

Physiological State Monitoring System of the Home Elderly Based on Multi-frequency Narrowband Power Line Communications

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Abstract: This paper designs and implements a home elderly physiological data monitoring system, which based on multi-frequency narrowband power line communications technology. The system combines wireless sensor network and narrowband power line communication method, realizes the real-time monitoring and transmission of the physiological status of the home elderly. This scheme overcomes the weakness that the traditional monitoring system using wireless network signal alone, there is no signal in the shielding area, then realizes no blind angle control in buildings. Finally, through the test and analysis, it proved that the system can meet the application requirements, and it is a suitable solution for home elderly physiological status monitoring.

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Keywords: Multi-frequency FSK, Physiological data monitoring system, Power line communication, Home elderly, Simulation and experiment.

1. Introduction

Recently, China is the world's the largest population in the elderly. According to the national related departments statistical forecast, by 2025, the elderly population will account for 19.34 % of the total population. With the development of China's aging process, the elderly medical care demand is increasing. The traditional medical monitoring must be conducted within a specific medical workshop, although monitored objects can be acting within a certain range when using simple wireless sensor network monitoring system, in some shield severely area will cause the disruption of normal data

transmission. In view of the above situation, this paper designs a kind of physiological data monitoring system, which based on wireless sensor network and narrowband power line communication. The elderly can act freely with portable monitoring equipment in the indoor area of power line network coverage, to complete the monitoring data acquisition and real-time transmission of physiological data at any time. Narrowband power line communication technology becomes a very competitive means of communication because of its low investment, wide coverage, safety and reliability and maintenance and low cost. It is very suitable for real-time monitoring of the elderly daily physiological state [1, 2], and to

provide meaningful solutions for the urban living of the elderly physiological data monitoring and emergency rescue in time.

2. The Composition of System

The overall system diagram is shown in Fig. 1. The mobile terminals collect the elderly physiological data such as body temperature, heart rate and blood pressure by all kinds of sensors that wearing in the body, than transmit it to indoor receiver by wireless way. The receiver transmits the real-time physiological parameters to the health care center in the community by the low voltage power line. The control center handles the data timely, and compares the physiological parameters with the normal value. In addition, the control center also can calculate the location information through a specific algorithm, etc. When the elderly issued an emergency call or physiological data is abnormal, the medical staff can find it timely, so as to strive for the precious time for the rescue work.

After collecting physiological data, sent it to the power line communication module, wireless transceiver module using the CC2430 chip. This chip is developed by TI, which used to implement the embedded ZigBee application system. As the sensor, it is a mature technology product. Therefore, the core algorithm of this paper is the design of multi frequency narrowband power line communication, which using DSP6713.

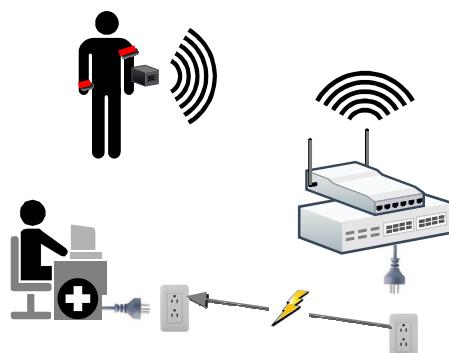


Fig. 1. Overall system diagram.

3. PLC System Design

The block diagram of multi-frequency narrowband power line communications is shown in Fig. 2. After the sender receives the home elderly physiological data from wireless sensor, using the power line communication (PLC) device to send data. First of all, the data in the PLC device coding by convolution code error correction and adding CRC efficacy code coding after interleaving coding. The data encoded using an adaptive FSK (Frequency-shift Keying) modulation.

The main process of the adaptive FSK is based on the SNR information of the receiver feedback to select the best transmission frequency. FSK modulated data transmission mode by using different frequency square-wave, after the hardware circuit filter amplified sent through the coupler to the low voltage power line network; Receiving end received the high frequency signal through coupler on the other end of the low voltage power grid, FSK demodulation using a specially designed differential demodulation, at the same time can demodulate three groups of the center frequency signal. Finally, we can obtain the actual data by decoding deinterleaving operations.

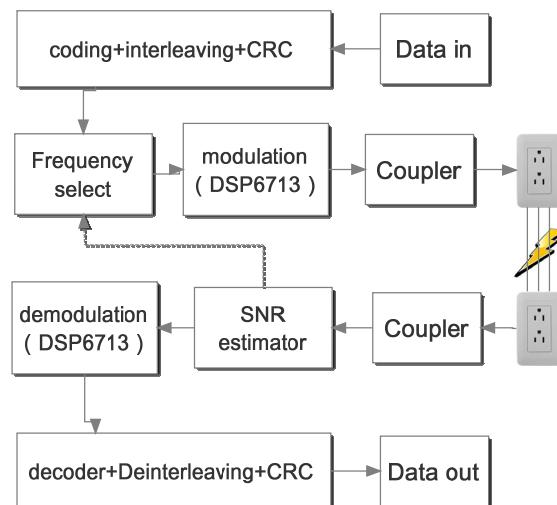


Fig. 2. The PLC Block Diagram.

4. Modulation and Demodulation Technology Design

FSK technology, which used in narrowband power line system, is a mature modulation and demodulation technology. FSK Demodulation methods mainly have coherent demodulation and no coherent demodulation. This article shows no coherent demodulation, the advantage is that the local carrier demodulation does not need to use the same frequency and phase, and the differential demodulation method need not use the complex equalization algorithm, so as to simplify the hardware requirements [3]. FSK demodulation in digital communication mainly including: 1. periodic statistical zero crossing detection demodulation; 2. fixed delay differential demodulation. The second method is adopted in this design. Signal demodulation of FSK can be used in three groups of center frequency flexibly. The schematic diagram of differential demodulation shows in Fig. 3.

The demodulation process is as follows: After the received signal delays K sampling, it multiplies by the original signal, and then it becomes a multi frequency signal. After it through the low pass filter, the high-frequency components are filtered out, and the

rest is low frequency component, finally through the sampling decision, we can get the demodulation results. Multiplying signal V(n) is as follows:

$$\begin{aligned}
 V(n) &= s(n)s(n-k) \\
 &= A^2 \sin(2\pi FnT) \sin[2\pi F(n-k)T] \\
 &= \frac{A^2}{2} [\cos(2\pi FkT) - \cos(4\pi FnT - 2\pi FkT)]
 \end{aligned} \quad (1)$$

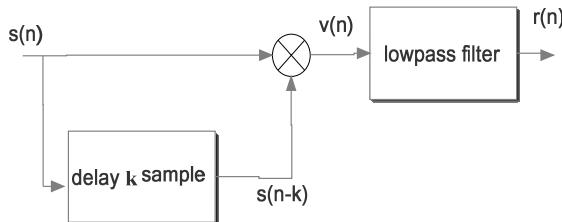


Fig. 3. Schematic diagram of differential demodulation.

From above equation we can see that product signal can be seen as two cosine adding. After filtering, it changed into the cosine component that delays sampling number as a parameter. Through proper design, it can make the "0" and "1" frequency components into a bipolar signal. Complete differential FSK modulation and demodulation process as shown in Fig. 4 to Fig. 7.

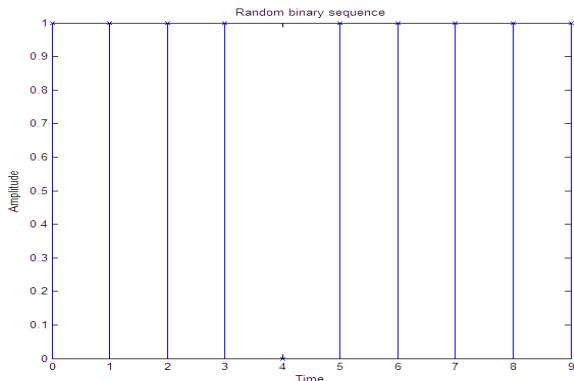


Fig. 4. Transmission bit.

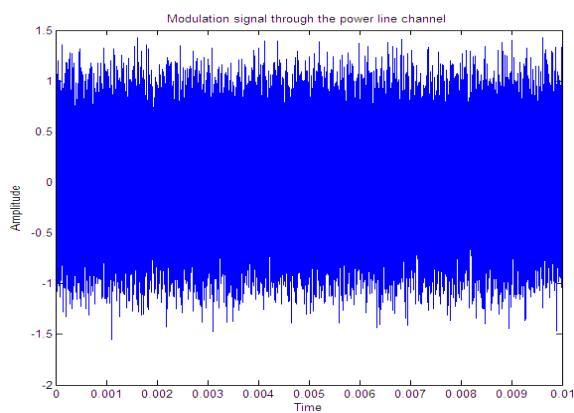


Fig. 5. Waveform after Power line channel.

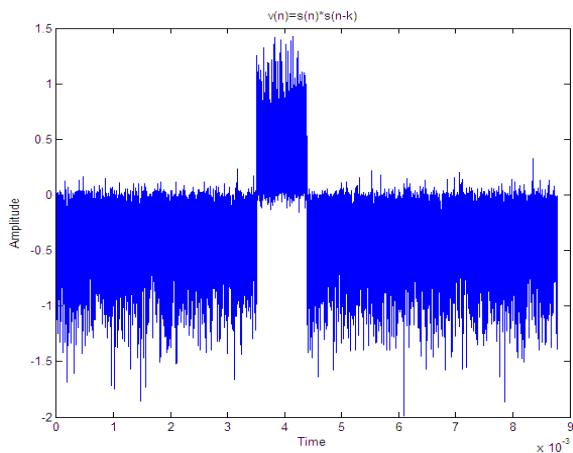


Fig. 6. Waveform after differential operation.

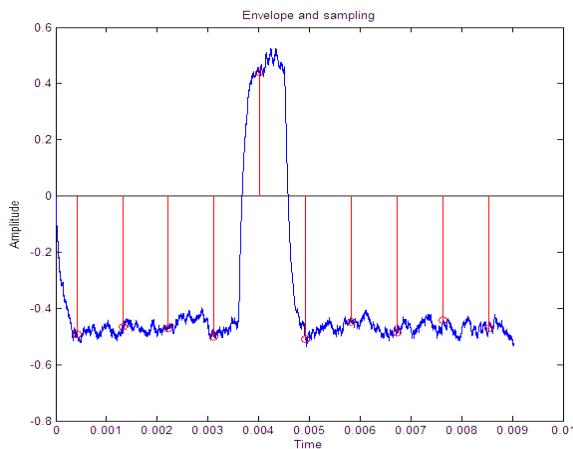


Fig. 7. Envelope of differential waveform and sampling.

The receiving terminal received the data that through the power line, after the difference operation, and using the 30 order Butterworth low-pass filter to find out the low-pass envelope of difference signal, after sampling sentence, the output demodulated signal as shown in Fig. 8.

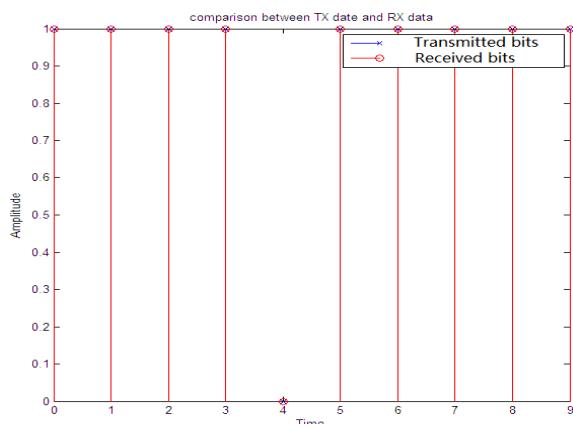


Fig. 8. Comparison between the transmission bits and received bits.

5. Adaptive Multi-Frequency FSK Technology

Adaptive multi frequency FSK technology is the signal-to-noise of feedback information by the receiving end that adaptive to send equipment, adaptive adjustment of sending center frequency. In this paper, through setting a reasonable delay differential demodulation sampling number, which makes the receiver does not need to use frequency monitoring means, multiple different frequency points can use the same delay to complete demodulation process. Compared with the single frequency point FSK, using adaptive FSK has three key technologies need to design: the design of multi-frequency points delay and signal-to-noise estimation technique design and pre filter design.

5.1. The Design of Multi-Frequency Points Delay

FSK differential demodulation technology using the appropriate number of delay and sending frequency, which makes the differential envelope in the 0 and 1 frequencies and present different polarity, thus completing the demodulation process. Fig. 9 shows when using the 54 kHz, 65 kHz and 75 kHz center frequency, the difference's absolute value between 0 and 1 low frequency component closer to 2, the better performance of demodulation has. As can be seen from the graph, when the delay is 35, difference of the three frequency points are agreement. The FSK demodulation with different center frequencies can be used the completely consistent demodulation algorithm.

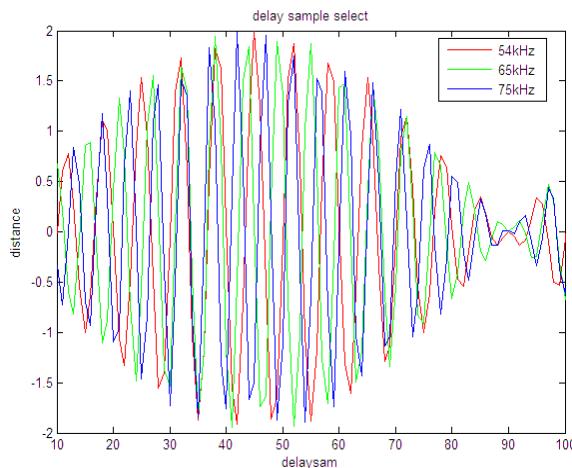


Fig. 9. Frequency delay selection result.

5.2. SNR Estimation Technology Design

SNR estimation technique is the basis of adaptive frequency selection. There are a lot of SNR estimation algorithms for narrowband communication systems, such as maximum likelihood estimation method (ML),

second order/fourth-order moment estimation method, based on signal subspace decomposition method (SB), signal projection algorithm (SP).

The ML method is the SNR estimation methods in digital sequence domain, and it must be carried out on the demodulated signal. Because the moment method has square root operation, large amount of calculation. SB, SP method requires matrix operations, the amount of calculation is large, it is not easy to hardware implementation.

This system adopts an improved correlation acquisition algorithm based on training sequence, and it mainly used the fact that noise distribution and communication signals unrelated in the power line.

Assuming that the training sequence is D_M , where M is the number of sampling points, then the receiving end receives signal from power line noise pollution is X_M , which shows :

$$X_M = fD_M + N_M, \quad (2)$$

where f is the signal attenuation constant, N_M is the noise; due to uncorrelated signal and noise:

$$E[(x_m - fd_m)d_m^*] = 0, \quad (3)$$

Both sides seek for mathematical expectation:

$$(X_M - fD_M)D_M^H = 0, \quad (4)$$

So:

$$f = \frac{X_M D_M^H}{D_M D_M^H}, \quad (5)$$

Finally, SNR calculated as follows:

$$SNR = \frac{|fD_M|^2}{|X - fD_M|^2}, \quad (6)$$

SNR estimation algorithm in Matlab simulation results shown in Fig. 10.

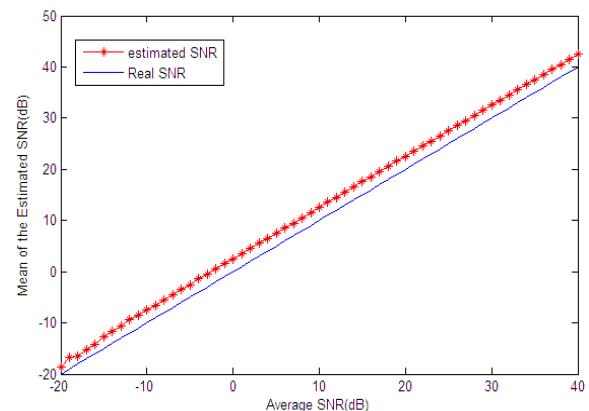


Fig. 10. SNR simulation result.

5.3. Pre-Filter Design

Low voltage power line channel noise is serious, and the high frequency signal attenuation is bigger. To improve the performance of the system against the narrow band interference, must first pass digital filter before receiving signal demodulation.

This design adopts the band-pass filter with pre-filter comb filter cascade. By Chebyshev uniform approximation method to confirm the optimal estimation of the filter order N_0 , the normalized cut-off frequency vector f_0 , the ideal of pass band and stop band filters A_0 amplitude vector and weight vector, based on the theory of Chebyshev best uniform approximation and in order to achieve the Parks McClellan algorithm, make the amplitude frequency response of the actual filter fits to optimally reasonable to amplitude frequency response of the filter, minimize the maximum error, in order to achieve better pass band and stop band performance, and accurately specified pass band and stop band edge, and has equiripple characteristics in the frequency domain. Cascade filter frequency response design is shown in Fig. 11.

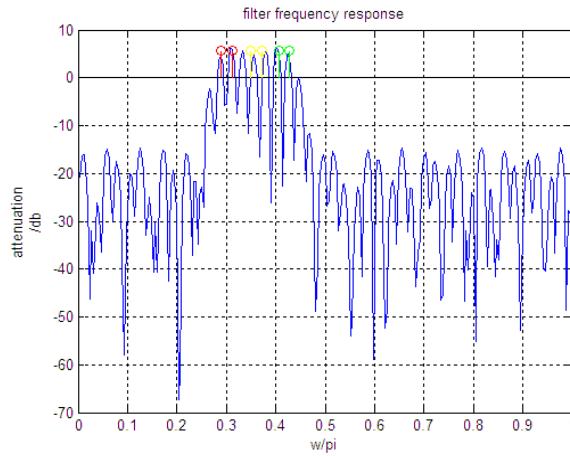


Fig. 11. Frequency response of cascade filter.

6. System Simulation of PLC

6.1. Simulation Environment

The bottom-up approach is used and measurements are carried out in home power line circumstance. Statistical results are obtained to build the channel model. PLC channel transfer function is obtained by the computation of the ratio between the receiver and transmitter as

$$H(f) = \frac{V_{rx}(f)}{V_{tx}(f)}, \quad (7)$$

According to the transmission line theory, to obtain the transfer function of home PLC channel we need to measure the network topology and the properties of cables and loads [4, 5]. The power line

network is divided into several units. Transfer function of each unit is calculated as:

$$\begin{aligned} H^{(n)}(f) &= \frac{V_{el}^{(n)}}{V_l^{(n)}} = \frac{V_{el}^{(n)}}{V_p^{(n)}} \frac{V_p^{(n)}}{V_l^{(n)}} \\ &= \frac{1 + \Gamma_{el}^{(n)}}{e^{r_2^{(n)}l_2^{(n)}} + \Gamma_{el}^{(n)} e^{-r_2^{(n)}l_2^{(n)}}} \frac{1 + \Gamma_p^{(n)}}{e^{r_1^{(n)}l_1^{(n)}} + \Gamma_p^{(n)} e^{-r_1^{(n)}l_1^{(n)}}} \end{aligned} \quad (8)$$

Then the integral channel transfer function is calculated as:

$$H(f) = \prod_{n=1}^N H^{(n)}(f), \quad (9)$$

Fig. 12 shows three amplitude-frequency response of low voltage power line channel with different transfer function from 10 kHz to 40 MHz. Fig. 13 shows corresponding three phase-frequency response.

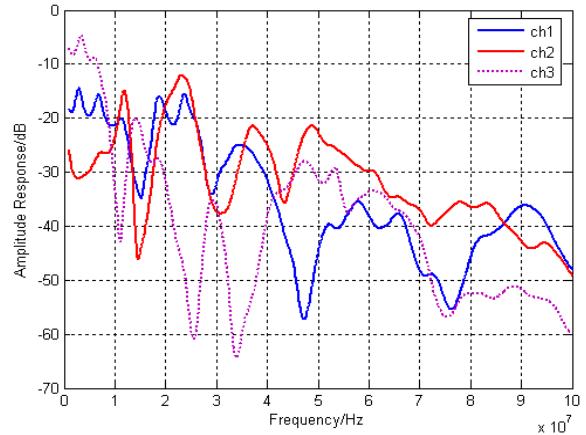


Fig. 12. Power line channel amplitude-frequency characteristic diagram.

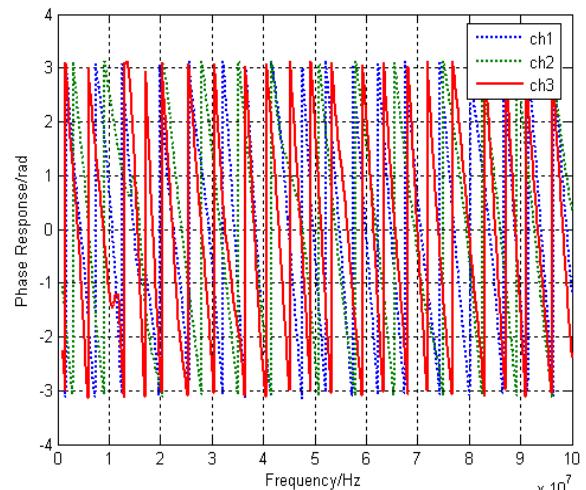


Fig. 13. Power line channel phase-frequency characteristic diagram.

Noise is measured in real home environment [6]. Fig. 14 shows a 24 hours noise measurement results.

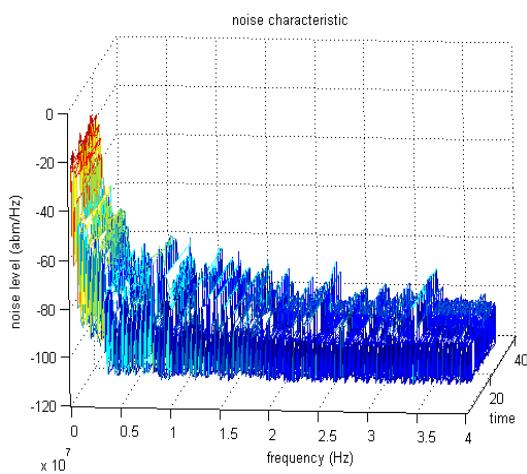


Fig. 14. 24 hours measured noise.

6.2. Simulation Result

Simulation work is carried out under power line channel with Monte-Carlo method. The bit error rate (BER) is calculated by run 10000 times. Simulation Settings as follow: sampling frequency is 360 kHz; three center frequencies are 54 kHz/65kHz/75kHz; Frequency difference between 0 & 1 is 4 kHz. Fig. 15 shows the BER performance of proposed multi-frequency FSK system. Proposed system shows better performance in power line channel.

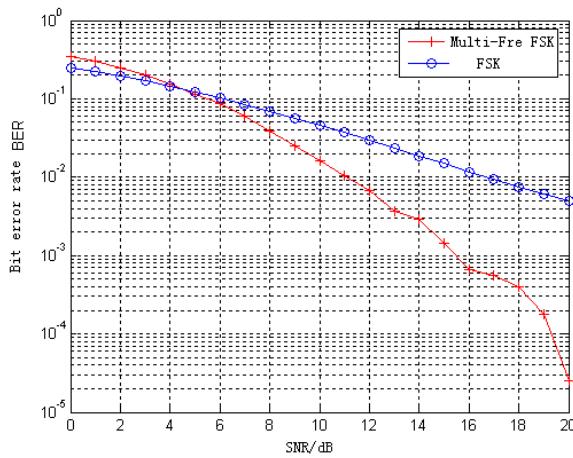


Fig. 15. Overall system performance simulation result.

7. Hardware Experiment Results

The proposed multi-frequency powerline based home elderly physiological status monitoring solutions are designed and implemented on a hardware platform [7]. Fig. 16 shows the experimental devices and schematic diagram.

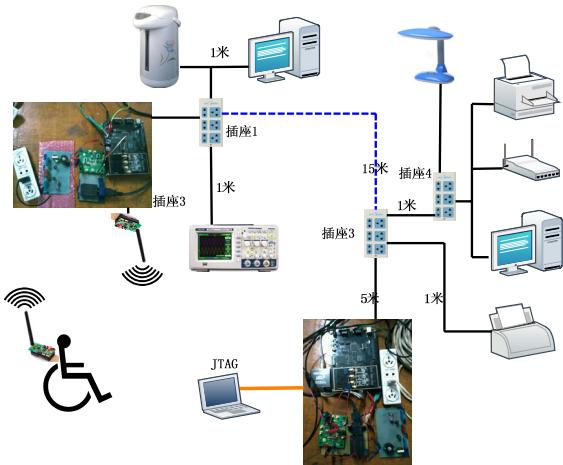


Fig. 16. Experimental schematic diagram of measurement system.

The physiological status data of elderly are collected by a variety of sensors. Physiological status data is transmitted by the wireless network to the PLC devices which will inject the data into the power line network. In the PLC device the output FSK signal is coupled to the low voltage networks with high pass coupler with 10 KHz cutoff frequency.

In the receiver, signal is coupled from another node of grid with several branches. Received data is first pass the VGA path of AD8260 evaluation board with lower than 2 V. Then the data is transmitted to AD sample of hardware development board. Digital oscilloscope is used to check the received waveform. And last the demodulated signal is transmit to computer by JTAG wires. Finally, analysis work is carried out by computer.

Fig. 17 shows the waveform of received data. The modulated data is contaminated by the power line noise and many impulse noises can be seen in received waveform. Fig. 18 is the envelope of differential operation and sampling. It shows the fact that performance of proposed system is very stable in home PLC environment.

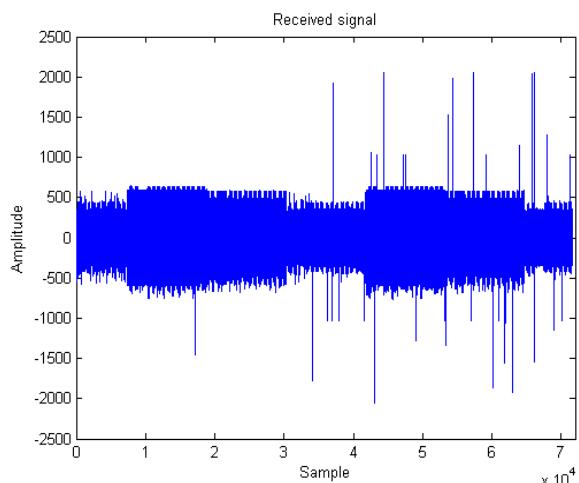


Fig. 17. Experimental waveforms of received waveform.

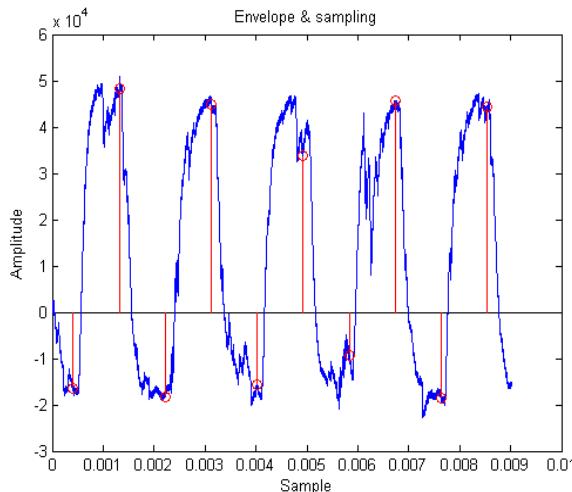


Fig. 18. Experimental waveforms of differential envelope and sampling.

8. Conclusions

In this paper, we proposed an elderly physiological status monitoring scheme based on low voltage power line communication. A novel multi-frequency FSK PLC system is presented to this situation. Simulation and hardware experiments confirmed that it is a feasible solution for home elderly physiological status monitoring application.

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