# Implementation of an Parallel Signal Processing System for All-purpose Radar

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**Abstract:** In this paper, A DSP-based all-purpose radar parallel signal processing system (RPSPS) with high-speed real-time signal processing is implemented to fulfil the all-purpose and system reconfiguration. High performance DSP chips is used as the kernel processing nodes. By means of local shared memory、global distributed memory parallel system and the pipelined data-flow method, it can perform absolutely parallel data processing of multi DSP. The finished system is simple in architecture, flexible in scale. The reconfiguration of this system through the embedded computer make it possible to implement different signal processing tasks of other radar system without changing the system hardware.

**Keywords:** all-purpose radar; real-time parallel signal processing; system reconfiguration

## 1. INTRODUCTION

Since all-purpose radar includes many functions of modern radar, it is widely used in many areas .The signal processing in all-purpose radar is more complex and flexible than that in the others. The design method of traditional radar signal processing system according to the chosen algorithms does not fit for its flexibility. In order to fulfil the high-speed real-time signal processing tasks in all-purpose radar, it is necessary for us to develop a general purpose、high-speed and real-time radar signal processing system, which is both re-configurable and scalable. On the one hand, simply expansion of system hardware can be used to adapt to the change of task-scales; On the other hand, the system software can easily re-programmed to adapt to the change of algorithms or the application itself.[1]

Nowadays, high efficient digital signal processing (DSP) chips made it possible to work out high-speed RPSRS. Some small-scale RPSRS have been implemented[2,3]. But large-scale RPSRS is dead against the characteristic of the radar signal is less discussed. In this paper, we present a multi-DSP parallel architecture of local shared memory、global distributed memory. An universal parallel processing module, which is used to compose large-scale RPSPS, have been worked out. It has many promising characteristics such as strong computational capability、broad I/O bandwidth、various communication method、topology flexibility and good expansion capability. It is very suitable for the demands of all-purpose radar to process the massive tasks in high-speed and system reconfiguration.

## 2. SYSTEM FUNCTION

All-purpose RPSPS is a modern radar signal processing system including many advanced signal processing functions, its function block as shown in figure 1. It has main functions of : quadrature sampling(QSAMP); adaptive equalization(AEQUA); pulse compression(PC); Sidelobe cancellation(SLC); Sidelobe blanking(SLB); Moving target indicate(MTI); Doppler filtering(FFT) ,Constant false alarm rate (CFAR), working-out modular(MOD) Azimuth angle correcting(AAC), anti-blurring of speed and range(ANTIB), adaptive frequency transformation(AFT) , PRF jitter .etc. Signal waves are LMF and code, which have about ten kinds of different time-width and frequencyband-width. It also has nine types of different PRF. Some functions of above are not compatible. Different function combine needs different processing scheme. The traditional radar signal processing system hardware does not fit for this because it is designed according to the chosen algorithms. In order to realize the variety of functions, a re-configurable、universal RPSPS should be designed.

## 3. SYSTEM DESIGN

The design of parallel processing system is a synthesis subject deals with many areas[3,4]. Here, only the parallel processing architecture、the characteristic of tasks partition for radar signal parallel processing and processing method of data are discussed In this paper.

3.1 Parallel Processing Module (PPM)

Processing node is key parts of the PPM. It is one of the factors that affects the performance of PPM directly. The ADSP2106x SHARC DSP developed by ADI is adopted as the processing node because of its great processing power、 large throughput and storage units、 flexible communication ability and high-speed FFT operation. It is very suitable for being made up of large-scale high-speed and real-time signal processing system [8].

Another factor that affects the performance of PPM is frequent conflict and wait of system bus. The ability of system reconfiguration and anti-error of DMS is also good over SMS. Synthesizing the advantages of above and considering the characteristic of the processing of radar signal is pipelined in each channel and each channel's processing is independent. The PPM based on the local shared memory、 global distributed memory parallel architecture have been designed. As shown in figure 2. Its communication topology architecture can be changed with different system program in order to fit for different data processing algorithm. In order to exchange massive data

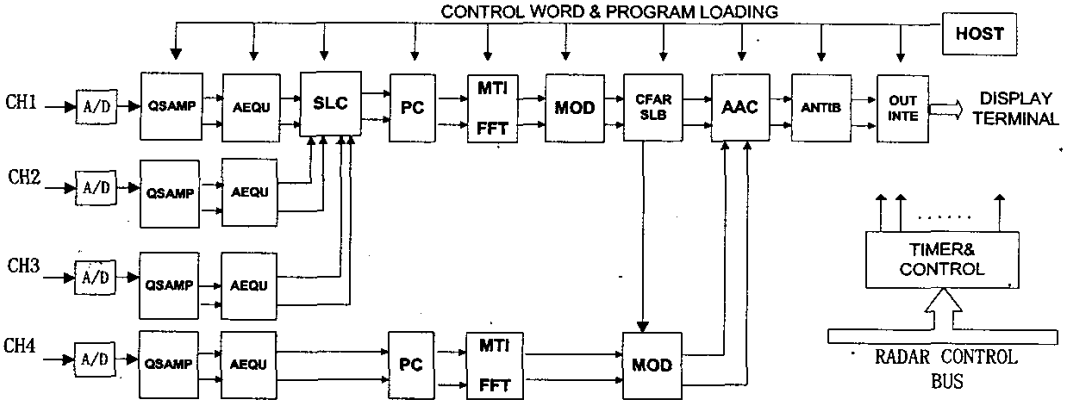
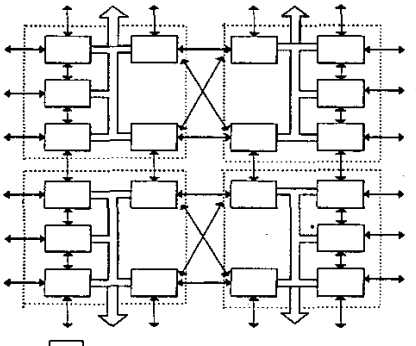



Figure 1. Function Block of All-purpose Radar

the parallel processing system architecture, which provides data exchange channel and transmission of subtask as well as control signal for each processing nodes. It can be divided into two classify: one is shared memory system (SMS); the other is distributed memory system (DMS).In the case of less processing nodes ,SMS is high efficiency. But to the large-scale system, DMS has many great advantages over SMS for its high flexibility、 no



□ : Processing Node

⟷ : Link Port

Figure 2. DSP Module Architecture

in small-scale area, a few local shared memory which need no bus arbitration logic are designed Inside the PPM. Each PPM can be interconnected through the high-speed communication ports to Compose even large DMS to fit for processing heavy task.

3.2 Parallel Processing of Radar Signal

Real-time radar signal processing deals with parallel task partition and fast algorithm. Because the processing of radar signal is chiefly to dispose radar digital echo series, and less correlation of it between two distance range units long distance apart. The operation of radar signal is basically one dimension disposal to distance unit、 channel or echo signal. Considered the reason what above. In order to decrease communication from each nodes ,we should according to the operation of distance and FFT、 correlation of echo signal when we partition and distribute the parallel tasks. The implementation of QSAMP, AEQUA, PC are all using long-stages FIR filter. It need massive computation and accompanying communication bandwidth. In order to solve this problem, we can use the frequency domain segment in range processing method through SHARC DSP doing FFT very fast and good parallel processing architecture [6]. But the

filter transient, which lead to discontinuity along the distance range when we parallel dispose distance units in segment, should be pay attention. Solving method is every data block should be overlapped some distance units equals to the filter-stages to the one before it (the method

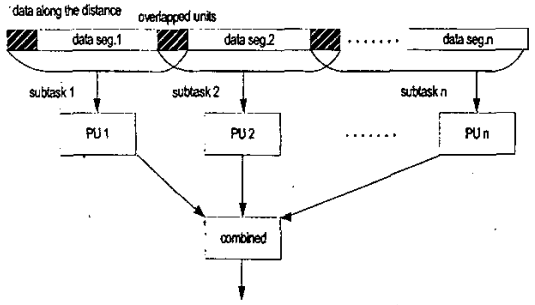



Figure 3. Parallel Task Distribution

names overlap hold)[7].as shown in figure 3. The continuity along distance range can be kept after we throw off the overlap part (filter transient) from the results.

3.3 Data Flow and Control

System data can be disposed with methods of segment in range parallel processing and pipelined data-flow. The whole range from A/D convert is first broke into several overlapped segments according to information from the control module. Each segment forms one data packet to be parallel processed by several group of DSP. The packet is composed as in figure 4. Length of this packet; method defining the parameter of data which decided the processing manner; description defining the data adhesive attribute labeling how the data be processed; check giving a tag of data ending which can be used preventing and


Figure 4. Packet of Data & Control Flow

correcting data transferring error. By this method, data synchronization with the radar control-timer can be changed into asynchronism data to radar. Data processing is data-flow driven and the self-synchronism without many control and clock signal. What DSPs will do is just according to the information including in the data packet. This is advantageous for pipelined processing、different application and easier maintenance.

Synthesized the ideas what above, an universal PPM have been worked out. It includes twenty processing nodes. Each nodes, which are interconnected through link port and flag port, has its private storage and locate shared memory .This PPM is characterized by its high parallel efficiency 、 high flexibility, 、 various communication methods,、 and good expansion capability.

## 4. IMPLEMENTATION

This all-purpose RPSPS has been implemented using the parallel processing module designed above .it consists of nine boards, as shown in figure 5. The pre-disposal board use large-scale FPGA chip to realize the data distribution according to the characteristic of radar signal. The Hardware of five PPMs are same . They are used to parallel dispose the data with segment in distance range and fast algorithm of convolution in frequency domain[6]. The interface board reads the processing results through communication channel from processing nodes 、 reorganizes the results into the pre-determined format and then sends them to display terminal to indicate .The five

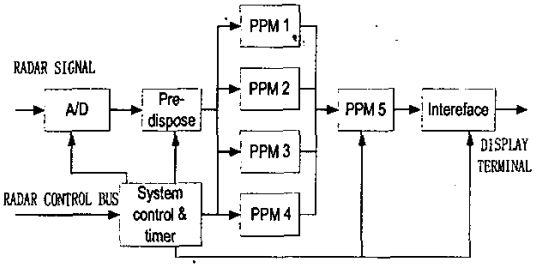



Figure 5. Structure of RPSPS

PPM include 100 processing nodes and the peak processing speed is about 10 TFLOPS($10^9$ floating point operation per-second). To realize different processing function is only loading the different program through the embedded computer who controlled by the system manager unit (also called reconfiguration of this system ). To add or take out some system function is just changing the processing program without changing the system hardware.

This parallel signal processing system has been finished now. The experiment results evidence that the system is small in size、 simple in topology、 good scalability, high flexibility and processing efficiency.

## 5. CONCLUSION

A parallel signal processing system of all-purpose radar has been designed in this paper. The system architecture、 data distribution and processing of this design are all fit for the characteristic of radar signal. An pipelined manner with data-flow driven is adopted in Data processing. Each processing node has its own private memory and local shared memory. It can realize fully parallel signal processing. The PPM of this system is

simple in structure and high flexibility. This design method is fit for not only parallel signal processing of all-purpose radar but also other areas needed large-scale and real-time parallel signal processing.

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