A digital transmission system for high intensity pulsed radial detection *

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Abstract: A digital transmission system with 900 MHz bandwidth and over 40 dB linear dynamic range for high intensity pulsed radial detection is designed. The transient signals (with a subnanoseconds rising edge) from the detectors can be transmitted to diagnosing systems kilometers away with high fidelity. It can adapt to interference and a hostile detecting environment by using the intelligent functions of this system. The feasibility and reliability of this system is verified by system evaluation tests.

Key words: digital transmission system, high intensity pulsed radial detection, fully-digital function design

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1 Introduction

The diagnosis of high intensity pulsed radiation requires recording and analyzing the transient signals (>500 MHz bandwidth) from detectors, several intelligent functions for unattended detection, and adaption in hostile detecting environments [1, 2]. To protect both the diagnosing systems and the engineers, the recording and analyzing station needs to be kept kilometers away. Transmitting the signals through cables or fibers from the detectors to the station will meet problems of limited bandwidth (<500 MHz) or limited linear dynamic range (<40 dB) [3]. To solve these problems, a digital transmission system is designed with 900 MHz bandwidth and over 40 dB linear dynamic range. This system can transmit the signals in digital codes at real time before it is damaged by the high-intensity pulsed radiation, or can even operate normally under a hostile detecting environment due to its 'fully-digital functional design'.

2 Principle analysis

As shown in Fig. 1, the digital transmission system converts the analog signals outputted by the detectors to digital signals, which have better anti-interference than analog signals while being transmitted. Then these digital signals are transmitted kilometers away to the recording and analyzing station. The limit of the bandwidth and the linear dynamic range is surmounted by using a converter with high sampling rate and bits.

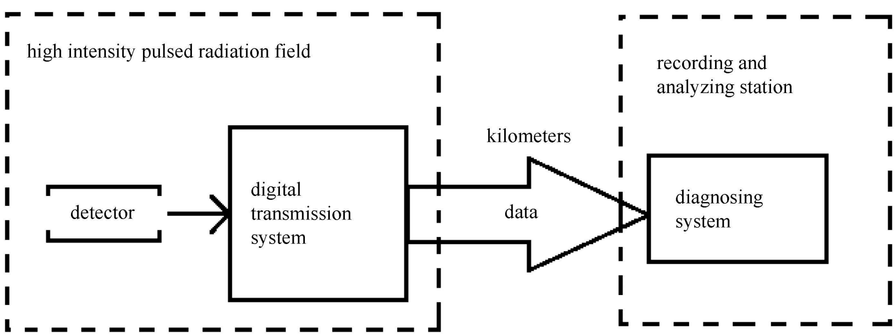

Fig. 1. The digital transmission system.

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2.1 System parameters

The key parameters of a transmission system are the bandwidth and the linear dynamic range, which influence the accuracy of the signal recording [4, 5]. In high intensity pulsed radial detection, the intensity of the radiation varies over 200 dB. The detection usually proceeds piecewise with 40 dB per measuring section (over 5 detectors are needed). In the fastest measuring section, the detector will output signals with a subnanoseconds rising edge (meaning the bandwidth >500 MHz) [6]. Therefore, the transmission system of these detectors must achieve over 500 MHz bandwidth and 40 dB linear dynamic range. To keep within the measurement margin, the bandwidth of the digital transmission system is set to 900 MHz, with 2×10^9/s sampling rate and 8bits (nearly 48 dB best linear dynamic range).

2.2 System function

To adapt to hostile detecting environments in high intensity radiation fields, the digital transmission system must achieve several key functions, as mentioned below.

1) Automatic Pretrigger. The pulsed radial occurs randomly and it is hard to catch the subnanoseconds rising edge of the signals from the detectors with an external trigger. Thus the signals must trigger the sampling by itself.

2) Delay External Calibration. Caused by the piecewise detection, the multi digital transmission systems must be calibrated by external clocks to ensure that the sampling of signals from each detector will process in a certain timing sequence.

3) Valid Signal Distinguishing and Auto Baseline Restoration. High intensity pulsed radiation will cause a high intensity electromagnetic pulse [6]. Through 'backdoor coupling', the electromagnetic pulse will cause interference in the digital transmission system even under normal electromagnetic shielding. That will cause the interfering signals and the baseline drift. The valid signal must be distinguished from the interfering signals accurately and intelligently, and the baseline of the digital transmission system must be restored intelligently by itself.

2.3 Fully-digital function design

The functions described in Section 2.2 are hard to achieve. In conventional system design, GHz processing speeds conflict with complicated functions. The conflict is mainly caused by the following two problems.

1) The necessary Gbytes/s processing rate for intelligent functions needs a subnanoseconds response between the chips on the printed circuit board.

2) The signal integrity is deteriorated by the high speed and the complicated functions of the circuits.

Through the fully-digital function design, the functions depending on analog signals can be performed by digital signals. The amplitude information and time information for operating an analog circuit can be converted to the 'code' of data and the 'multiple' of the sampling interval. This design makes most of the analog circuit become a digital circuit, which can be integrated in one piece of FPGA [7]. As shown in Fig. 2, the transmission circuit system can then be simplified to solve the conflict.

3 System evaluation

3.1 System design

The refined designs of the digital transmission system are shown in Fig. 3–Fig. 6, as the detailed views of the simplified circuit shown in Fig. 2. 'FOT' in Fig. 6 is the abbreviation of 'fiber optical transceiver'.

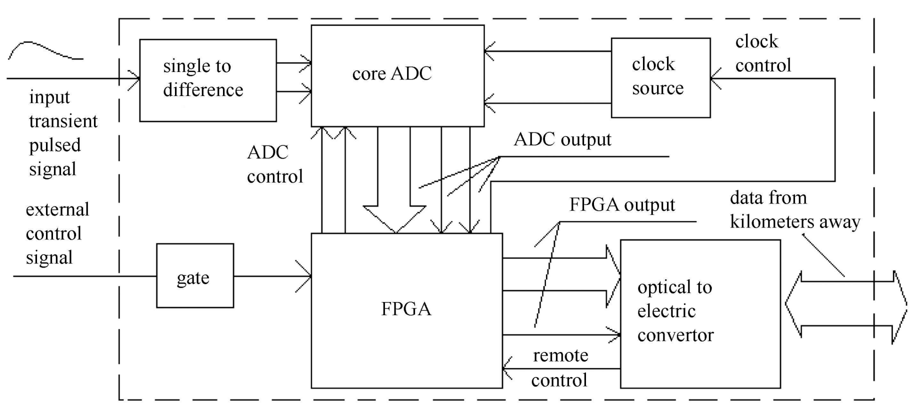

Fig. 2. The simplified measuring system circuit.

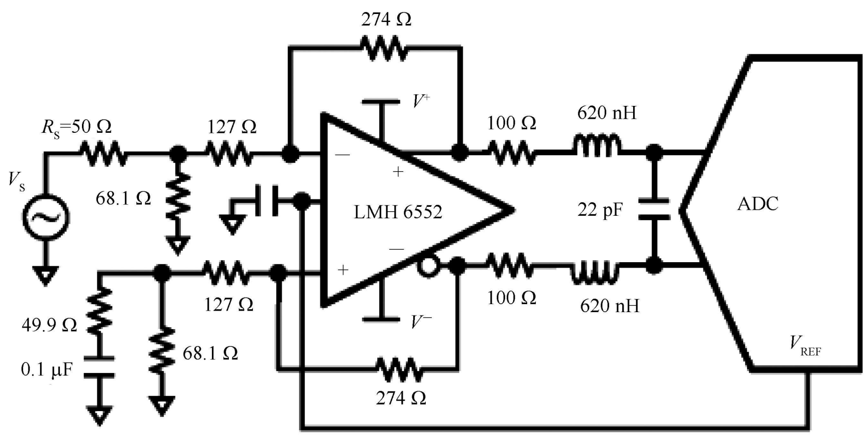

Fig. 3. The single-to-difference conversion circuit.

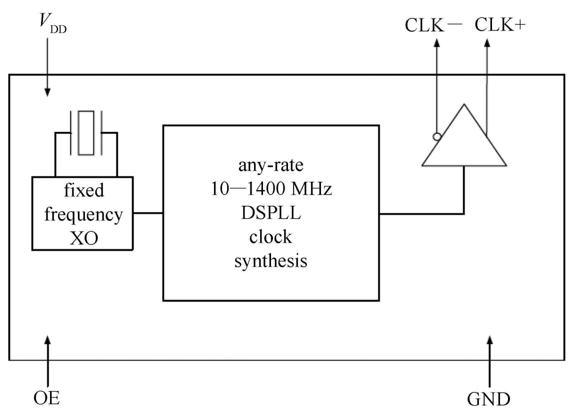

Fig. 4. The clock source circuit.

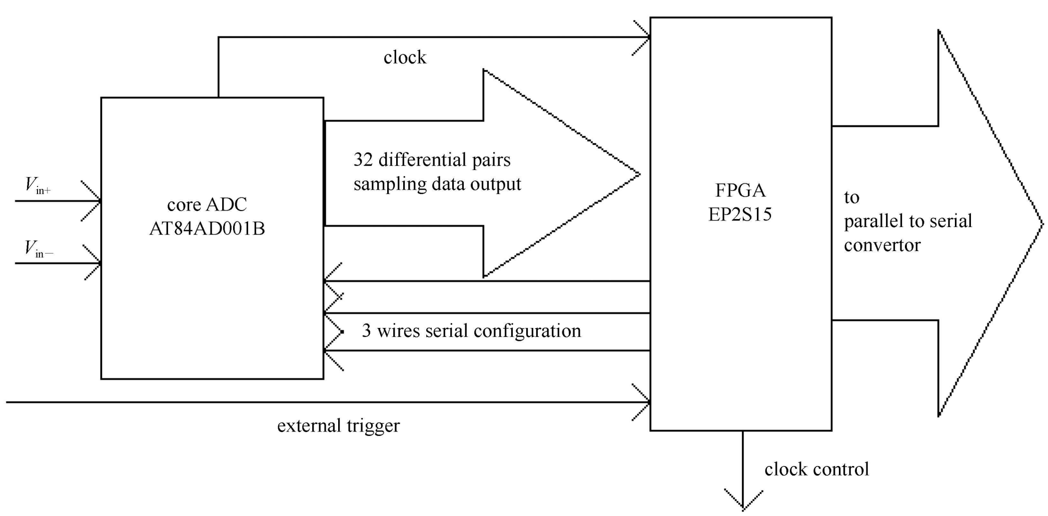

Fig. 5. The circuit with ADC and FPGA.

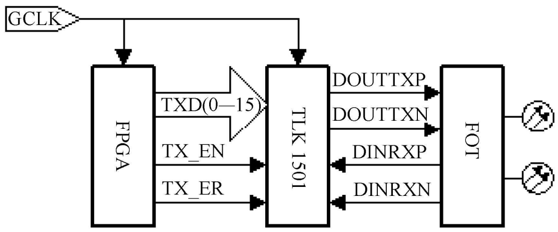

Fig. 6. The circuit of parallel/serial and electrical/optical conversion.

3.2 System test

1) Bandwidth and linear dynamic range test

In the bandwidth test, the −3 dB bandwidth of the digital transmission system is nearly 900 MHz.

In the linear dynamic range test, the digital transmission system could transmit signals with 1.986 V full scale range and 12 mV equivalent noise voltage. That means its linear dynamic range is 20lg (1986/12) ≈44.38 (dB).

2) Automatic pretrigger test

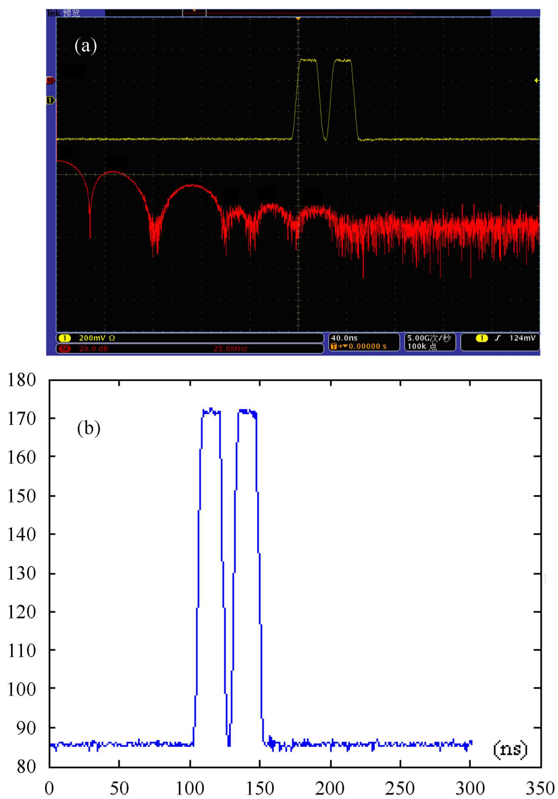

Fig. 7. Test for the automatic pretrigger. (a) Recording from the digital oscilloscope; (b) Recording from the digital transmission system.

As shown in Fig. 7, the special 5 ns rising edge of a transient signal could be caught accurately without using external pretrigger circuits.

3) Delayed external calibration

As shown in Fig. 8 (a copy of the oscilloscope screen, with 5 ns/div horizontal axis), the interval between the global clock and the start of sampling could be controlled as it has been required (25 ns in this test). As shown in Fig. 9, a mark will be inserted into the sampling result to mark the temporal relation between the signal and the start of sampling. From that relation, the temporal relation between the signal and the global clock can be figured out.

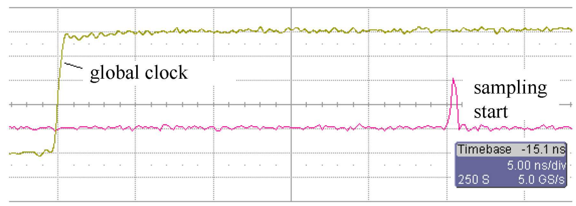

Fig. 8. (color online) The delayed external calibration.

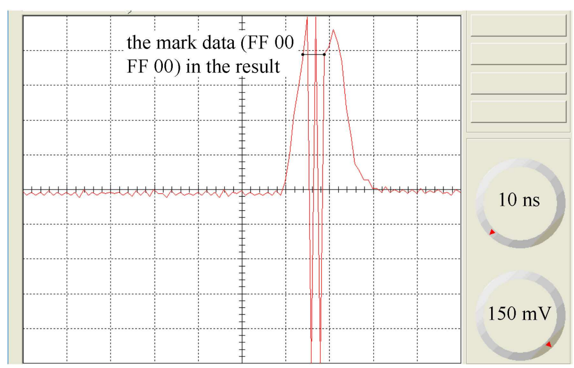

Fig. 9. (color online) The mark in the sampling result.

4) Valid signal distinguishing

As shown in Fig. 10, the sampling of this system will not be triggered by transient interference signals (pulsed width <3 ns in this test). It can be triggered only by valid signals (pulsed width >3 ns in this test).

5) Auto baseline restoration

As shown in Fig. 11, the baseline of the input signal could be restored by the logical operation in the FPGA of this system.

4 Conclusion

The parameters and functions of the digital transmission system have been tested and verified by using the

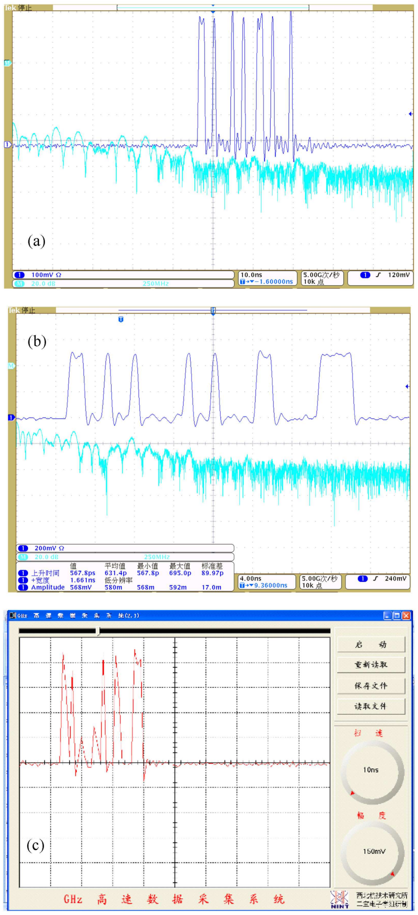

Fig. 10. (color online) Test for valid signal distinguishing. (a) The input signal #1 (all pulsed widths <3 ns, the sampling is not triggered); (b) The input signal #2(one pulsed width >3 ns); (c) The sampling result for #2.

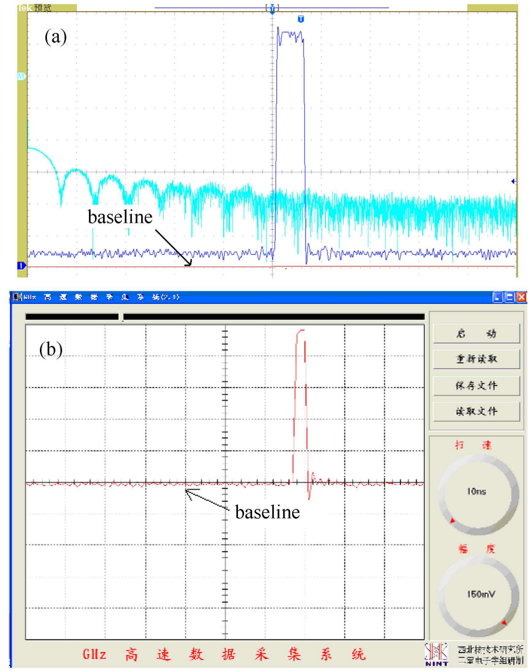

Fig. 11. (color online) Test for the baseline restoration. (a) The input signal (50 mV baseline drift); (b) Sampling result.

evaluation system introduced above. Through the ‘fully-digital functional design’, the problem caused by the conflict between GHz processing speed and complicated functions is solved. By using the medium of digital fiber [8], the digital transmission system could transmit the signals from the high intensity pulsed radial detectors to the diagnosing systems kilometers away accurately and reliably.

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