A shock wave overpressure test system based on WLAN

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Abstract: Due to short transmission distance and low transmission speed when testing the shock wave overpressure with storage test method based on ZigBee technology, a new test method based on wireless local area network (WLAN) technology is proposed, which can monitor remote test nodes. Moreover, the wireless network is designed based on 802.11b/g protocol, which is helpful for reading the data of the test nodes quickly. Therefore, the accessibility of distributed test system can be improved greatly. The field test results show that the test system performance is good and the transmission speed is high.

Key words: explosion field; wireless local area network (WLAN); wireless transmission

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0 Introduction

With the improvement in shock wave test requirements, test nodes are distributed more and more widely, and the number of test nodes correspondingly increases. Therefore, it becomes poorly efficient for storage test method to monitor the field test before explosion and to collect the data after explosion. In recent years, ZigBee technology has been used in shock wave tests with the development of wireless network technology[1-7]. Although ZigBee technology makes the test more flexible and convenient, it still has some limitations, for example, its transmission rate is only 20—200 kbps and its transmission distance is less than 100 m[8]. Therefore, it is merely used to procuce a trigger signal for synchronization[1-7]. For wireless local area network (WLAN)[9-10], the safety distance can reach up to several kilometers in the shock wave test for weapons, which is far beyond the communication range of ZigBee. Besides, the transmission speed of ZigBee is too low to transmit the large amount of data from a multi-point distributed test. Therefore, a new shock wave overpressure test system based on WLAN technology using 802.11b/g protocol is proposed, whose speed is as high as 54 Mbps and transmission distance is up to several kilometers. Therefore, the WLAN technology functions are better in remote control and data transmission.

1 Overall design

Generally, if WLAN technology is used for a test system, all test nodes can access WLAN. Thus, the remote control center can monitor the state of each test node and collect the data. The remote control center is mainly composed of PC and remote AP(c), where AP means access point. PC is linked with AP through network cable and thus has access to the WLAN. Fig. 1 shows the structure of the system.

All the test nodes are mounted to the leading end of AP(a) to be linked with the WLAN. Through a relay AP(b), data can be transmitted wirelessly for a long distance in order to communicate with the remote control center.

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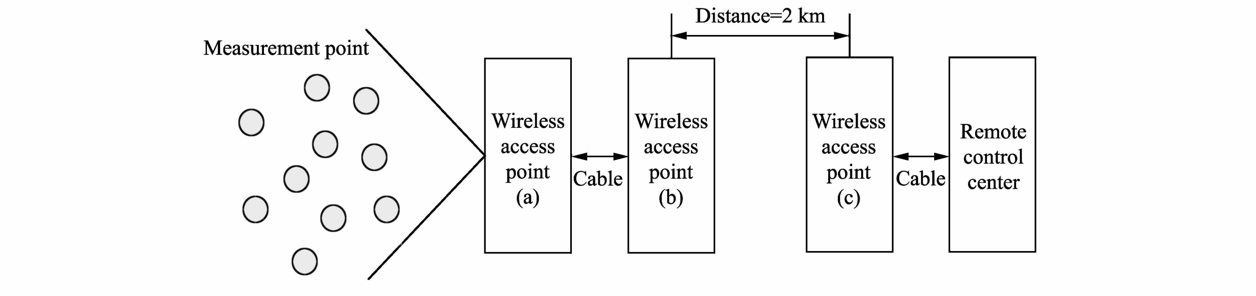

Fig. 1 Structure diagram of test system

The functions of wireless control center include state motoring, parameter setting, wireless control and data processing. They are accomplished by control software based on LabVIEW, which adopts socket technology to fulfill the network communications. Fig. 2 shows the functions of control software.

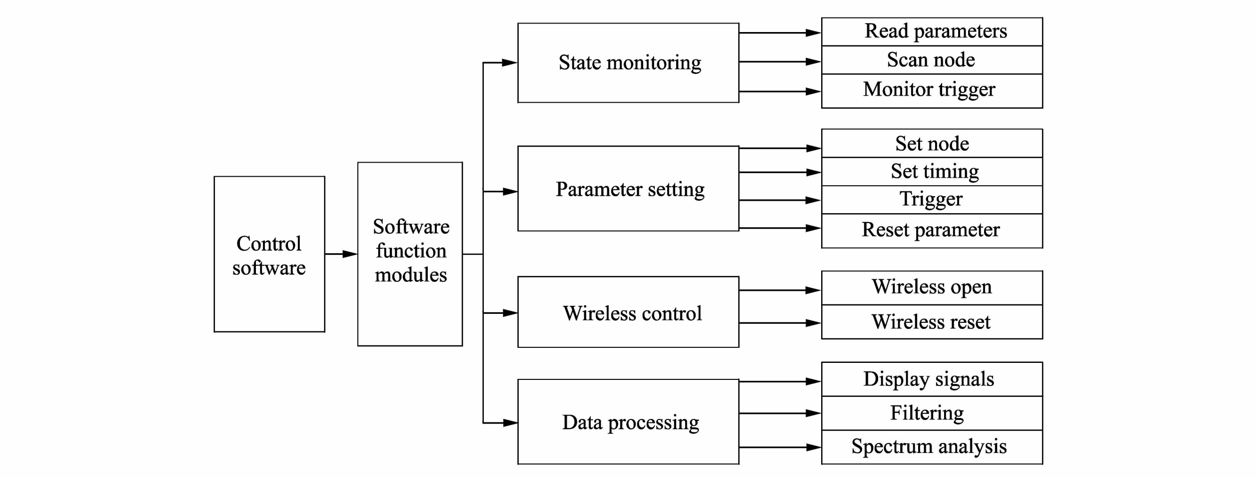

Fig. 2 Block diagram of control software

Fig. 3 shows the hardware block diagram of the test nodes. A field-programmable gate array (FPGA) chip is used for the timing and logic control of the system. Internal electronics piezoelectric (ICP) sensor with free field is adopted since its output voltage signals can simplify conditioning circuit design. After filtered, these output signals are converted to digital signals by analog-to-digital (A/D) converter and stored in flash memory. And then the stored data are read through universal serial bus (USB) if not through wireless network. Wi-Fi module can exchange the data at high speed through universal asynchronous receiver/transmitter(UART). When Wi-Fi module receives the command from remote control center, it sends the command to FPGA chip through UART. After FPGA chip receives the command, it controls the procedures to perform and then sends handshake signals back to the remote control center by wireless network, which means the operation is successful.

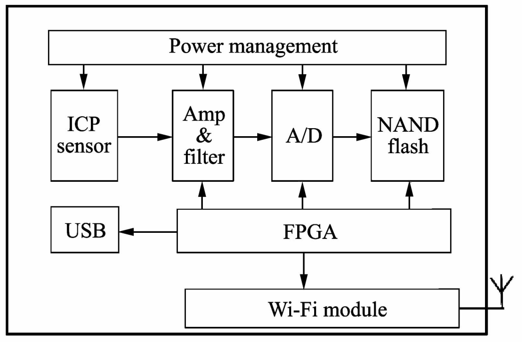

Fig. 3 Hardware block diagram of test nodes

2 Key technologies

2.1 Design of Wi-Fi module

With the rapid development of Wi-Fi technology, wireless chip has more powerful functions. In this paper, a Wi-Fi chip is chosen for wireless communication. It conforms to 802. 11g/n standard with internal integration of TCP/IP protocol stack and Wi-Fi communication driver. It communicates with micro-controller chip through UART with the baud rate up to 921 600 bps. Other chips are connected with FPGA chip by UART, which accepts and sends data through RXD, TXD, CTS and RTS signals and achieves reliable transmission with hardware flow control. The working parameters of Wi-Fi module is configured by command mode. The system is designed based on client/server mode, and Wi-Fi chip is for server mode and the remote control center is for client mode.

The working process of Wi-Fi module is as follows:

1) The Wi-Fi chip continuously monitor request signal from nearby access point(AP) after power on. When AP sends a connection request, a connection is established by WizFi220 chip.

2) The Wi-Fi chip waits for the commands from the remote control center. If the tester wants to modify configuration parameters dynamically, the chip needs to be command mode; otherwise, it will be working mode.

3) In working mode, the Wi-Fi chip waits for the commands from the remote control center. If receiving a command, it sends this command to FPGA chip and FPGA chip performs corresponding operations and simultaneously sends the handshake signal back to the remote control center.

2. 2 Design of WLAN module

WLAN module is designed for high-speed communication and remote monitoring.

2. 2. 1 Wireless topology and coverage methods

There are two kinds of network topology: ad-hoc network and infrastructure network. The control center needs to manage all the test nodes, therefore, infrastructure network is suitable for the increase of the test nodes and centralized management. In this way, all the data can be sent by the remote control center. In order to reduce the complexity of network design, a single AP is used for radio coverage. UBNT rocket M2 and AM2G15-120 high-gain antenna are selected to cover the explosion filed that is generally circular with the radius of tens of meters. The system uses 802. 11g protocol, which requires the AP maximum number of concurrent users no more than 20. This test system currently arranges 15 measurement nodes, which can meet the coverage requirements.

2. 2. 2 IP address assignment and AP mode

In order to add new test nodes for network expansion, a static IP allocation method is used in this design. All devices use IP segment 192. 168. 1. XXX, of which XXX could be an arbitrary value from 0 to 255. All test nodes use 192. 168. 1. 100-192. 168. 1. 199 segment, and AP equipment uses 192. 168. 1. 1-192. 168. 1. 99 segment. To communicate with the measurement nodes that are 2 km away from the remote control center, AP repeater mode must be used. UBNT Nano Station M2 is used as AP relay whose transmission distance is up to 15 km. To establish a WLAN, reasonable AP settings are important to achieve inter-operable network. The AP(a) uses access point module. The AP(b) and AP(c) use point to point bridge mode, which are set to be access point wireless distributed system (WDS) and station WDS, respectively. Although 802. 11g has the bandwidth of 83. 5 MHz, which is divided into 13 channels and the bandwidth of each channel is 22 MHz, only No. 1, 6 and 11 channels are non-overlapping channels. In order to abate co-channel interference in neighboring AP, No. 1 and 11 channels are used.

3 Experimental verification

In order to verify wireless performance, an experiment is conducted in general explosion field. All test nodes are arranged according to the explosion requirements. The experiment flow is as follows:

1) Test nodes and AP are powered up to search for wireless network;

2) Verify wireless parameter settings and wireless condition;

3) Wireless is triggered and wireless transmission is carried out.

The test nodes are arranged as shown in Fig. 4. The AP(a), AP(b) and AP(c) are elevated the top of pole with the height of 6 m. Fig. 5 shows the position of AP(c).

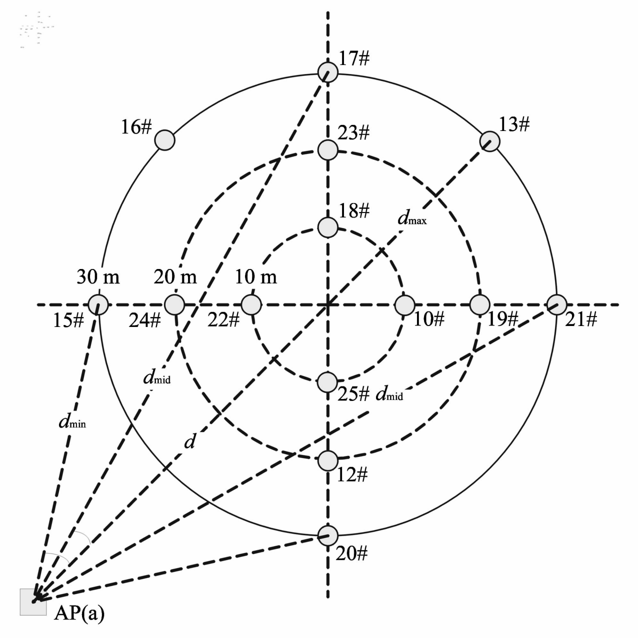

Fig. 4 Arrangement of test nodes

Fig. 5 AP(C)

In Fig. 4，the distance between AP(c) and point o is $d = 150$ m，where $d_{\min} = 130.52$ m and $d_{\max} = 180$ m. And the distance between AP(b) and AP(c) is 2 km. The identical experiment is conducted for three times. The signal strength and noise strength of the test nodes are monitored and recorded by software airOS which is embedded in UBNT device. Three test results are shown in Tables 1，2 and 3. The software functions perform well in three tests. The data of seven test nodes are simultaneously read by remote control center. The transmission time can be seen in Tables 1，2 and 3.

Table 1 Test result of experiment 1

Test node	Signal (dB)	Noise (dB)	Data (Mega Words) /time (s)
10＃	−50	−88	1/49
12＃	−59	−90	1/49
13＃	−57	−87	1/49
15＃	−50	−90	1/49
16＃	−53	−89	1/49
17＃	−60	−91	1/49
18＃	−48	−93	1/49
19＃	−55	−89	1/49
20＃	−56	−85	1/50
21＃	−54	−89	1/49
22＃	−53	−87	1/49
23＃	−53	−92	1/49
24＃	−50	−95	1/51
25＃	−53	−91	1/49

Table 2 Test result of experiment 2

Test node	Signal (dB)	Noise (dB)	Data (Mega Words) /time (s)
10＃	−51	−89	2/98
12＃	−57	−91	2/98
13＃	−58	−87	2/98
15＃	−52	−90	2/98
16＃	−54	−90	2/99
17＃	−59	−92	2/98
18＃	−49	−93	2/98
19＃	−53	−89	2/98
20＃	−56	−87	2/101
21＃	−54	−89	2/99
22＃	−53	−88	2/98
23＃	−54	−91	2/98
24＃	−50	−93	2/98
25＃	−53	−91	2/98

Table 3 Test result of experiment 3

Test node	Signal (dB)	Noise (dB)	Data (Mega Words) /time (s)
10＃	−51	−88	2/98
12＃	−56	−91	2/98
13＃	−59	−87	2/98
15＃	−53	−90	2/99
16＃	−54	−89	2/98
17＃	−59	−92	2/98
18＃	−50	−93	2/98
19＃	−53	−90	2/98
20＃	−52	−89	2/101
21＃	−53	−89	2/99
22＃	−53	−88	2/98
23＃	−54	−91	2/98
24＃	−51	−92	2/98
25＃	−53	−90	2/98

The storage capacity of data in the measurement node can be 1 Mega words and 2 Mega words. To measure the transmission speed, these two kinds of storage capacity are used in this experiment. Fig. 6 shows the shock wave signal obtained by measurement node 10# with some equivalent TNT explodes at first sting.

As seen from tables, the signal strength of all the measurement nodes is greater than −60 dB and the noise signal strength all the measurement nodes is less than −90 dB. The receiving sensitivity of AP(a) is −97 dB in the range of 1−24 Mbps, which contributes to data transmission. The transmission time in experiment 2 and experiment 3 is twice as that of experiment 1, but the transmission speed is almost the same. This indicates the transmission speed of the system is stable. The maximum speed and minimum speed are calculated as v_1 = 7 Mega words/49 s = 292. 57 KB / s and v_2 = 7 Mega words/51 s = 281. 098 KB/s.

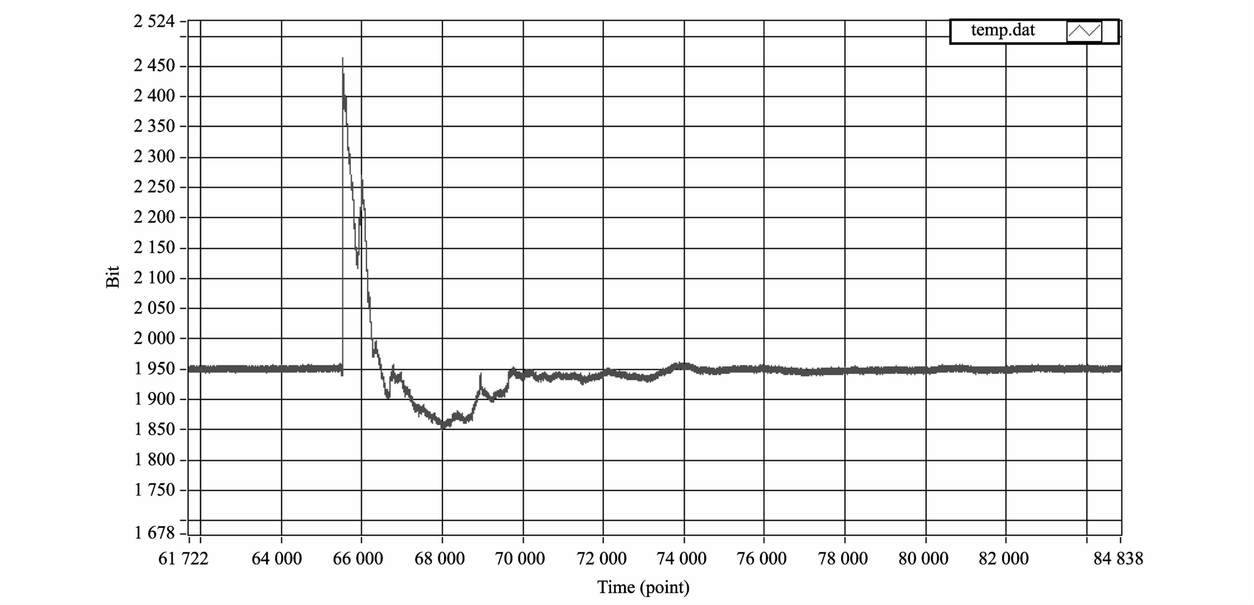

Fig. 6 Test curve in 10 m

4 Conclusion

When the number of test nodes increases in shock wave test, ZigBee technology will be faced with some problems, such as a short transmission distance and slow transmission speed. Therefore, in this paper, WLAN technology is used for shock wave test system. After experiment verification, it can be seen that the wireless transmission distance of the designed system can reach up to 2 km and transmission speed can be up to 292. 57 KB/s. WLAN technology helps the system add new test nodes quickly. Using multiple APs makes the system cover more test nodes and transmission speed higher. The system is applicable for distributed test with more measurement points.

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基于 WLAN 的冲击波超压测试系统

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摘　要： 采用基于ZigBee技术的存储测试方法进行爆炸场冲击波超压测试时，存在监测距离近和传输速率慢的问题。为此，提出了一种基于WLAN技术的新测量方法，可实现对测试节点的远程监测。同时，采用802.11g协议设计了无线网络，可通过无线方式快速读取测试结点的数据，从而大大提高了分布式测试系统的便捷性。爆炸场试验结果表明，测量系统性能良好，传输速度快。

关键词： 爆炸场；WLAN；无线传输

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