EAI Endorsed Transactions
on Cognitive Communications
Research Article EAI.EU

Research on Intelligent anti-jamming communication with Cognitive Radio

Jingning Wang[1,*], Meng Liu[2] and Yi Zhang[3]

[1] The 54th Research Institute of CETC, No.589 West Zhongshan Road, Shijiazhuang, China
[2] The 54th Research Institute of CETC, No.589 West Zhongshan Road, Shijiazhuang, China
[3] The 54th Research Institute of CETC, No.589 West Zhongshan Road, Shijiazhuang, China

Abstract

In order to solve the interfere problem in complex electromagnetic environment, NC-OFDM and TDCS are efficient transmit wave form proposed for cognitive radio. The spectral efficiency and the applicable environment of TDCS are different from NC-OFDM. The simulation results show that NC-OFDM can obtain the higher spectral efficiency and the required SINR is higher, and TDCS can work well in lower SINR environment with different spreading factor. When there is little spectrum hole, spread spectrum is a better choice. There is no threshold of some parameter which can make decision. An artificial intelligence algorithm is proposed to select the optimal one from several wave forms. The input parameters of the algorithm include SINR, interference bandwidth, spectrum holes, etc.

Keywords: intelligent anti-jamming communication, transform domain communication system, artificial intelligence algorithm.

Received on 29 May 2018, accepted on 05 June 2018, published on 18 July 2018

doi: 10.4108/eai.11-5-2018.155074

1. Introduction

In complex electromagnetic environment, cognitive radio technology is an effective means to resist interference. Both Non-Contiguous OFDM (NC-OFDM) and Transform Domain Communication System (TDCS) are waveforms suitable for discrete spectrum situations of cognitive radio scenarios, they can obtain real-time spectrum and interference distribution through spectrum sensing. If it is difficult to find the available spectrum holes, spread spectrum is a suitable anti-interference waveform.

From Fig. 1, it can be seen the energy distribution of NC-OFDM and TDCS is in the frequency band from which interference is removed. Firstly, the spectrum sensing module is required to provide accurate spectrum information, and the unavailable frequency band (occupied or interfered by other systems) is removed to achieve spectral hole access to the spectrum hole.

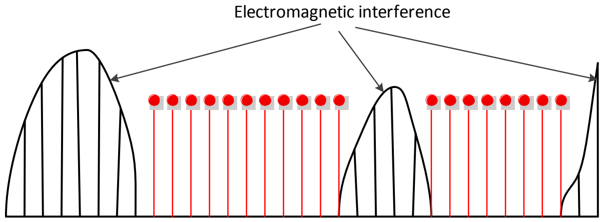

Figure 1. NC-OFDM/TDCS energy distribution

Because the interference signal is often time-varying, the available spectrum is often discrete and irregular. This requires the study of smart anti-jamming technology. Intelligent anti-jamming technology is the application of intelligent communication in the field of anti-jamming communication. According to the electromagnetic interference environment, it intelligently generates the best anti-jamming method, improves the system's anti-jamming capability and spectrum utilization, and achieves efficient and

*Corresponding author. Email:wjnhit@126.com

reliable anti-jamming communication. Since the result of spectrum sensing is a random sequence, it is difficult to determine the corresponding waveform with several parameters. Therefore, this paper explores the use of artificial intelligence algorithms such as neural networks to select the best waveform.

2. Communication Waveform and Artificial Intelligence Algorithm

2.1. NC-OFDM Waveform

The basic principle of NC-OFDM is shown in Fig. 2, which is include spectrum sensing, coding and decoding, modulation and demodulation, OFDM modulation and demodulation, SNR estimation, channel estimation and other modules. Compared with the traditional OFDM technology, the basic structure of NC-OFDM is that there is more dynamic spectrum sensing at the transceiver end to eliminate the unavailable subcarriers.

2.2. TDCS Waveform

TDCS can be seen as a combination of cognitive radio technology and spread spectrum technology. The basic idea is to construct a signal waveform in the frequency domain that does not have an interfering frequency band. Combined with the spread spectrum approach, the useful signal is spread over the entire available frequency band with a low power spectral density.

The basic principle of TDCS is shown in Fig. 3. First, the environmental spectrum is scanned, and the target frequency band is quantized into N sub-carriers so as to facilitate hardware implementation. Then, by comparing the spectral amplitude of the scan result with a preset threshold threshold and marking the availability of the k-th subcarrier as A_k. If the spectrum amplitude at the available frequency points is less than the threshold value, note A_k=1, It is considered that the interference within this frequency range can be used directly; otherwise, A_k =0, it is considered that there is a large amount of interference here, or there is an authorized user conducting communication, where the spectrum is not available. In the above manner, the transceiver obtains all the subcarrier utility sequences in the TDCS system, denoted by $A=\{A_0,A_1,A_2,\ldots,A_{N-1}\}$. This sequence determines the spectral shape of the TDCS signal.

The transmitter first generates a set of N-point long pseudo-random multi-phase sequences through a random phase mapper, $P=\{e^{jm_0}, e^{jm_1}, \ldots, e^{jm_{N-1}}\}$. The phase mapping method can be generated using a Linear Feedback Shift Register (LFSR). Then, the obtained pseudo-random phase sequence is multiplied by the above-mentioned spectrum vector A point by point to obtain the frequency domain coding sequence of the TDCS, ie:

$$B=[B_0,B_1,\ldots B_k,\ldots B_{N-1}]=\lambda \bullet A \otimes P \tag{1}$$

$$B_k=\lambda A_k e^{jm_k},\ k\in\{0,1,\ldots,N-1\} \tag{2}$$

Among them, $\otimes$ represents the dot multiplication operation, $\lambda=\sqrt{\varepsilon_s / N_A}$ is the power normalization adjustment factor, ε_s is the energy needed to transmit one symbol, and N_A is the number of all A_k =1. The frequency domain sequence s makes the TDCS signal have the following two characteristics: 1) The frequency domain amplitude only has a valid value at the position where the frequency spectrum decision is available, and the remaining positions are zero, thereby effectively avoiding the interference; 2) The multi-phase information makes The signal waveform of TDCS has pseudo-random noise-like correlation characteristics, which is the anti-intercept feature of the TDCS and the technical foundation of multiple access. By performing an inverse fast Fourier transform on B, its time-domain expression is obtained:

$$b=\{b_0,b_1,\ldots b_n,\ldots b_{N-1}\}=IFFT\{B\} \tag{3}$$

$$bn=\frac{1}{\sqrt{N}}\sum_{k=0}^{N-1}B_k e^{\frac{j2\pi kn}{N}}=\frac{\lambda}{\sqrt{N}}\sum_{k=0}^{N-1}A_k e^{jm_k}e^{\frac{j2\pi kn}{N}} \tag{4}$$

The b in the above equation is also called the basic modulation waveform and is buffered for the subsequent modulation operation to continue to use.

A typical modulation method in TDCS is a circular shift keying, which uses a basic modulation waveform as a basis function to realize modulation transmission of effective data bits. Corresponding receivers use a similar RAKE receiver for signal demodulation.

2.3. Spread Spectrum Waveform

The information input by the spread spectrum communication transmitting terminal is modulated by information to form a digital signal, and then the digital signal is modulated by the spreading code sequence generated by the spreading code generator to broaden the spectrum of the signal. The signal after widening modulates the carrier frequency again.

The spreading factor is an important parameter in spread spectrum communication. It is the number of chips each symbol is converted into. It is also the ratio of the post-spreading chip rate to the pre-spreading signal rate, which directly reflects the spread gain.

2.4. Artificial Intelligence Algorithm

Neural network algorithm is used to realize intelligent anti-jamming decision algorithm. The input parameters include spectrum sensing information, communication demand parameters, other constraints, and some knowledge bases composed of measured or simulated data. The spectrum sensing information is the energy at each frequency point of the entire frequency band obtained by the energy detection

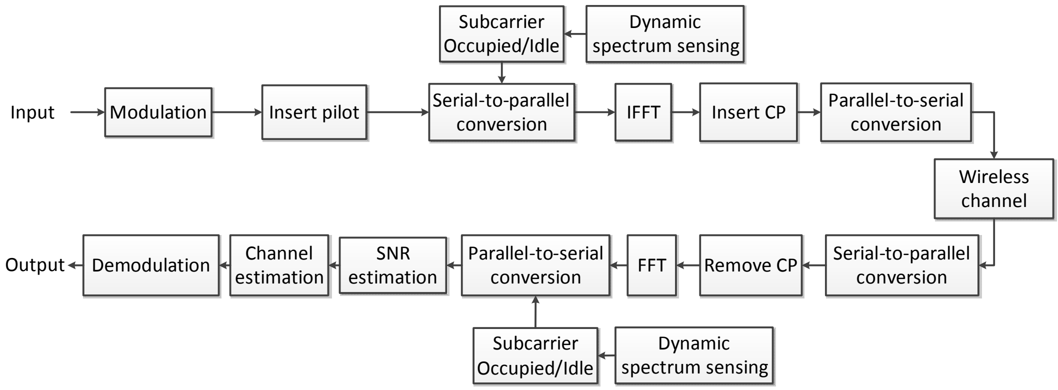

Figure 2. The basic principle of NC-OFDM

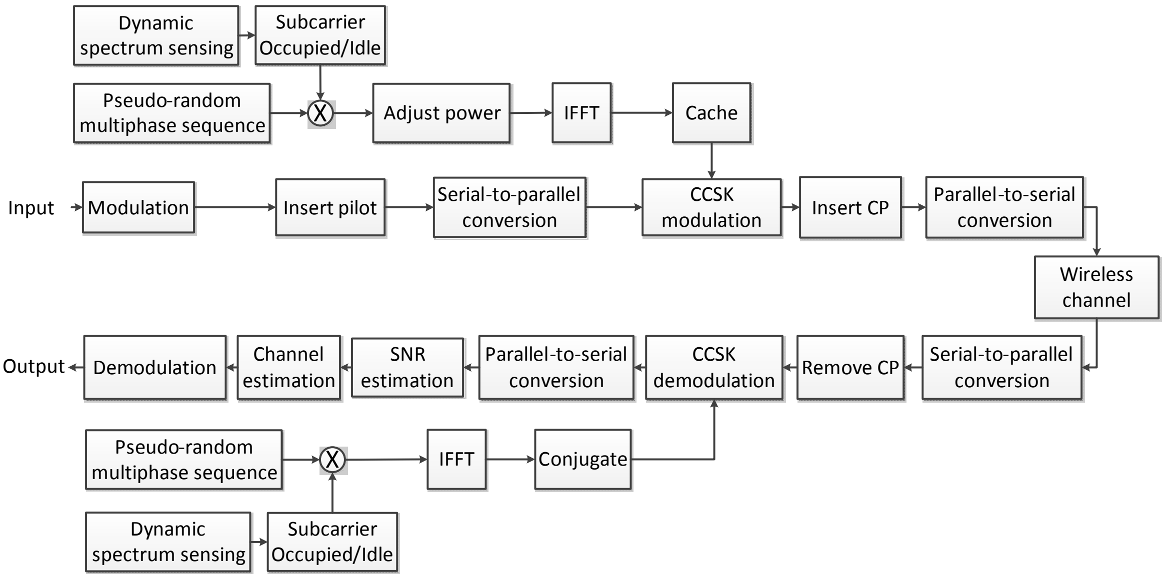

Figure 3. The basic principle of TDCS

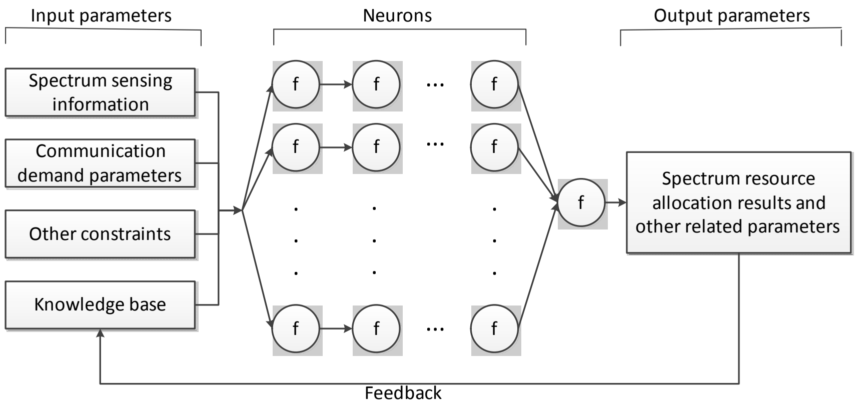

Figure 4. The basic principle of artificial intelligence algorithm

method, or reduced to the number of interferences quantified by various thresholds, the interference bandwidth, the interference intensity, the signal to noise ratio of the non-interference area, and other parameters. Communication demand parameters include expected speed and reliability; other constraints include hardware complexity and other parameters; knowledge base includes known training data and original parameters obtained from actual measurement or simulation. The output parameters obtained after passing through a plurality of neuron function models include waveform selection results and corresponding parameters (such as modulation method of OFDM, basis function of TDCS, spreading factor of spread spectrum, etc.).

3. Simulation Results

3.1. Parameter setting

The setting of this simulation parameter is:

- Transmission bandwidth: 20MHz
- OFDM: FFT points are 256 and cyclic prefix length is 64
- TDCS: the basic modulation waveform frequency is 256, FFT points is 256, the cyclic prefix length is 64;
- Spread spectrum factor: 256
- BER requirement: 10^{-3} (regardless of encoding)

3.2. Simulation analysis

Fig. 5 and Fig. 6 are simulation results in different interference. There are 256 subcarriers and 0, 128, 192 or 250 subcarriers exist interference with I/S=10dB.

The upper left of Fig. 5 and Fig. 6 show the simulation results without interference. Simulation results show that when the SNR is above 10dB OFDM waveforms can be used for high speed data transmission, if not TDCS or spread spectrum should be used.

The upper right of Fig. 5 and Fig. 6 show the simulation results with interference in 128 sub-carriers. Simulation results show that OFDM waveform cannot meet the BER requirements anytime. TDCS waveform can meet the maximum rate requirements when SNR is above -10dB, and spread spectrum waveform can be used in lower SNR.

The lower left of Fig. 5 and Fig. 6 show the simulation results with interference in 192 sub-carriers. The required SNR is above -4dB with TDCS.

The lower right of Fig. 5 and Fig. 6 show the simulation results with interference in 250 sub-carriers. OFDM. TDCS cannot meet BER requirement, and spread spectrum waveform can be used when SNR is above -17dB.

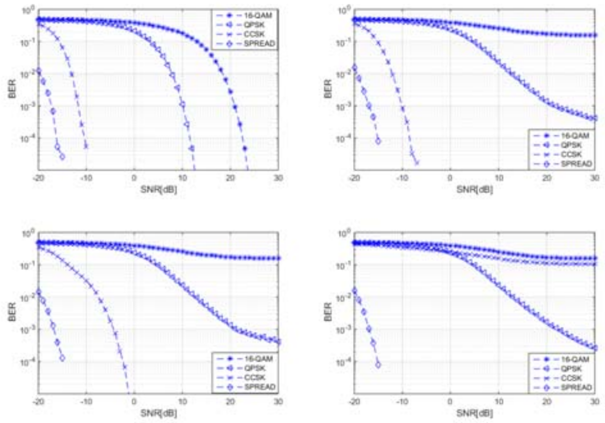

Figure 5. BER simulation of different interference

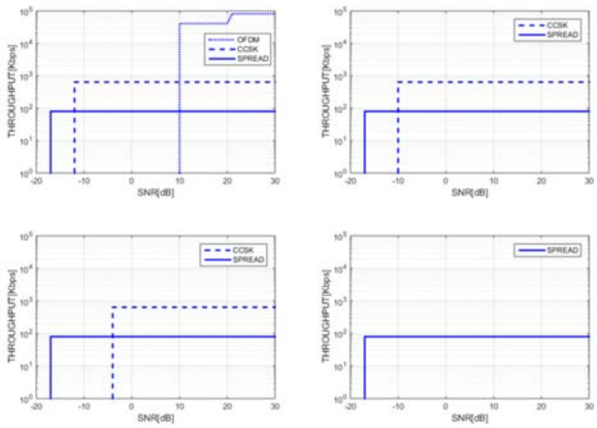

Figure 6. Throughput simulation of different interference

A decision protocol that combines NC-OFDM, TDCS and spread spectrum techniques should be proposed for various interference conditions. NC-OFDM is suitable for scenarios with weak interference and high spectrum utilization. The TDCS is suitable for scenarios with strong interference and has good anti-interference performance. It has good anti-interference performance and spectrum utilization efficiency.

The input parameters of the adaptive protocol include interference intensity, interference bandwidth, interference type, PAPR, etc. The output parameters of the adaptive protocol include transmission waveform and waveform parameters.

Since there is no definite correspondence between the results of spectrum sensing and the results of waveform selection, it is necessary to extract the characteristic values of the spectrum sensing results, and then use an artificial intelligence algorithm to choose the best time for switching.

4. Conclusion

Both NC-OFDM and TDCS can eliminate the interfered and occupied sub-carriers through the spectrum sensing module. NC-OFDM can achieve high-speed transmission in the case of small narrowband interference. The TDCS can achieve reliable transmission of data in the case of large narrowband interference. Spread spectrum can achieve the reliability of data transmission without spectrum cavitation. The electromagnetic environment is becoming more and more complex and changes rapidly. It is difficult to solve the problem of maximizing the communication effect under complex interference situations by simply relying on interference waveforms such as TDCS, and the combination of multiple waveforms through intelligent algorithms is an important means of future communication anti-jamming technology. Direction of development.

References

[1] Budiarjo I, Nikookar H and Ligthart LP. (2008) Cognitive radio modulation techniques. *IEEE Signal Processing Magazine* **25**(6): 24-34.

[2] Li S, Cheng Y, Dong B et al. (2012) Research on Intelligent Anti-jam Communication Techniques. *Radio Communications Technology* **38**(1): 1-4.

[3] Chakravarthy V, Nunez AS, Stephens JP et al. (2005) TDCS, OFDM, and MC-CDMA: a Brief Tutorial. *IEEE Communications Magazine* **43**(9): S11-S16.

[4] Tanweer MR, Auditya R, Suresh S et al. (2016) Directionally Driven Self-Regulating Particle Swarm Optimization algorithm. *Swarm and Evolutionary Computation* **28**: 98-116.