on that, the simulator can correct the final echo signal power.

## 4. Conclusion

The experiment results on Doppler weather radar WSR-98D/XD show that the simulator not only can simulate a great diversity of signals which approximated to the real weather echo signals, but also can simulate the complex environmental that close to the radar actual work condition. Some echo of the extreme weather phenomenal which are hardly received or never occurred in the test field can be used for improving the performance of the Doppler weather radar. And the ultimate performance of radar receiver is obtained through quantitative test and analysis.

**Acknowledgement**

This work is supported by the National Natural Science Foundation of China (No. 41075010). The authors are grateful for the anonymous reviewers who made constructive comments.

## References

Mitchell R L. 1976: Radar Signal Simulation [M]. [S.I.], Artech House, INC.

Doviak,R.j..andD.S.Zrinc.,1984:Doppler Radar and Weather Observations[M]. Academic Press, Orlando, Fla.

Serafin,R.J., and R.Srtauch, 1977: Meteorological Radar Signal Processing，in”air Quality Meteorology and Atmospheric Ozone”, American Society for Testing and Materials,Philadelphia,pp.159-182.

RYAN M. MAY AND MICHAEL I. BIGGERSTAFF, 2007: A Doppler Radar Emulator with an Application to the Detectability of Tornadic Signatures, JOURNAL OF ATMOSPHERIC AND OCEANIC TECHNOLOGY., 24 ,1973 -1996.

Agilent Technologies, Inc.2005: User’s Guide Agilent Technologies E4428C/38C ESG Signal Generators.

Agilent Technologies, Inc.2005:N5102A Baseband Studio Digital Signal Interface Module