

Design of Radar Signal Playback Module Based on FPGA

Jing He, Yang Liu

China Satellite Maritime Tracking and Control Department, Jiangyin, 214431, China

Abstract. This article mainly studies the design ideas of radar signal playback technology. Mainly from the data extraction and playback of these two aspects of the work, its design in addition to considering that the system can adapt to pulse radar in the normal state of the work of the trigger, but also requires that the radar can work in the "solution distance blur" and "blind" state Data playback.

1. Introduction

The radar signal playback module mainly realizes the functions of radar data extraction and radar signal playback. It is composed of data extraction state machine, data playback state machine and on-chip FIFO. Since the radar is operating in a "distance-disturbed" or "avoided-blind" state when the target is located outside the maximum unambiguous distance of the pulse radar or when the target echo is close to the main pulse.

2. Radar data extraction

When the CPCI interface controller reads radar data from the PCI bus and sends it to the cache module of the playback board, the radar signal playback module first reads the radar data from the cache module and extracts the radar data. Echo information, delay information, and other auxiliary information are then sent to the data latch unit for subsequent playback.

The order and timing of radar data extraction are actually performed in accordance with the format of the radar data file, so we only care about the data format of the radar data file. The design ideas of the format are not discussed here. The radar data file mainly contains two parts: header information and frame data, as shown in Figure 1.

Head information	Frame data				
	First frame	Second frame	Frame N-1	Nth frame

Figure 1. Radar data file format

The header information is located at the beginning of the echo file, which mainly includes the delay ΔT_3 of the leading wave gate pulse and echo, and the number N of sampling points of the intermediate frequency echo. ΔT_3 is set by the radar transmitter. After the radar transmitter sets this value, ΔT_3 is fixed during the entire radar ranging process; N is set by the user before acquiring the radar signal, so N in the collection process is also fixed.

The radar solves the two problems of range ambiguity and traversal blindness by continuously adjusting the phase of the synchronizing pulse by encoding the synchronizing pulse. When radar does



not receive echoes or only one echo is received, we use one frame of data to represent the radar echo information in one main pulse period; when the radar machine receives two echoes, two frames are used. The data represents the radar echo information during a main pulse period. The frame data format is shown in Figure 2. The format is as follows:

Frame header	Frame number	The delay between the transmit pulse and the pilot wave gate is ΔT_2	N-point echo data	Frame marker (Flag)	The delay of the main pulse period is ΔT_1	End of frame
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Figure 2. Frame data format

- a). Frame header, quantized 32 bits. The frame header is the start of each frame.
- b). Frame number, quantization bit 32bits. The frame number represents the frame data in the current frame as an echo file.
- c). Synchronization pulse and leading wave delay. If there is only one echo in the main pulse period, this field indicates the time delay between the first sync pulse in the main pulse period and the leading wave gate of the echo; when there are two echoes in the main pulse period, according to the frame Different from the flag, this field indicates the delay of the first sync pulse in the main pulse period and the leading wave gate pulse of the two echoes; if there is no echo in the main pulse period, this field is all 0. The number of quantization bits is 32 bits.
- d). Echo sampling data, data length 32bits * N, of these data only 160 sampling points for intra-pulse echo information, other sampling points for the noise.
- e). Synchronization pulse delay, the number of quantization bits is 29bits. If the current frame records radar information with no echo in the main pulse period or echo information of the first echo of the two echoes in the main pulse period, the sync pulse delay is zero.
- f). Frame flag Flag, quantization bit 3bits. When Flag=000, this frame data records the radar information when there is no echo in the main pulse period; when Flag=001, this frame data records the radar echo information when there is only one echo in the main pulse period; When Flag=101, this frame records the radar information when there are two echoes in the main pulse period, and this frame is the information of the first echo in the two echoes; when Flag=110, this frame records The radar information is that there are two echoes in the main pulse period, and this frame is the information of the second echo in the two echoes.
- g). End of frame. The end of the frame is the end of each frame. The number of quantizer bits is 32 bits.

The timing of radar data extraction is controlled by the data extraction state machine inside the radar signal playback module. The data extraction state opportunity sends the extracted radar delay parameters and sampling points to several registers for registration; the extracted echo data will be first registered in the on-chip FIFO.

Here is a brief introduction to the design of the on-chip FIFO. The on-chip FIFO is implemented using the internal RAM memory of the FPGA. Since the radar data extracted by the data extraction state machine from the cache module is 64 bits and the total number of bits of the three echo samples is 32 bits, the on-chip FIFO is designed to read and write asynchronous FIFOs, and the entry data width of the FIFO is 64-bit, the output data bit width of 32; In addition, the radar signal playback module data clock is 200MHz, so on-chip FIFO read and write clock design is 200MHz; on-chip FIFO depth is 32768words, can accommodate at least two radar Echoes.

The data extraction state machine has a total of 7 states. The conversion relationship between the states is shown in Figure 3.

- a). IDLE state. The state machine is idle and continuously detects whether the playback start signal has arrived. When the arrival of the system playback signal is detected, the read enable of the state machine and the cache module is enabled and the extraction of radar data begins.

- b). GET_HEADINF state. The header information is extracted and sent to the data register in the data latch unit.
- c). CHECK_FRAMEHEAD state. If a frame header is detected, the 32-bit high frame number of the cache module is registered.
- d). GET_SENPGATE state. Register synchronization pulse and leading wave gate delay ΔT_2 .
- e). GET_WAVE state. Enables on-chip FIFO write enable to register IF echo data.
- f). GET_SENTPULSE state. Extract and register sync pulse period ΔT_1 and frame flag.
- g). CHECK_FRAMETAIL state. In this state, the frame flag is first judged. When Flag = 101, it means that there are two echoes in the current main pulse period, and this frame is the information of the first echo. In order to obtain complete information within a main pulse period, the state machine jumps back to the CHECK_FRAMEHEAD state on the arrival of the next clock's rising edge to continuously extract the next frame of radar data; when the frame flags are other values, ie Only one echo, no echo, or current frame in the pulse period is the second echo of the two echoes in the main pulse period. They all indicate that the state machine has obtained complete information in one main pulse period. Therefore, the cache must be closed. The read enable of the module ends the data extraction.

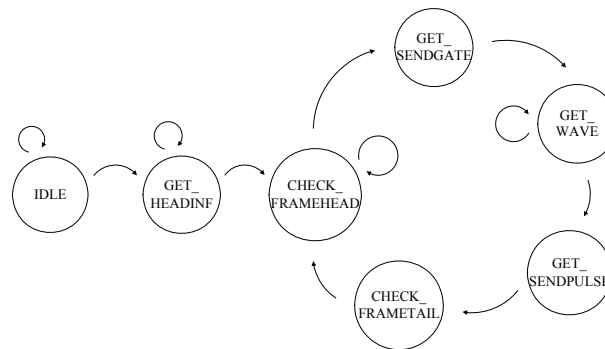


Figure 3. Data Extraction State Machine State Diagram

3. Radar signal playback

After all the radar data in one main pulse period have been extracted, the radar signal playback will be completed according to the timing of the pulse radar. As mentioned earlier, when the radar is in the working state of “distance-distortion” and “anti-blindness”, the echoes in the main sync pulse cycle may appear in three situations. Figure 4, Figure 5, and Figure 6 are corresponding.

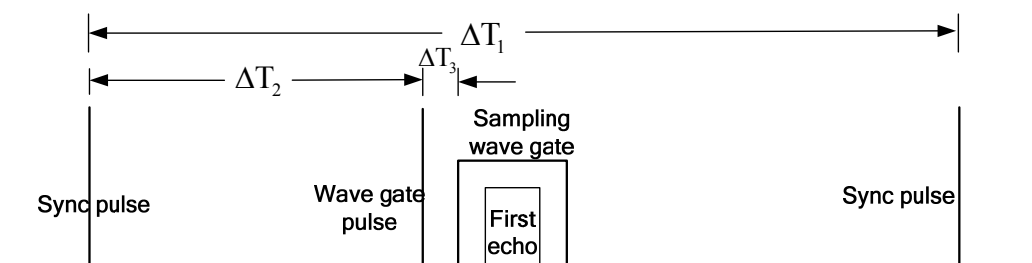


Figure 4. The timing diagram of only one echo in the main pulse period

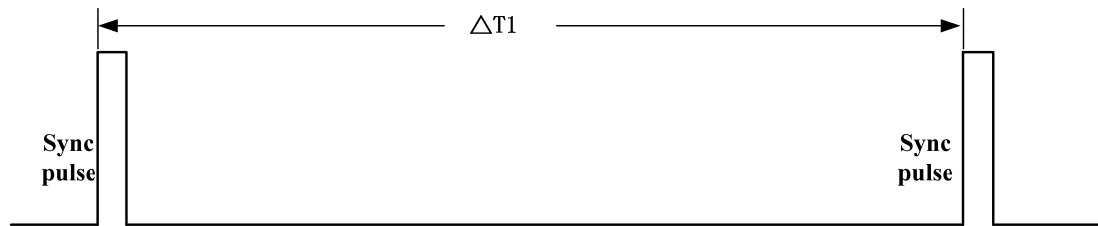


Figure 5. No echo in the main pulse cycle.

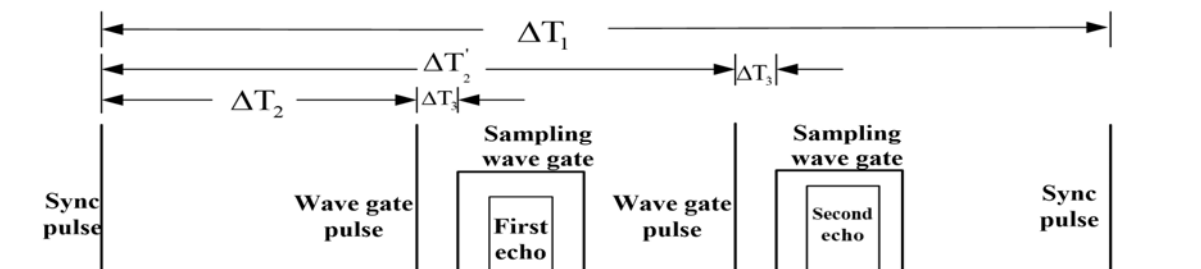


Figure 6. The timing diagram of two echoes in the main pulse period

The timing of the radar signal playback is controlled by the data playback state machine. Before the data playback state machine starts, the data extraction state machine must have previously extracted all the radar data in a main pulse period to be played back, so that the data playback state machine has enough time to analyze the radar data and complete the playback. There are 6 states in the data playback state machine. The state diagram is shown in Figure 7:

a). IDLE state, the state machine is idle. In this state, the triggering of the state machine needs to consider two situations: if there is no echo or only one echo in the current main pulse cycle, then after the data extraction state machine has extracted the data of this frame, the data playback state machine starts; If there are two echoes in the current main pulse period, the data playback state machine is started after the data extraction state machine has extracted the frame information of these two echoes. In a word, only the data extraction state machine pre-extracts all radar data in the next main pulse period, and the data playback state machine will start.

b). REPLAY_SENDPULSE state. After the start of REPLAY_SENDPULSE, a sync pulse (width of 0.8us) is generated and played back first, and the frame flag is judged at the same time. If there is no echo in the current main pulse period, the state machine generates and plays back the second sync pulse in the current main pulse period after the delay ΔT_1 , and ends the playback of radar data in the current main pulse period; as long as there is a return within the current main pulse period. The wave enters the REPLAY_GATEPULSE state after the state delay ΔT_2 .

c). REPLAY_GATEPULSE state. A lead wave is generated and played back, and the state machine transitions to REPLAY_WAVE after a delay of ΔT_3 .

d). REPLAY_WAVE state. First determine the frame flag. If there is only one echo in the current main pulse cycle, the IF echo signal will be played back. After the state machine delays, it will be switched back to REPLAY_SENDPULSE to finish the radar signal playback in the main pulse cycle; if the current master There are two echoes in the pulse period. The first IF echo signal is played back first. At the same time, the state machine enters REPLAY_GATEPULSE2.

e). REPLAY_GATEPULSE2 state. Play back the second leading wave pulse in the main pulse period, and enter the REPLAY_WAVE2 state after delay.

f). REPLAY_WAVE2 state. Play back the second IF echo signal in the main pulse period. After the delay, the state machine returns to the REPLAY_SENDPULSE state and plays back the next sync pulse, thus ending the playback of the radar signal in the main pulse period.

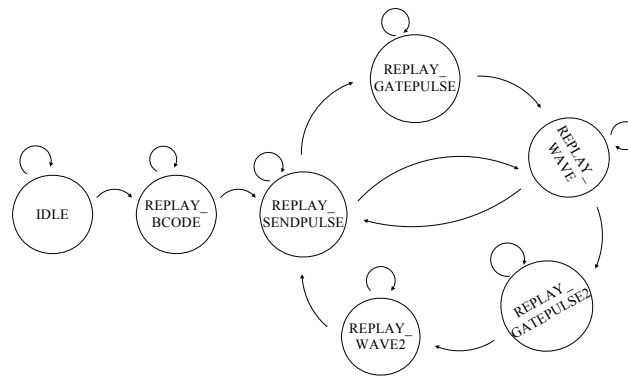


Figure 7. Data playback state machine state diagram

4. Summary

In this paper, by analyzing the two working states of the radar, it is known that there may be three kinds of echo states in one main pulse period: no echo, one echo, and two echoes. The design of the radar signal playback module is mainly focused on these three situations and is of key significance to the construction of the entire system.

References

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