Implementation of Multi-rate Data Exchange System for Radar Signal Processing

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***Abstract*—** On the basis of the characteristic analysis of data transmission and interconnection interface in complicated radar real-time signal processing system, a multi-rate data exchange system is designed. Then the structure and composition of this system are described in detail. The system has the characteristics of standardization, modularization and scalability. And through the implementation and application in an airborne SAR signal processing system, the universality and flexibility of this system were proved. The simulation results for multirate data exchange system are developed according to the literature survey on the RADAR signal processing. The RADAR signal processing analysis is accomplished with the help of MATLAB environments.

***Keywords*—**Multi-rate Data Exchange, RADAR Signal Processing, MATLAB, SIMULINK, Performance Evaluation.

Introduction

IN complicated radar real time signal processing systems, data communication or exchange is frequently required among various function modules in the process of signal handling. Furthermore, data from different function modules usually have different physical interface and transmission rate. So it is necessary to design a multi-rate data exchange system which is appropriate for data communication among each function module in signal processing system. As for conventional design method, each type of data electric interface and data interchanging function on the multi-rate data exchange system are usually implemented based on application specific integrated circuit (ASIC). Because the function of ASIC is fixed, the universality, expansibility and flexibility of system are undoubtedly limited.

This paper presents a design and realization of multi-rate data exchange system based on RADAR signal processing, which integrates with various data interface and is configurable according actual demand. And it provides flexible data interface and efficient data transmission rate for the entire radar signal processing system, and the performance of signal processing system would be improved greatly.

Radar Signal Processing Techniques

Signal processing is used in the radar receiver to extract information from the returned radar signal such as target detection, tracking, measurement, and signal processing to mitigate the effects of electronic countermeasures, including radar jamming. Additional signal processing techniques often employed include moving-target indication (MTI), pulse-Doppler, and synthetic-aperture radar (SAR) processing.

MTI is often used by terrestrial radar to separate moving targets of interest (e.g., aircraft) from background returns (e.g., from terrain and the ocean), called radar clutter. This is done using the Doppler-frequency shift of the received signals. The clutter has only small radial velocity components due to the motion of vegetation or waves, while moving targets are likely to have larger radial velocities. The MTI filters out the received signal frequencies that have low Doppler-frequency shift and correspond to the clutter. This is done by processing the phases of two or more successive pulses in a canceller.

Limitations of MTI processing result from the stability of the radar components and the velocity spread of the clutter. Targets traveling tangentially to the radar will have little or no radial-velocity component, and will be cancelled along with the clutter. MTI processors may be simply characterized by the minimum detectable target velocity (MDV), and the clutter cancellation ratio.

In pulse-Doppler radar, a coherent burst of pulses is transmitted. Coherency implies that the phases of the individual pulses are derived from a continuous stable signal, that is also used in processing the received signals. The returned signals are processed using a Fourier-transform–type algorithm to divide the received signal into a series of spectral bands. Those bands that correspond to the Doppler shift of clutter may be rejected, and those that correspond to potential targets may be examined for detections. The pulse-Doppler band in which a target is detected also gives a measure of its Doppler-frequency shift, and hence its radial velocity.

Pulse-Doppler processing is often used in airborne and space-based radar. With these moving platforms, the radar returns from terrestrial clutter may have a large Doppler frequency spread, due to the spread of angles at which the clutter is viewed, both in the main radar beam and through the antenna sidelobes. Thus, cancellation of the clutter by MTI techniques is often not effective. Pulse-Doppler processing, however, allows rejection of bands having large clutter components, detection of targets in bands clear of clutter returns, and setting of detection thresholds over the clutter signal return in bands, where target returns may exceed clutter returns. Pulse-Doppler processing may be simply characterized by the velocity resolution corresponding to the processed Doppler frequency bands, and the suppression of clutter not in a band.

Synthetic-aperture radar (SAR) processing is used by moving radar (e.g., those on aircraft or satellite platforms), to produce high-resolution terrain maps and images of targets. Radar may achieve good range resolution by using short pulses or employing pulse compression. For example, a signal bandwidth of 100 MHz may provide a range resolution of 1.5m. However, with conventional (real-aperture) processing, the radar beamwidth is rarely small enough to provide cross-range target resolution useful for ground mapping. For example, with a beamwidth of 10 mR (0.57°), cross-range resolution at a range of 50 km is 500m.

With SAR, radar data taken while the radar travels a significant distance is processed to produce the effect of an aperture dimension equal to the distance traveled. For example, with an aircraft velocity of 250 m/s and a SAR processing time of 2 seconds, the synthetic aperture is 500m long. With an X-band wavelength of 0.03m, the cross-range resolution at 50 km range is 1.5m. An SAR radar processor may be simply characterized by the resolution it provides, 1.5m in the above example.

SAR processing is based on Fourier transforms, but corrections are made for factors such as changes in target range and platform path perturbations during the processing time. In a strip-mapping mode, a SAR collects and processes data at a fixed angle relative to the platform as it moves along its path. This technique, often referred to as side-looking radar, generates a continuous strip map. In a spotlight SAR, the radar beam is scanned relative to the platform to keep the desired target region in coverage. This allows increased processing time, and hence greater angular resolution for the region imaged.

System Architecture Design

Based on the above characteristics of multi-rate data flow in radar real-time signal processing system, it is necessary to design a system that supports multiple rate data communication and exchange. And as the centre of data interchange, it provides a platform in which each module in signal processing system can communication each other efficiently. Eventually, a radar real-time signal processing system based on data exchange would be established and illustrated in Fig.1.

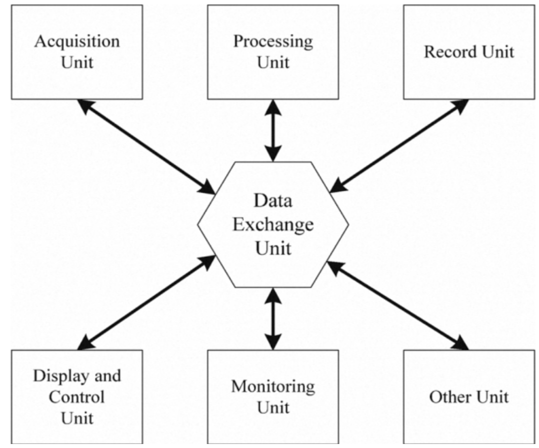

Fig.1. Block diagram of radar signal processing system based on data exchange

Implementation

The system flowchart for implemented multi-rate data exchange unit is illustrated in Fig.2. The specification of RADAR signal processing and target for data exchange analysis are specified by the input of data exchange unit. And then the noise , measurement and azimuth parameter are declared based on the signal processing stage. The range compression is calculated according to the declaration parameters. The azimuth compression result is displayed after implementing the data exchange processes.

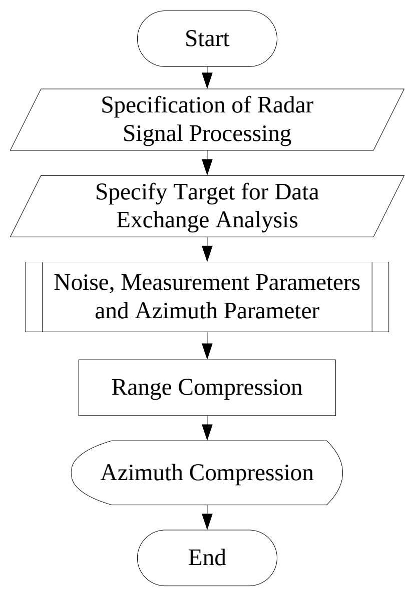

Fig.2. System Flowchart

The sub function for overall system flowchart is mentioned in Fig.3. The noise and linear azimuth FM rate are inputted to the evaluation of range samples and time array for data acquisition process.

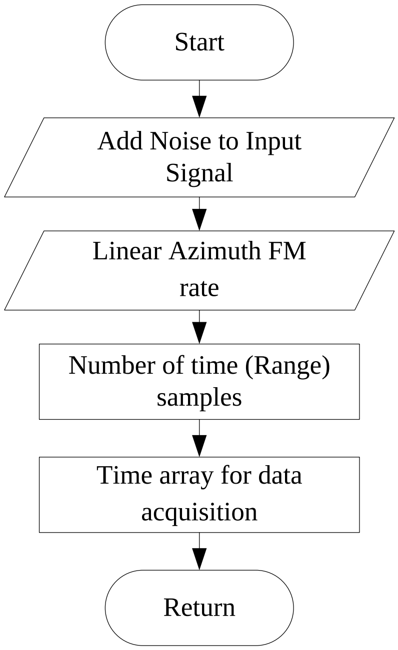

Fig.3. Sub Function of System Flowchart

SIMULATION RESULTS

The specified target for Multi Rate Data Exchange Analysis is only helicopter and the range is evaluated according to the specified parameters of the implementation. The Data Exchange Stage for RADAR Target is shown in Fig.4. It is only based on the azimuth samples for RADAR signal processing.

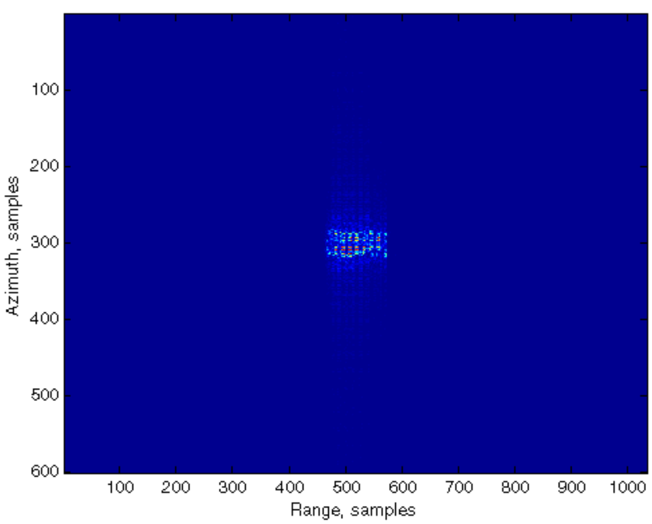

Fig.4. Data Exchange Stage for RADAR Target

The enlightenment of SIMULINK Model for Multi Rate Data Exchange Analysis is as follows. Input/Output are connected to Data Exchange Unit. Band limited whit noise are acquired for acquisition unit. Delay unit is used for Display and Control unit. Output terminal is linked with Record unit. Error terminal is employed for Monitoring unit. Equalizer response and filter tap are utilized for processing unit. SIMULINK model is accomplished to analyze the multi rate data exchange unit for SAR radar signal processing

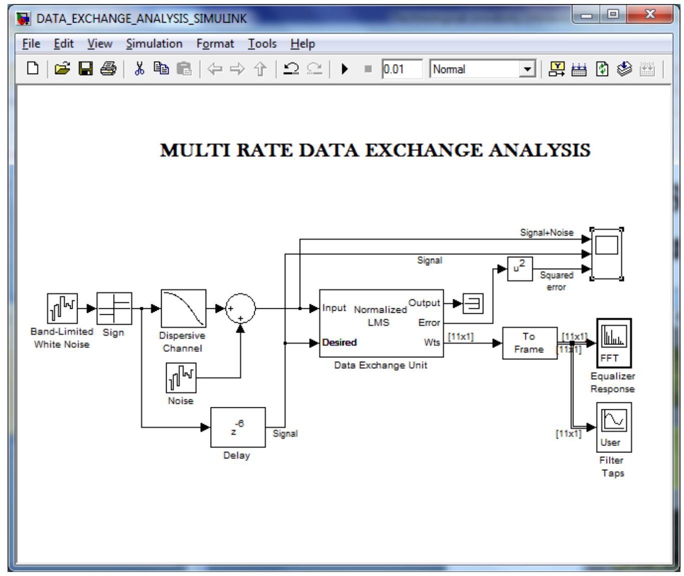

Fig.5. SIMULINK Model for Multi Rate Data Exchange Analysis

After debugging the SIMULINK Model for Multi Rate Data Exchange Analysis, there are three major responses for simulation results. Signal, Signal with Noise and Squared Error response are illustrated in Fig.6. According to this response, the noise level is approach to zero for data exchange process. Magnitude Response Vs Frequency is shown in Fig.7. This response says the magnitude values are gradually higher for increasing the frequency in kilohertz.

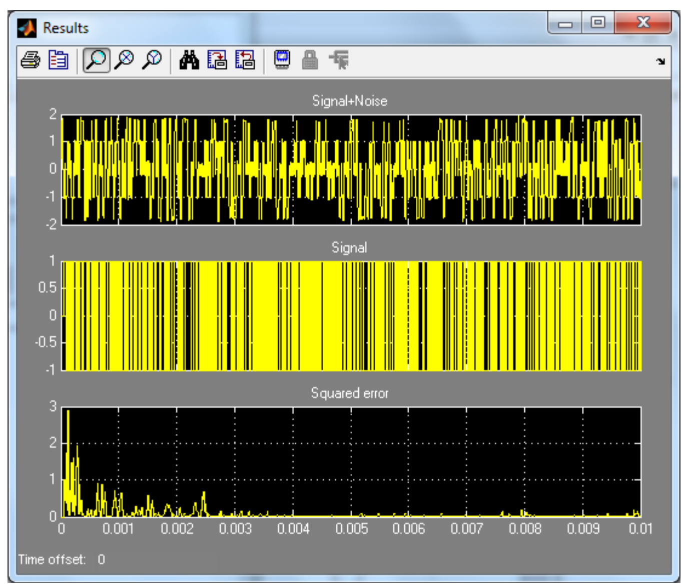

Fig.6. Signal, Signal with Noise and Squared Error

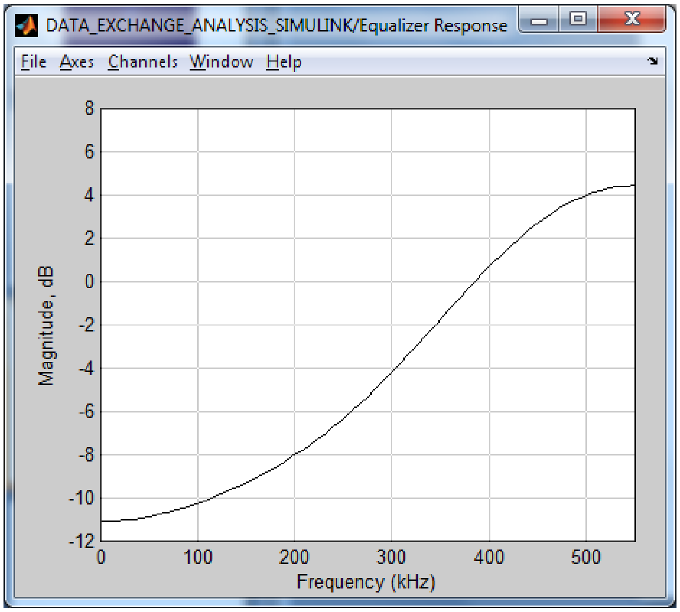

Fig.7. Magnitude Response Vs Frequency

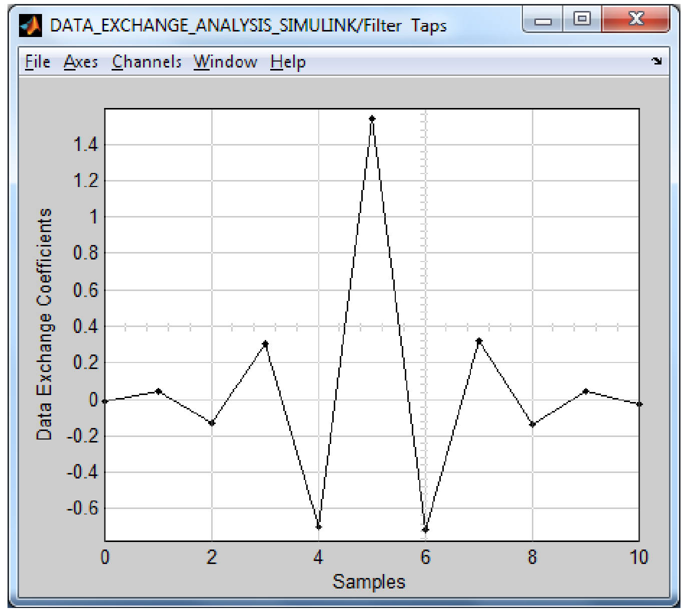

Fig.8. Data Exchange Coefficients

Data Exchange Coefficients response is illustrated in Fig.8. This response says the highest coefficients for data exchange is between four and six samples.

CONCLUSION

The multi-rate data exchange platform described above is used in a SAR real-time signal processing system which block diagram is shown in previous chapters. In this SAR signal processing system, data exchange platform receives the raw echo data from acquisition unit, and receives the radar carrier motion parameters from motion compensation unit simultaneously. The radar echo data and carrier motion parameters are packed and sent to the signal processing unit by means of LINK channel. Through the serial Rapid I/O interface, the packed data from data exchange platform can directly be sent to record unit for real-time storage. Accordingly, via the data exchange platform, data stored in record unit can also be transferred to the processing unit when necessary. Moreover, the working mode of the data exchange platform can also be determined by main control unit which can send command data to the platform by the PCI interface. Thereby, with the flexible interconnection function of the multi-rate data exchange platform, each function unit in the SAR signal processing system is effectively connected as a whole.

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