Design of Anti-Co-Frequency Interference System for Wireless Spread Spectrum Communication Based on Internet of Things Technology

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Abstract. An anti-co-frequency interference suppression method for wireless spread spectrum communication based on equivalent low-pass time-varying pulse modulation technology is proposed. The anti-co-frequency interference system for wireless spread spectrum communication is designed based on Internet of things technology, and the multi-path channel model for wireless spread spectrum communication is constructed. The Doppler spread technique is used to design the channel equalization of wireless spread spectrum communication system. The equivalent low-pass time-varying pulse modulation method is used to suppress the same-frequency interference and blind source separation. Improve the lossless transmission ability of the Internet of things (IoT) transmission signal in the wireless spread spectrum communication system. The simulation results show that this method is used to design the wireless spread spectrum communication system and the co-frequency interference is effectively suppressed and the bit error rate of communication is lower than that of the traditional method.

Keywords: Wireless spread spectrum communication · Internet of things · Co-frequency interference · Channel equalization · Blind source separation

1 Introduction

With the rapid development of the wireless communication technology, the accuracy and the high-capacity of the wireless communication are required to be higher, and the wireless spread spectrum communication is a new communication technology, which has the advantages of large transmission bandwidth, strong confidentiality and the like, and has the advantages of large data wireless transmission field. by adopting the wireless spread spectrum communication technology [1], the communication system is designed in combination with the radio principle, the long-distance transmission of the non-stationary signal is realized, the modulation and the demodulation of the signal are realized, The information such as an image is converted into an electric signal and an optical signal, and the like, and the spread spectrum communication is realized by using a wireless communication signal. It can be seen that the wireless spread spectrum communication has a wide application in the field of communication [2].

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In wireless spread spectrum communication, Internet of things transmission signal transmission is easy to be affected by initial frequency and initial phase co-frequency disturbance, resulting in increased error code and signal transmission distortion, so, it is necessary to optimize the lossless transmission of the IoT transmission signal in wireless spread spectrum communication system [3], so as to reduce the BER of communication. In the traditional method, the lossless transmission of the signal transmitted by the Internet of things in wireless spread spectrum communication is designed mainly through signal interference filtering and modulation and demodulation, such as keying phase shift algorithm, the vertical linear array spatial beamforming method and the interference suppression method based on BPSK modulation are used to optimize the transmission of communication signals using channel equalization design to reduce the bit error rate of wireless spread spectrum communication, and some research results have been achieved [4]. In reference [5], a frequency domain equalization technique for wireless spread spectrum communication channel based on vertical linear array spatial gain modulation is proposed to achieve error suppression and modulation and demodulation [6]. The multi-path interference separation of the wireless spread spectrum communication system is realized by BPSK modulation, and the multipath effect in the communication process is suppressed. However, in this method, there is drift distortion of the received signal. With the increase of the interference intensity, the distortion of communication transmission increases. In view of the disadvantages of traditional methods, this paper proposes an anti-co-frequency interference suppression method for wireless spread spectrum communication based on equivalent low-pass time-varying pulse modulation technology, which can realize the lossless transmission of communication signals in the Internet of things environment. Firstly, the multipath channel model of wireless spread spectrum communication is constructed, then channel equalization design and co-frequency interference suppression design are carried out. Finally, the performance of wireless spread spectrum communication is tested and the validity conclusion is drawn.

2 Channel Model and Analysis of Internet of Things Transmission Signal

2.1 Channel Model of Wireless Spread Spectrum Communication System

In order to realize lossless transmission and channel equalization design of Internet of things transmission signal in wireless spread spectrum communication system, the channel model of wireless spread spectrum communication system needs to be constructed firstly [7], and the impact response in wireless spread spectrum communication channel is assumed to be $n(n)$. The statistical average of time delay spread is $y(n)$, the signal of Internet of things transmission is $\tilde{x}(n)$ channel equalization system output signal is $n(n)$. Taking the discrete multipath case as an example, the signals received by the spread spectrum communication channel are as follows:

$$x(t) = \mathrm{Re}\{a_n(t)e^{-j2\pi f_c \tau_n(t)} s_l(t - \tau_n(t))e^{-j2\pi f_c t}\} \tag{1}$$

It can be seen that the received signal is a time-varying signal and the time-reversal mirror (TRM) recombination of the multipath signal transmitted in the wireless spread spectrum communication channel is carried out. The frequency domain characteristics of the communication channel can be described as follows:

$$c(\tau, t) = \sum_n a_n(t)e^{-j2\pi f_c \tau_n(t)} \delta(t - \tau_n(t)) \tag{2}$$

Where, $a_n(t)$ is the propagation loss of the nth path, $\tau_n(t)$ is the channel attenuation coefficient of the nth path, $s_l(t)$ is the modulation frequency, and f_c is the noise component of the signal transmitted by the Internet of things. Because the bandwidth of the spread spectrum code sequence is much larger than the minimum bandwidth of the transmitted information, the pulse response of the multipath channel in the wireless spread spectrum communication system is obtained by adaptive equalization of the instantaneous frequency and time of the signal:

$$R(t) = \frac{\sqrt{WT}}{WT} \sin[\pi WT(1 - \frac{|\tau|}{T})] \cos(2\pi f_0 \tau) \tag{3}$$

In this case, WT is the channel output gain with a fixed initial frequency. If the extended sweep bandwidth of the frequency band is W and the time length of the LFM signal is T, there are:

$$\beta = \frac{W}{T} \tag{4}$$

On the basis of the above-mentioned communication channel model, narrow band filter is used to filter the signal of the input spread spectrum communication system and blind source separation is carried out, and the adaptive algorithm is used to suppress the same frequency interference to realize the optimization of the spread spectrum communication. The block diagram of the overall design is shown in Fig. 1.

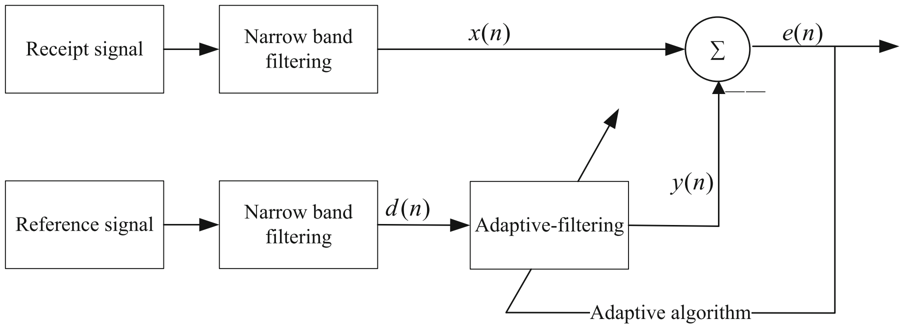


Fig. 1. Structure model of spread spectrum communication system

2.2 Multi-path Characteristic Measurement and Signal Analysis of the Signal Transmitted by the Internet of Things

The wireless spread spectrum communication channel model is constructed, the signal analysis is carried out to realize the lossless transmission design of the Internet of things transmission signal [8], and the multi-path characteristic measurement method is used to analyze the Internet of things transmission signal. Suppose the impulse response expression for the Internet of things transmission signal transmission for each multipath channel is:

$$h(\tau_{i,}t) = \sum_{i=1}^{N_m} a_i(t)e^{j\theta_i(t)}\delta(t - \tau_i(t)) \tag{5}$$

In the above formula, $a_i(t)$ is the normalized amplitude of each path of wireless spread spectrum communication, $\tau_i(t)$ is the time delay of multi-channel components, and the number of paths of H communication channel. The transmitted signals of the Internet of things are spread and blindly separated by pseudo-random (PN) sequence coding. The fast frequency hopping method is used to spread the time delay between each path and the direct path. The multipath component of the channel expansion is obtained as follows:

$$x_k = \sum_{n=0}^{N/2-1} 2(a_n \cos\frac{2\pi kn}{N} - b_n \sin\frac{2\pi kn}{N}) \quad k = 0, 1, \ldots N - 1 \tag{6}$$

When $S_0(t) = a_0\delta(t)$ to receiver, the Internet of things transmission signal $S(t)$, which is obtained by adaptive equalization modulation, is composed of multi-pulse of transmission signal, which is expressed as:

$$S(t) = a_0 \sum_{i=1}^{N} a_i\delta(t - \tau_i)e^{jw_c t} \tag{7}$$

$$e(n) = d(n) - u^T(n)w(n) \tag{8}$$

The channel modulation is carried out by keying phase shift technique (PSK), and the frequency domain data signal is obtained [9]. The iterative formula of coded amplitude modulation for spread spectrum communication is expressed as follows:

$$\boldsymbol{f}(k+1) = \boldsymbol{f}(k) - \mu \cdot \rho \cdot e_{MDMMA}(k)\boldsymbol{y}^*(k) \tag{9}$$

Wherein:

$$e_{MDMMA}(k) = z(k)[|z(k)|^2 - R_{MDMMA}(k)] \tag{10}$$

Where, ρ is the symbol width and complex coefficient is used to simulate the pulse response of the channel accurately. The information code signal $S_r(t)$ received by the wireless spread spectrum communication system is as follows:

$$S_r(t) = S(t) * h(t) + n_s(t) \tag{11}$$

According to the above-mentioned design principle, the optimization design of wireless spread spectrum communication system is carried out.

3 Improved Algorithm Implementation

3.1 Channel Equalization

On the basis of the channel model construction and signal analysis of the wireless spread spectrum communication system mentioned above, the communication optimization design is carried out. Under the influence of the multi-path effect, the communication channel produces the same frequency interference, which leads to the increase of the error code and the distortion of the signal transmission [10]. In this paper, an anti-co-frequency interference suppression method for wireless spread spectrum communication based on equivalent low-pass time-varying pulse modulation technique is proposed. The channel equalization is designed by Doppler spread technique. It is assumed that the transmission signal of the wireless spread spectrum communication system under the multi-path effect is expressed as follows:

$$x_k = \sum_{n=0}^{N-1} C_n \cdot e^{j2\pi kn/N} \; k = 0, 1, \cdots, N-1 \tag{12}$$

The channel has the characteristic of fast time-varying fading. The time-frequency decomposition method is used to decompose the Internet of things transmission signal into positive signal and negative signal:

$$x_k^+ = \begin{cases} x_k & x_k \geq 0 \\ 0 & x_k < 0 \end{cases} \qquad x_k^- = \begin{cases} x_k & x_k < 0 \\ 0 & x_k \geq 0 \end{cases} \tag{13}$$

Signal superposition is generated between received pulses and fractional interval equalization is designed by introducing limiting noise [11]. The transmission model of independent fading channel is obtained by using adaptive equalization technique:

$$\{b'_1, b'_2, \cdots, b'_v\} = \underset{\{b_1, b_2, \cdots, b_v\}}{\operatorname{argmin}} \left(\max_{\sum_{v=1}^{V} b_v \bullet x_v < 0, 1 \leq n \leq N} \left| \sum_{v=1}^{V} b_v \bullet x_v \right|^2 \right) \tag{14}$$

By combining the total received signals properly, the $x' = \sum_{v=1}^{V} b'_v x_v$ is designed for fractional interval equalization through multiple independent fading channels, and the sampling amplitude of fractional interval equalization is satisfied:

$$\tilde{y}_k^+ = \begin{cases} y_k^+, & y_k^+ \geq 0 \\ 0, & y_k^+ < 0 \end{cases}, \quad \tilde{y}_k^- = \begin{cases} y_k^-, & y_k^- \geq 0 \\ 0 & y_k^- < 0 \end{cases} \tag{15}$$

The equalizer detects the data in a channel with co-frequency interference. The equalizer detects the signal model is expressed as follows:

$$y_k = \begin{cases} -y_k^- & y_k^- > y_k^+ \\ y_k^+ & y_k^+ \geq y_k^- \& y_k^- < \gamma \\ y_k^+ + y_k^- & y_k^+ \geq y_k^- \& y_k^- \geq \gamma \end{cases} \tag{16}$$

When $\tilde{y}_k^- < \gamma$, it is regarded as the number of information symbols covered by channel co-frequency interference. The frequency spectrum of the received signal is equalized by the equalizer with D tap interval, and the channel information power of the wireless spread spectrum communication channel is expressed as follows:

$$P_r = \frac{P_t}{(4\pi)^2 \left(\frac{d}{\lambda}\right)^\gamma} \left[1 + \alpha^2 + 2\alpha \cos\left(\frac{4\pi h^2}{d\lambda}\right)\right] \tag{17}$$

According to the above analysis, the Doppler spread technique is used for channel equalization, which reduces the channel attenuation loss and avoids the channel distortion caused by aliasing effect.

3.2 Co-frequency Interference Suppression and Blind Source Separation

On the basis of channel equalization design, in order to improve the lossless transmission ability of communication signals, the equivalent low-pass time-varying pulse modulation method is used to suppress the same-frequency interference and blind source separation. The process of equivalent low-pass time-varying pulse modulation in wireless spread spectrum communication systems can be expressed as follows:

$$p_{ri}(t) = p(t) * h_i(t) + n_{pi}(t) \tag{18}$$

The $h_i(t)$ indicates the impulse response of the received signal spectrum $p(t)$ during transmission. The interference information beyond Nyquist frequency is suppressed by time mirror inversion. The transfer function of time mirror inversion is as follows:

$$S_{ri}(t) = S(t) * h_i'(t) + n_{si}(t) \tag{19}$$

The $h_i^{'}(t)$ in the communication system is the multi-path spread impulse response between the I elements of the receiving array of the Internet of things transmission signal in the communication system, from which the following can be obtained:

$$r_i^{'}(t) = S_{ri}(t) * p_{ri}(-t) = S(t) * p(-t) * h_i^{'}(t) * h_i(-t) + n_{1i}(t) \tag{20}$$

Where

$$n_{1i}(t) = S(t) * h_i^{'}(t) * n_{pi}(-t) + n_{si}(t) * p(-t) * h_i(-t) + n_{si}(t) * n_{pi}(-t) \tag{21}$$

Because of the complexity of multipath structure, the blind source separation of signal is carried out by interference suppression method, the received signal is copied and correlated [12], and the channel impulse response function between receiving and sending nodes of wireless spread spectrum communication system is processed by adaptive weighting, and the results are as follows:

$$r(t) \cong S(t) * \delta(t) * \sum_{i=1}^{M} \delta(t) + \sum_{i=1}^{M} n_i(t) = MS(t) + \sum_{i=1}^{M} n_i(t) \tag{22}$$

By estimating the autocorrelation function of the channel impulse response function in frequency domain, it is found that the impulse response $S(t)$ output by the time-backchannel modulation of the signal $\hat{h}(t) = \sum_{i=1}^{M} h_i^{'}(t) * h_i(-t)$ is isomerism with $p(t)$, and its equivalent backimpulse response function should be as follows:

$$H(t) = \hat{h}(t) * p(t) * p(-t) = (\sum_{i=1}^{M} h_i^{'}(t) * h_i(-t)) * p(t) * p(-t) \tag{23}$$

Because $\hat{h}(t)$ and $p(t) * p(-t)$ are similar to $\delta(t)$ coherent multi-path channel, the equivalent low-pass time-varying pulse modulation method is used to suppress co-frequency interference and blind source separation, which can effectively achieve lossless transmission of the signal transmitted by Internet of things and reduce the bit error rate (BER) of communication.

4 Analysis of Simulation Experiment

The application performance of this method in improving the communication quality of wireless spread spectrum communication network is analyzed by simulation experiment, and the wireless spread spectrum communication network communication system is constructed. The input communication signal is LFM signal with the frequency band of 23 kHz–25 kHz and the time width of 5 ms. BPSK modulation carrier uses sine signal with frequency 10 kHz, multipath spread time of 34 ms, Internet of things transmission signal S, sampling frequency band of 2 kHz–10 kHz, time width of 4 ms

LFM signal, and signal-to-noise ratio of-10 dB of the same frequency interference, and the signal-to-noise ratio of the same frequency interference is-10 dB. The signal-to-noise ratio is-10 dB. The similarity between $H(t)$ and $\delta(t)$ is 0.23, and the signal autocorrelation spectral density is 3.23 dB. According to the above simulation environment and parameter setting, the time domain waveform of the Internet of things signal input from the wireless spread spectrum communication system is obtained as shown in Fig. 2.

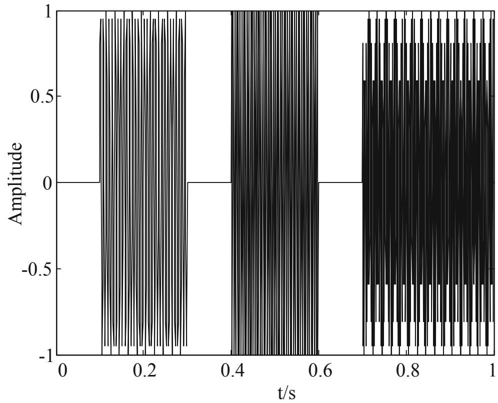
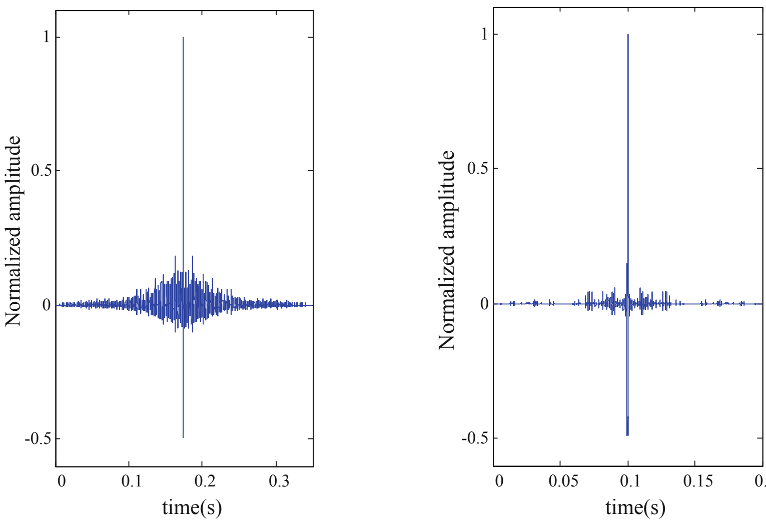


Fig. 2. Time-domain waveform of Internet of things transmission signal input from spread spectrum communication system



(a) Before interference suppression (b) Interference suppression

Fig. 3. Impulse response pulses of communication channels

As can be seen from Fig. 2, the input signal of the spread spectrum communication system is affected by the initial frequency and the initial phase co-frequency disturbance, which causes the frequency domain aliasing and affects the equalization of the communication channel. The channel equalization design and interference suppression are carried out in this paper, and the impulse response signal of the communication channel before and after the same frequency interference suppression is obtained as shown in Fig. 3.

From the analysis of the simulation results in Fig. 3, it can be seen that this method is used to suppress the same frequency interference, and the blind source separation of the communication Internet of things transmission signal is realized. The equalization performance of the channel is improved, and the impulse response pulse output is relatively clean. The lossless transmission of the signal is realized. Finally, in order to compare the performance of the algorithm, the average value of 1000 experiments is carried out by different methods, and the BER of the transmitted signal of the Internet of things is obtained as shown in Fig. 4.

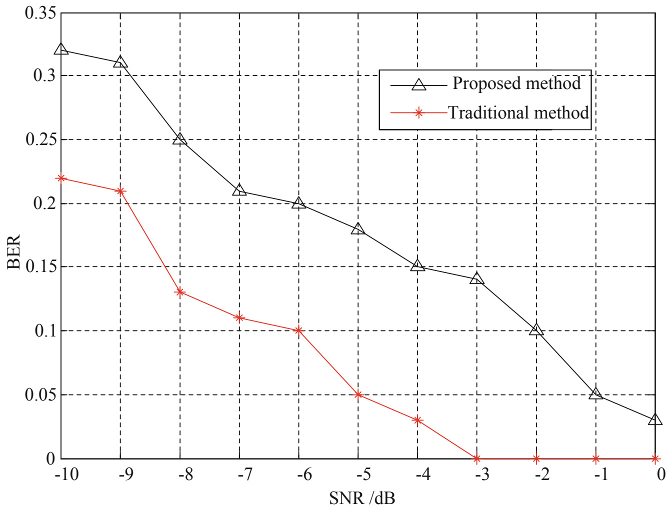


Fig. 4. BER comparison results

According to the data analysis of the above simulation results, the wireless spread spectrum communication system design using this method can eliminate the multipath channel co-frequency interference under the influence of multi-path effect, and make the channel equalization effect approximate to the ideal level. Reduce the bit error rate of communication and realize the lossless transmission of signal.

5 Conclusions

In this paper, an anti-co-frequency interference suppression method for wireless spread spectrum communication based on equivalent low-pass time-varying pulse modulation technology is proposed. The anti-co-frequency interference system for wireless spread spectrum communication is designed based on Internet of things technology, and the multi-path channel model for wireless spread spectrum communication is constructed. The Doppler spread technique is used to design the channel equalization of wireless spread spectrum communication system. The equivalent low-pass time-varying pulse modulation method is used to suppress the same-frequency interference and blind source separation. Improve the lossless transmission ability of the Internet of things transmission signal in the wireless spread spectrum communication system. The simulation results show that this method is used to design the wireless spread spectrum communication system and the co-frequency interference is effectively suppressed and the bit error rate of communication is lower than that of the traditional method. This method has good application value in wireless spread spectrum communication optimization.

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