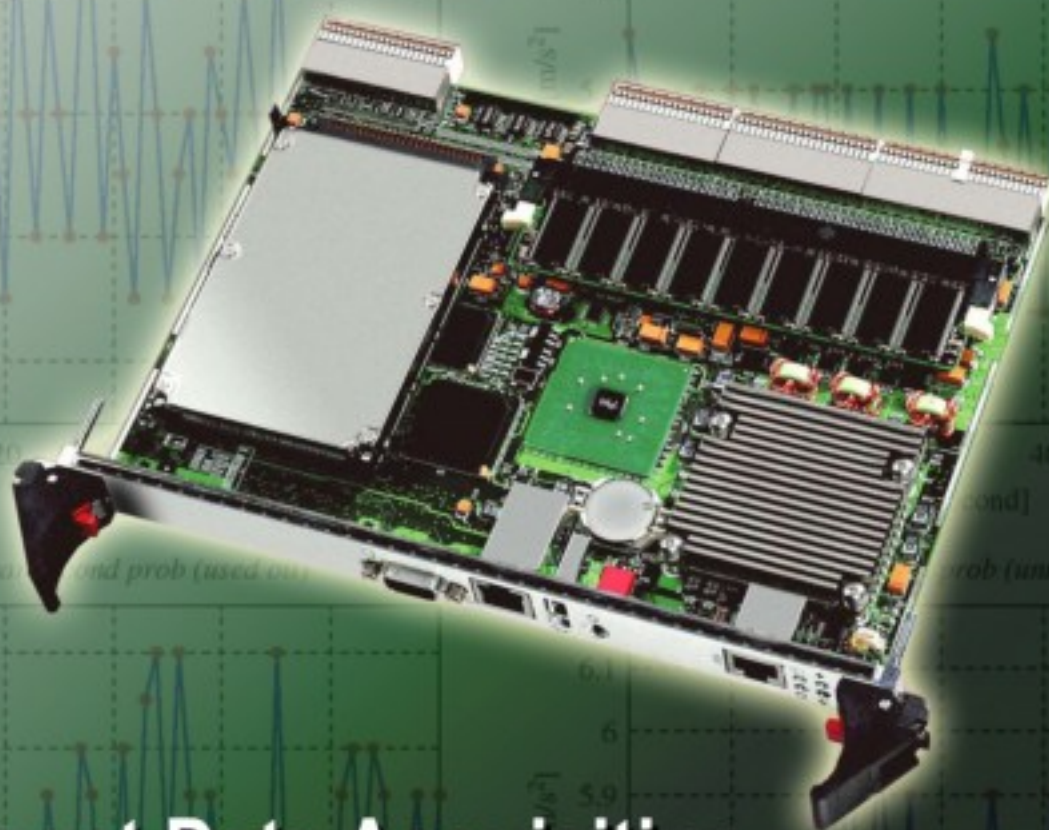


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A Multi-pipe and Multi-address Switching Wireless Network for Distributed Seismic Data Acquisition System

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Abstract: It has some issues such as cable layout trouble and low efficiency to wired shallow seismograph when working in complex environment. In this paper, it takes advantage of the current non-standard wireless communication technology, and according to the requirements of distributed seismic data acquisition with multi-node and multi-parameter, a star-shaped wireless network was built which is suitable for seismic data transmission using the networking mode of multi-channel and multi-address switching, and the distributed seismic data acquisition system was accomplished which had the function of synchronous control and asynchronous transmission adopting the method of address matching identification and custom packet combination, thus the additional accessories of traditional wired seismograph was greatly reduced to improve its capacity and efficiency of construction in a harsh environment. The key technical problems and solutions of wireless seismic data transmission is analyzed in detail in this paper, and provided a reliable wireless networking method which is easy to implement and its highly efficient and stable data transport control protocol. *Copyright © 2012 IFSA.*

Keywords: Wireless network, Shallow seismograph, Data acquisition, WSN, WGN.

1. Introduction

As the main equipment of seismic exploration, seismograph is the core of seismic data field acquisition. Currently mainstream shallow seismographs which are applied widely adopting wired data transmission mode, such as Strata Visor NZXP (USA), Summit II PLUS (Germany) and DZQ48 (China), WZQ96A (China). In adverse environment, such as mountains, hills and lakes region, it's difficult for them to

layout. In addition, it's quite inconvenience for integrated seismograph to apply in complex environment due to itself big volume and heavy weight [1, 2].

However, plentiful wireless supporting platform provides conditions to solve these kinds of problems at present. Compared with wired transmission mode, wireless transmission mode has many comprehensive advantages of low-cost, stable performance, flexible networking, easy to extend and so on [3, 4], and breakthrough the limit of applying in complex geographical environment.

Taking improvement of construction efficient with seismic exploration as starting point, this paper adopts high-speed RF wireless networking replacing traditional wired transmission mode, to simplify hardware of seismograph and to improve its portability. This paper provided a wireless self-networking method which is suitable for shallow seismograph and transplant easily to other platform, including a data transmission control protocol with point-to-multipoint which based on address cycling switch, matching identification and custom message combination.

2. Wireless Transmission Requirements

2.1. Wireless Transmission Requirement of Shallow Seismic Data

In the actual engineering survey and evaluation, the reflection wave exploration with 48 channels is given the priority to adopt in seismic exploration. The geophone is usually used as a string of 12 channels, and using 24 channels in single acquisition, migrating 2 channels, to realize 6 times fold and stack, it can improve the SNR of seismic signal. The field application parameters are set with 4 kps sampling rate, 5 m trace interval, 50 m shot offset and 2048 sampling point [5, 6]. So, the data quantity of single acquisition is 144 k ($2k \times 24 \times 3$) bytes when using A/D with 24 bits resolution, plus the header information of message, it has nearly 200 k bytes to single transmission by the wireless network.

In order to ensure exploration efficiency, therefore, wireless network transmission rate should be not less than 800 kbps, and its distance should be more than 170 m ($5 \times 12 \times 2 + 50$) when any obstacles is not being considered. In the actual application, it needs relevant capacity for wireless network that can bypass obstacles to ensure normal communication in the complex environment. Overall, wireless network is required to have more characteristics such as better scalability, higher speed, larger amount of data and stronger immunity from interference.

2.2. Wireless Mode Selection

Among existing standard wireless protocols, comparatively mature protocols including IrDA (Infrared Data Association), Bluetooth, Zigbee, WiFi and the emerging UWB technology at present. They play different technical advantages in their respective applied fields, their rate, distance and frequency band are shown in Table 1.

Table 1. Mainstream standard and non-standard wireless communication technology.

	IrDA	Bluetooth	Zigbee	WiFi	UWB	AirMesh900	nRF24L01
Rate (Max)/bps	16 M	2 M	250 k	54M	480 M	20 M	2 M
Distance/m	4	10	10-75	70	10	1 k	750 m/PA
Bandwidth/Hz	38 k	2.4 G	2.4 G	2.4G	>1.5 G	910 M	2.4 G

Seen from Table 1, currently mainstream wireless communication technology, especially for the Bluetooth, Zigbee, WiFi within the unauthorized 2.4 GHz frequency band, all of their rate can meet the design requirement of system, however they can't be applied this system due to the limit of communication distance and penetration ability [7-13], all indexes of wireless network station (taking Air Mesh900 for example) meet the system requirement, but its excessive power consumption greatly reduces the portability of the system. So, nRF24L01 based on ANT protocol that belongs to the non-standard radio frequency (RF) protocol is selected to build a wireless network for this system, its max rate is 2Mbps, added with PA (Power Amplifier) and LNA (Low Noise Amplifier) in the actual application, its transmit power is up to 20dBm, and effective communication distance is up to 750m or more, whereas, its distance will decrease when in obstacle environment but it still meet the data transmission requirement. In addition, it includes 125 selectable channels, and supporting six receive pipes at the same time, using 5 bytes address and 32 bytes data packet, these characteristics are very suitable for multi-node seismic data transmission [12, 13], especially for synchronization function of data acquisition.

3. Networking Mode and Synchronous Acquisition Problems

3.1. Wireless Networking Mode

Taking large amount of data into account, 4 acquisition channels share one wireless node in network. It means that 3 wireless nodes are integrated in signal acquisition station which including 12 acquisition channels, and 12 wireless nodes are needed to 48 channels, therefore, a star-shape networking structure with 1 to 12 is adopted in the entire wireless network. Combined with the nRF24L01 features, switching mode of multi-address and multi-channel shall be taken to complete data transmission between host and each acquisition station in final network. It is divided sending address and receiving address (pipe address) to nRF24L01 that is all nodes and host must work in the same frequency band, and only matching sending address and corresponding receiving address can communicate with each other.

Pipes of P0, P1 and P2 are put into service to control host in networking process, P0 is used to receive ACK, receiving data from acquisition station for P1, and P2 is used to receive synchronization instruction. The list of sending address for host corresponds to P1 pipe address of each acquisition node, and its list of P1 pipe address corresponds to sending address of each acquisition node.

Acquisition nodes also start the P0, P1 and P2 pipe, P0 is used to receive ACK, and P1 receives host configuration instruction and synchronization instructions while P2 receives starting work instruction from host. Synchronous node only has P0 to receive ACK. Besides, sending address of host, acquisition node and synchronization node must be the same with themselves P0 pipe address. Sending address and P0 address of host switches between corresponding each node address and global address, the address list corresponds to P1 pipe address of each node, its P1 address list is same with sending address of each node, and P2 is public address.

P0 and P1 pipe address of acquisition node must be unique, its P1 pipe address switches between the local node address and public address, and P2 pipe address is global address. Sending address of synchronization node is public address. Distribution scheme of pipe address of each part is shown in Fig. 1. Single transmission data packet of nRF24L01 is 32 bytes, and corresponding message format is defined when transmitting instruction and data. Therefore, lost data packet can be located according to message flag. The specified message format is shown in Table 2 and Table 3.

3.2. Synchronous Acquisition Problems

Acquisition synchronization of each acquisition channel is crucial to shallow seismic exploration. Namely, the TB synchronous signal must meet corresponding accuracy requirements. For wireless transmission, TB shall be less than $0.625 T_s$ (T_s means the sampling period) [14]. Taking max $250 \mu s$ as most conventional sampling period in shallow exploration, TB shall be less than $151 \mu s$.

To shorten this time, the network takes full advantage of IRQ interrupt function that IRQ pin will form high to low level transition when successfully receiving data, it means to trigger external interrupt function of the host controller using this transition pulse. It can be guaranteed that no more than $5 \mu s$ will be taken for FPGA to response this interrupt in acquisition node [15]. It will take less time for other controllers that support hardware external interrupt.

At the same time, with the rate of 1 Mbps, it will take $4 \mu s$ for nRF24L01 to transmit one data packet, and will take no more than $10 \mu s$ for acquisition station plus the operation instruction execution time. Synchronization system adopts the STM32 microcontroller, it will take no more than $1 \mu s$ to respond interrupt when working at dominant frequency of 72 MHz, and instruction execution cycle is at ns level [16], thus it can be guaranteed that TB time is within $25 \mu s$ using this network model which can meet fully the synchronization requirements.

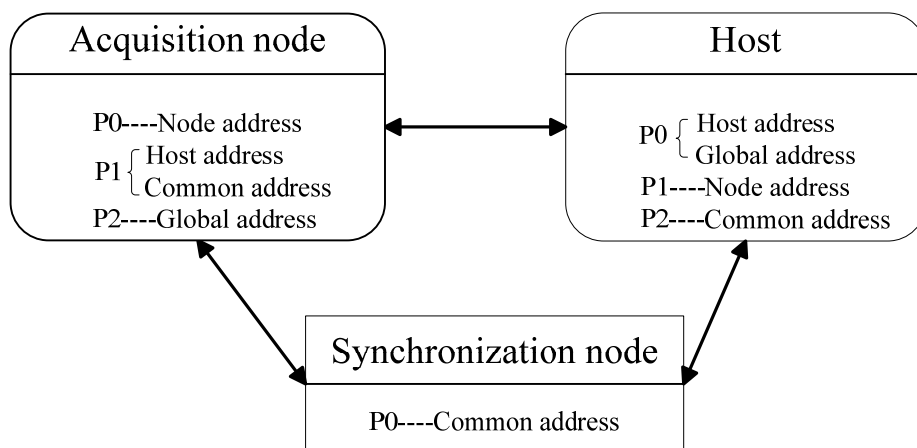


Fig. 1. Networking pipe address distribution scheme.

Table 2. Configuration and synchronization command message format.

Function/Packet	31	30	29	28	27~4	3	2	1	0
Configuration instruction	0xa0	0xa1	0xa2	0xa3	parameter	0xa0	0xa1	0xa2	0xa3
Synchronization instruction	0x05	0x05	0x05	0x05	null	0x05	0x05	0x05	0x05

Table 3. Transmission seismic data message format.

31~30	29	28	27~26	25~24	23~0
Node finish flag	Node number	Acquisition channel number	Packet count	Channel finish flag	Seismic data

4. Communication Process and Protocol

Wireless data transmission is divided into the following three processes.

4.1. Host Configures Acquisition Node

Seen from Fig. 2 and Fig. 3, the host addresses of sending and P0 are switched to corresponding first node address, it sends data according with setting message format, and acquisition node will return completion mark to the host after acquisition completion. The host address switches to the corresponding next node after receiving configuration completion mark, and implements circularly the same operation until configures completely all acquisition nodes in the network. If it fails to receive this mark, multi-retransmission function will be enabled, and it will skip this node if no response after retransmission, and the hardware of this node should be checked.

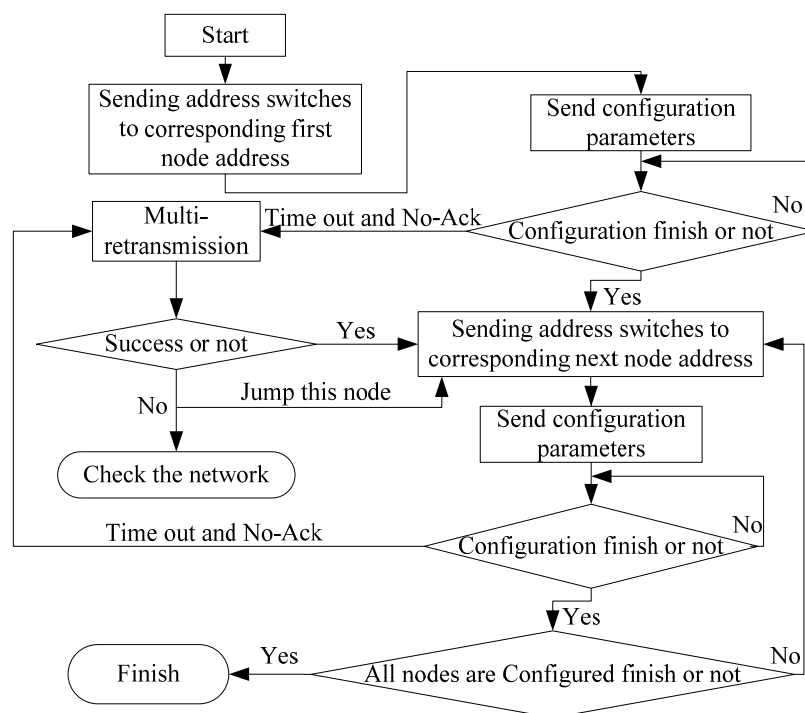


Fig. 2. Flow chart of host configures acquisition node.

4.2. Synchronization Signal Transmission

P1 pipe address of each acquisition node need switch to public address, and synchronization system sends a data packet as synchronous instruction according to setting message format, each node executes corresponding operation after receiving data. P1 pipe address of the acquisition node switches back to the local address after operation completion (Fig. 4).

4.3. Seismic Data Transmission

In the actual communication process, host obtains data using active query. That is host sends instruction of continuous read data to the first node, and acquisition node responds to this command only after

completion of the acquisition work. Acquisition nodes will pack data prior to sending. In order to ensure communication speed, acquisition node adopts the mode of continuous data transmission to host without waiting for confirmation mark due to large amount of data. After that, lost packet will be looked up according to setting message mark.

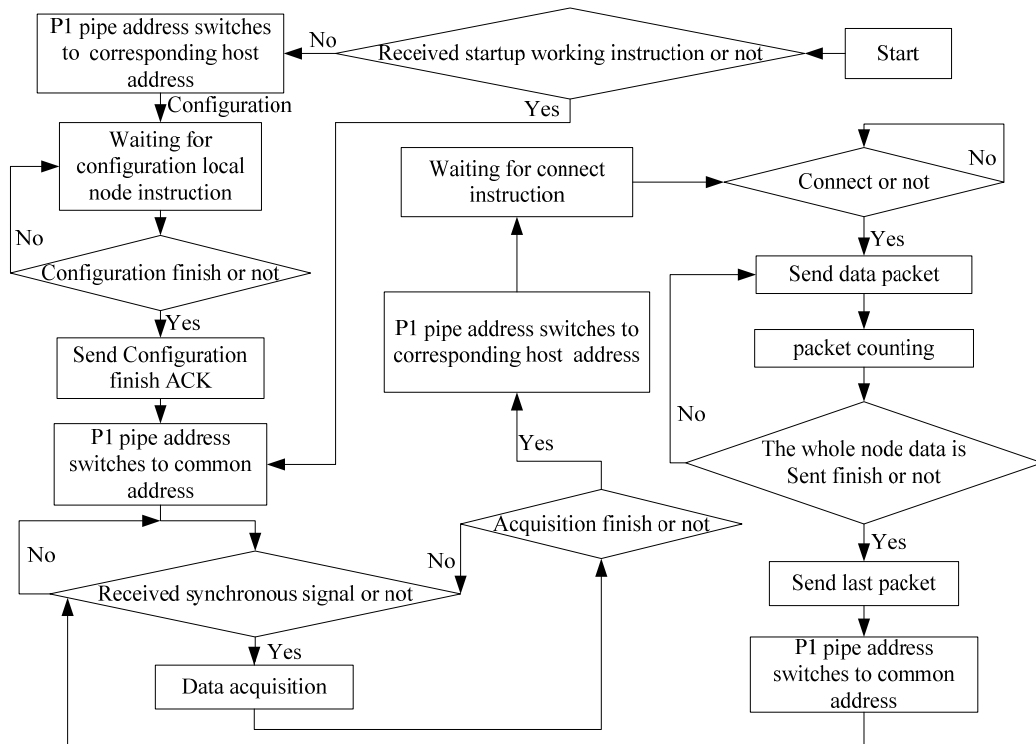


Fig. 3. Flow chart of configuring and send data for acquisition node.

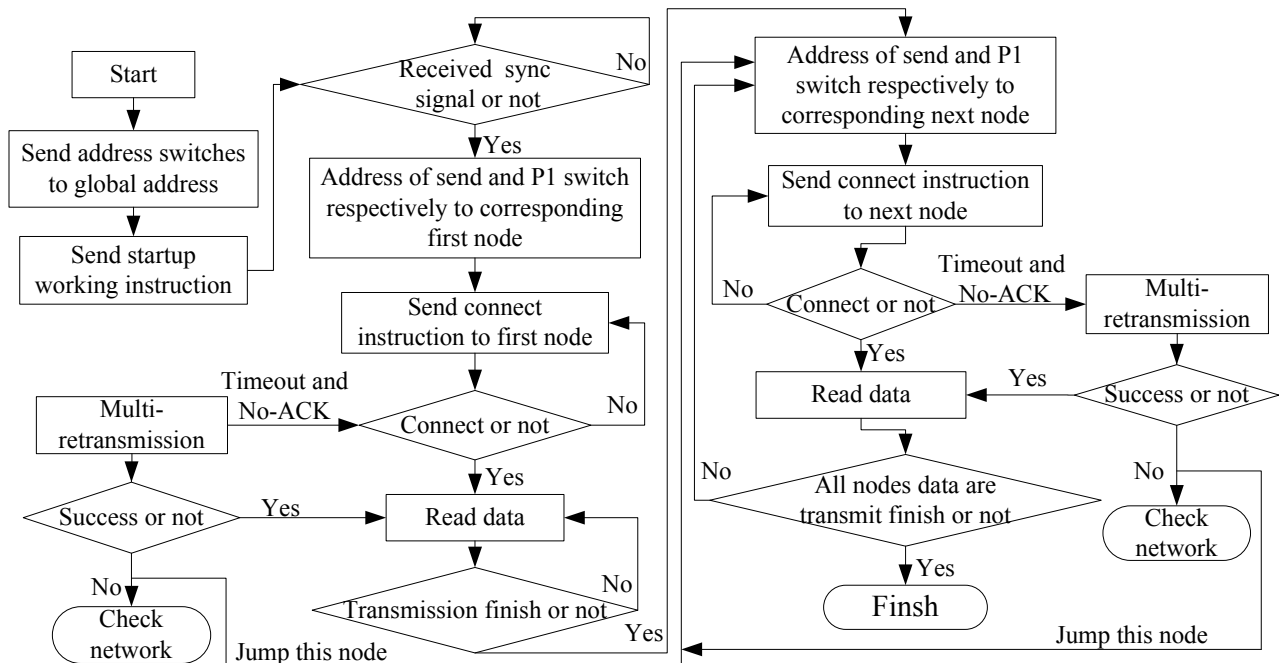


Fig. 4. Flow chart of host receive data from acquisition node.

Data transmission procedure is shown in Fig. 3 and Fig. 4. The process is as follows that host switches its sending address to global address and sends start working instructions, and waiting for the synchronous signal. After all acquisition nodes receiving the start working command, its P1 pipe address is switched to public address, and waiting for synchronous signal.

After receiving synchronous signal, host switches respectively its sending address and P1 pipe address to corresponding address for the first node in the network, and sends continuous connection instruction to the first node. After receiving synchronous instruction, the first node startups acquisition function, and switches P1 pipe address to corresponding host sending address after acquisition completion, and waiting for receiving connection instruction from host. After connection, the first node sends data packet to host continuously, and switches P1 pipe address back to public address when completion, waiting for next operation. Host stitches data according to received message, and sends continuous read data instruction to the next node after reading data completion for the first node. Seismic data transmission of whole system will be completed when perform the above same operation.

In order to ensure the fluency of the data transmission in the network, during host requests to connect with acquisition node, host will skip this node and requests to connect with next node if no response after multiple retransmission, and check the skipped node prior to next operation.

5. Performance Test

For wireless transmission mode, 48 channels engineering prototype were developed, and compared test with the wired integrated seismograph DZQ48 which is produced by Chongqing Geological Instrument Factory under the same conditions. Field test was carried out by artificial hammering source to trigger synchronous acquisition function, using 24 channels migration stack, 250 μ s sampling interval and 512 ms sampling length. It takes about 15s for single shot to store completion of host from hammering trigger shown in actual operation. That's four times acquisition operations can be completed in one minute while six times for wire mode. Due to its removal of various seismograph attached equipments (Seen from Fig. 5), wireless mode increase efficiency more than 50 % compared with wire mode when layout in the field construction. Meanwhile, seen from Fig. 6, field test seismic waveforms of two sets of instrument, it takes same time for each acquisition station from first arrival to reflection wave, indicating accuracy of wireless synchronous meets the requirement of shallow exploration.



Fig. 5. Shallow seismograph (prototype on the left, DZQ48 to the right).

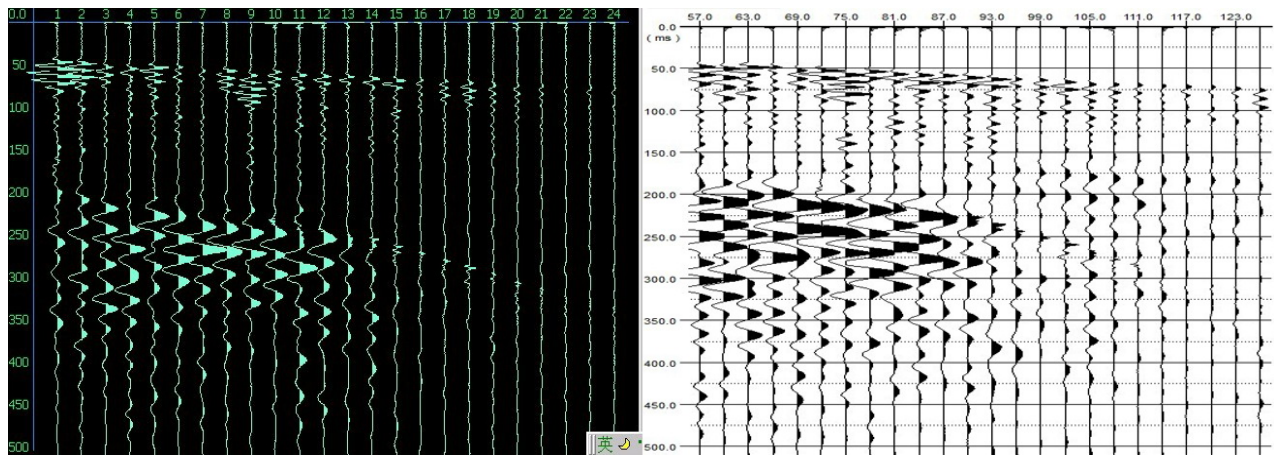


Fig. 6. Acquisition seismic waveform (prototype on the left, DZQ48 to the right).

6. Conclusions

This paper built 1 to 12 star mode wireless transmission network suitable for shallow seismograph data transmission adopting nRF24L01. With communication mode of multi-channel and multi-address switching, it achieved a conflict-free multi-node synchronization control and asynchronous data transmission methods, and formed self-defined message format that can locates and detects lost packet. Ultimately it provided a reliable and easy to implement wireless network method, highly efficiency and stable data transmission control protocol, improving performance of small channels shallow seismograph. However, there are great limitations for this wireless communication mode to apply large-scale seismic exploration due to inherent limit of rate and distance. Certainly, it can improve greatly the efficiency of seismic exploration to wireless mode when constructing in harsh environment, and this network mode can provide technical basis for future development of wireless detector network (WGN), and even can be expanded to various wireless application filed.

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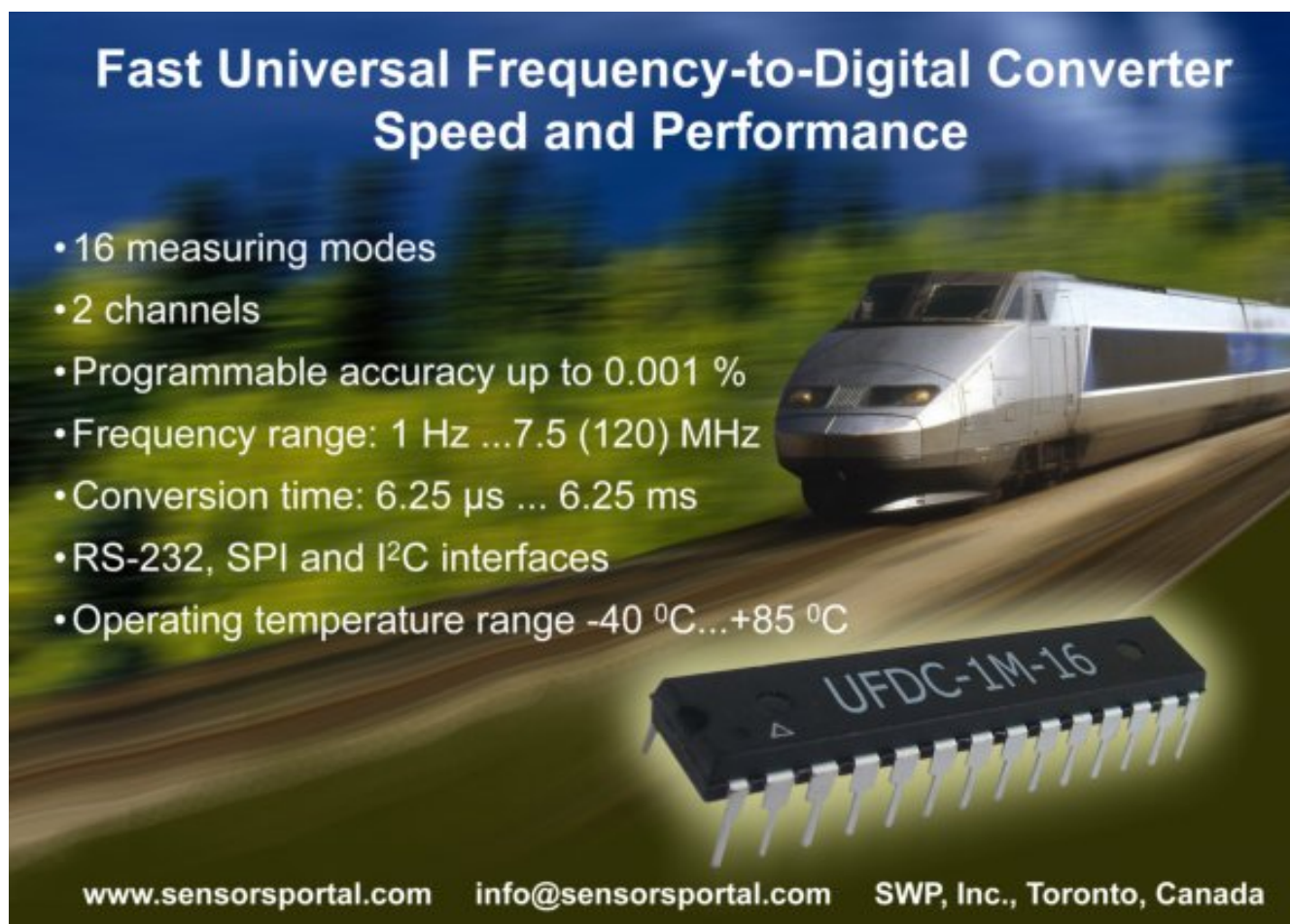
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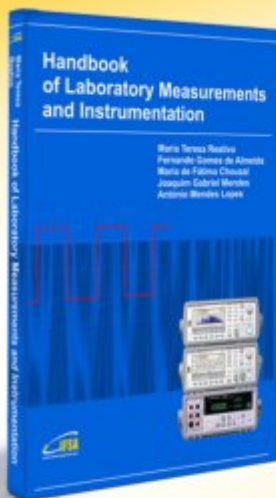


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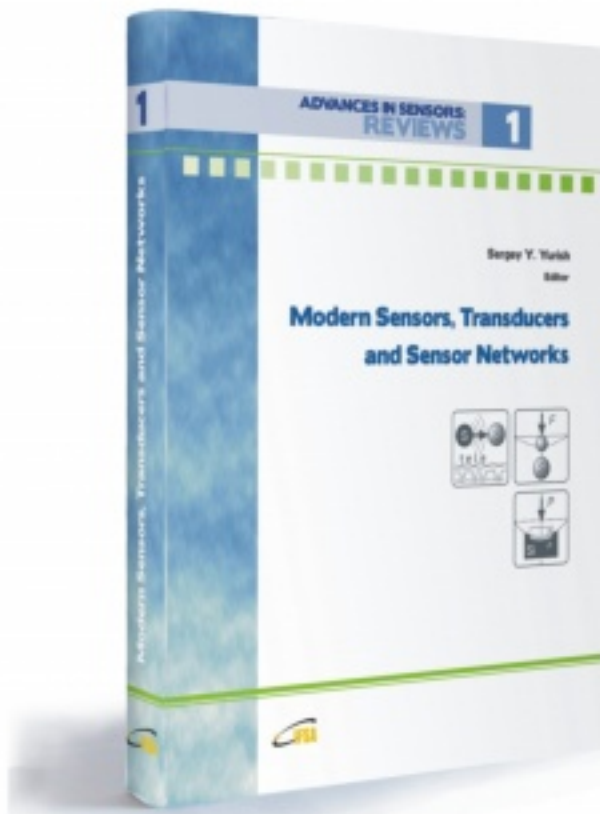
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