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PAPR Performance of Carrier Interferometry OFDM by Wavelet Transform in Cooperative Relay Networks

Cebraıl CIFLIKI and Bilgin YAZLIK*

Kayseri University, Kayseri, Turkey

Van Yuzuncu Yil University, Van, Turkey

*bilginyazlik@yyu.edu.tr

Abstract. Cooperative diversity has spatial diversity effects on wireless communication systems to combat fading effects by using idle antennas as relays which are already located in the system. OFDM based cooperative communication is widely used in wireless communication systems and promises high data rate. However, OFDM has high PAPR problem. The high PAPR causes the interference and performance loss. Carrier interferometry codes boost overall performance of OFDM communication systems and decrease the level of PAPR. FFT can be used to realize carrier interferometry with no performance degradation. In this paper PAPR performance of the carrier interferometry OFDM by wavelet transform is analysed in a cooperative relay network. The results show that, the system which is a novel design of CI-OFDM has obviously better performance than traditional systems in terms of both BER and PAPR with the assist of wavelet transform.

1. Introduction

Because of the nature of the wireless communication system, any transmitted signal is exposed to fading effects [1], [2], [3]. Fading effects can lead to performance loss on communication system. There are various methods to combat channel's fading effects, diversity is among them. Original signal's copies are transmitted to the receiver over different paths to realize diversity effect. Copies of a signal can transmit in different slots of time, frequency and spatial domain. At the end of the transmission, the receiver has several copies of the original signal which arrive over different time, frequency or location slots, then the receiver combines all of the incoming signals by using different combiners to benefit diversity gain [1]. If there is not enough resource to realize the multiple antenna system for spatial diversity, then cooperative diversity arises as the best alternative. In a cooperative network, there is at least one source, one receiver and one relay; the signal is transmitted to the receiver at least over two channels. Cooperative network achieves spatial diversity effect for wireless communication systems [3].

Carrier interferometry (CI) codes are used to reduce high PAPR level and enhance BER performance of OFDM system [4]. CI codes are orthogonal codes and by using CI codes, OFDM system uses all available subcarriers instead of allocated subcarriers. This approach leads to performance benefits. CI-OFDM performs better than traditional OFDM system. FFT is used instead of CI spreading codes in [4], according to [4], CI-FFT OFDM has same performance comparing to CI-OFDM system. OFDM systems leads to high peak to average power ratio (PAPR), this situation is a typical problem for OFDM and multicarrier modulation techniques [5].

In our previous work [5], we proposed a new system which uses wavelet transform instead of FFT



as spreading code. Our previous work [5] proves that wavelet based CI-FFT OFDM system performs better than CI-FFT OFDM system. Also, in another work [6] we investigate the performance of the relay position. In the other work [7] it is showed that wavelet based OFDM receivers has better performance. There are many researches in literature which are concentrated to combat PAPR in OFDM systems and there are also many techniques to reduce PAPR level [8], [9], [10], [11]. In this paper, we analyze the PAPR performance of the carrier interferometry OFDM system by wavelet transform in a one source, one relay and one destination cooperative wireless network.

2. Relaying strategies

Relay has a key role in a cooperative network, it gets a signal from the source and then resend it to the receiver. There are two very well-known relaying strategies: Decode and Forward (DAF) and Amplitude and Forward (AAF). At AAF, relaying node receives the original signal with noise, then amplitude the received signal and resend it to the receiver [12], but in this strategy, it is necessary to note that, the noise is also amplified. At DAF, the relaying node receives the original signal, decodes it, corrects it with the help of error correction codes, re-encodes it and resends it to the receiver [12]. DAF has obviously better performance than AAF [13], [14], but only when there is an error correction code.

3. Combining techniques

In a cooperative network, there are always at least two signal copies which arrive to receiver from different paths. To be able to get diversity gain, it is necessary to combine these incoming signals. There are different combiners, in this paper we use Signal to Noise Ratio Combiner (SNRC), Fixed Ratio Combiner (FRC) and Equal Ratio Combiner (ERC). The weights which are used by a combiner is essential in combining process, SNRC uses weights which are proportional to the received signal's SNR value. Because of that SNRC has better performance than both ERC and FRC [15].

4. Carrier interferometry

Carrier interferometry concept arises from the wave which constitutes by super position of the N carrier [16]. The transmitted n^{th} symbol of a CI/OFDM system is formulated as:

$$s_n(t) = A \cdot \text{Re} \left\{ \sum_{i=0}^{N-1} \alpha_n^q e^{j(2\pi f_c t + 2\pi f_i t + \frac{2\pi}{N} n \cdot i)} \right\} \quad (1)$$

where α_n^q denotes q^{th} symbol in the n^{th} stream, $2\pi/N \cdot n \cdot i$ is the phase offset used to generate the n^{th} symbol's spreading code and A is the energy. CI codes can be employed in OFDM systems, CI coded OFDM systems show better performance [17], [18] and CI codes have reduction effect on the Peak to Average Power Ratio (PAPR) of the system. CI codes can be realized by the Fast Fourier transform (FFT) and the new system has similar performance to the original system [4], [19].

5. Proposed system

In this work, we realize CI-OFDM for cooperative diversity by wavelet transform. Wavelet transform is used instead of FFT to realize the CI codes. Proposed system includes one source, one relay and one receiver. Proposed system is illustrated in Figure 1. As seen in the Figure 1, signal is modulated with QPSK while IFFT is used for OFDM. After OFDM, wavelet transform is applied to realize the CI codes, then the signal is being sent to the receiver or the relay over Rayleigh channel. Rayleigh channel model has been used for cooperative diversity in several works [15]. At the receiver, the received signal is despreading by wavelet transform, then FFT is applied for OFDM receiving, and finally QPSK demodulation is applied to the received signal.

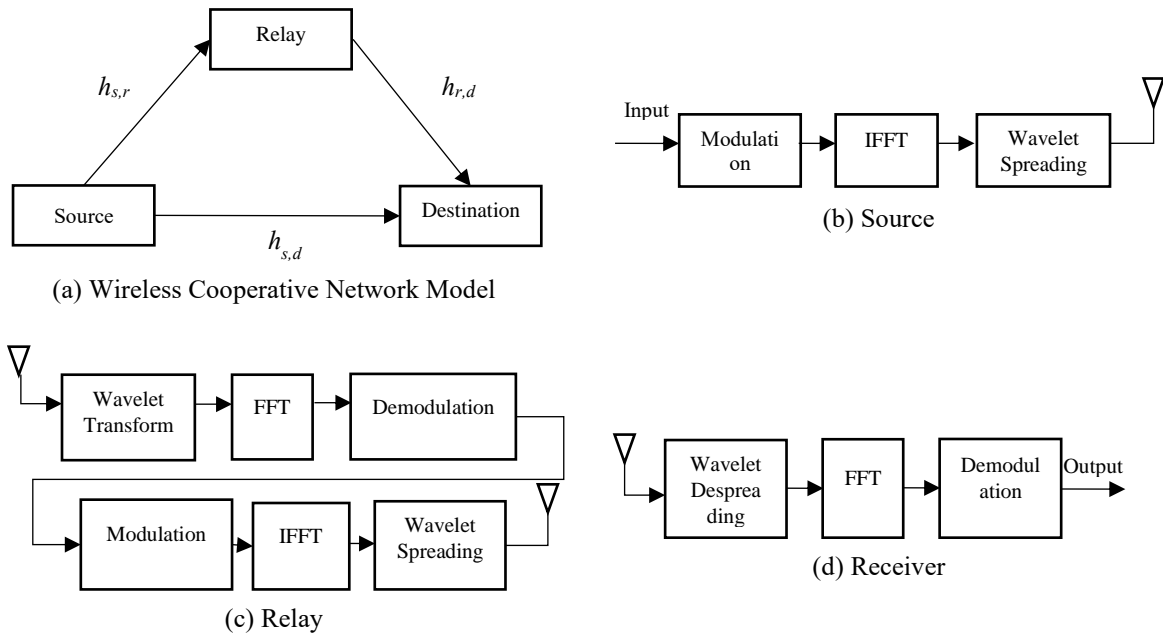


Figure 1. Proposed System Model (CI/OFDM Cooperative Network with Wavelet)

6. Results

The Proposed System’s Bit Error Rate (BER) and PAPR performance is investigated in MatLab environment. Simulation parameters are shown in Table 1.

Table 1. Simulation Parameters

Modulation Type	QPSK
Channel	Rayleigh Fading Channel
Number of Bits	2^{10}
Relaying Strategies	AAF and DAF
Combining Techniques	ERC, FRC and SNRC
SNR	0-20 dB

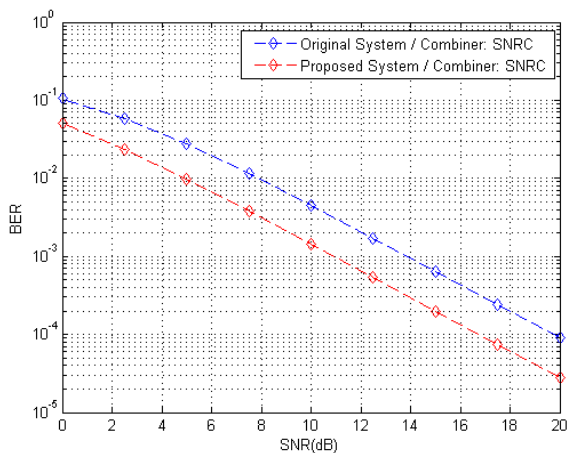


Figure 2. BER Performance of the Proposed System Comparing to Original System (DAF)

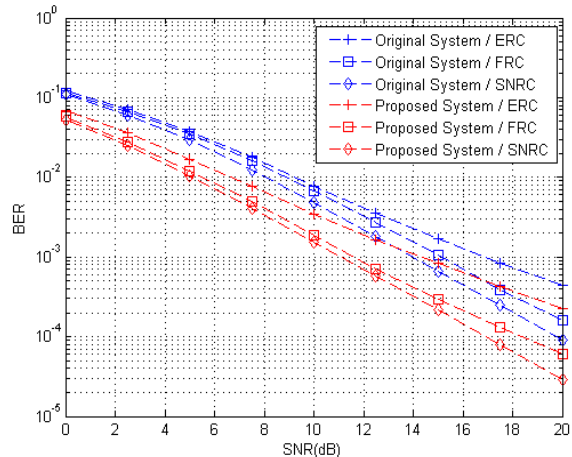


Figure 3. BER Performance of the Proposed System with Different Combiners (DAF)

In Figure 2, the proposed system’s BER performance is compared to the original system (non-CI

OFDM cooperative network) by using DAF relaying strategy and SNRC combiner. It is obvious from the results that; the proposed system's performance better than the original system. For example, at 10 dB the original system's BER is $4,5 \times 10^{-3}$ dB while the proposed system's BER is $1,45 \times 10^{-3}$ dB. In Figure 3, BER performance of the proposed system is analyzed by using different combiners and using DAF. It is obvious from the results that; SNRC has the best performance. For all the combiners, the proposed system has better performance comparing to each other. In Figure 4, complementary CDF of the proposed system and the OFDM is compared to each other with same parameters. It can be seen from the results that proposed system has better performance on reduction of the PAPR level.

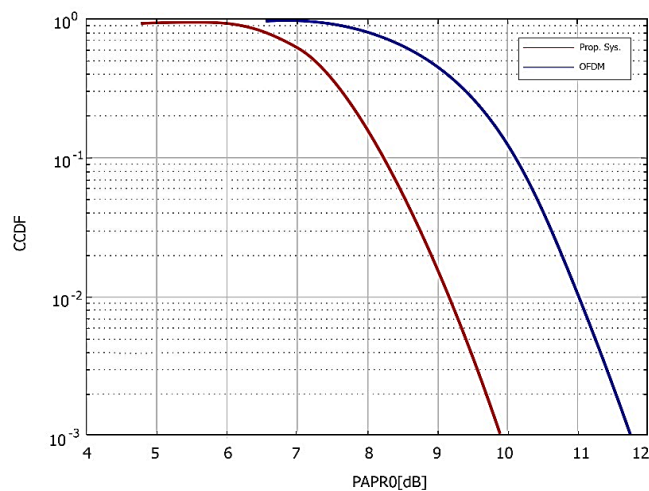


Figure 4. Complementary CDF of Proposed System

In Table 2, the proposed system is analyzed in terms of computational complexity (process duration in terms of time). Despite its better performance the proposed system has a disadvantage, because it demands more energy and computational source.

Table 2. Computational Complexity

Scheme	Original System(second)	Proposed System(second)
AAF-ERC	3,625418	83,824211
AAF-SNRC	4,213749	97,806881
DAF-ERC	3,261025	86,742993
DAF-SNRC	5,273098	103,358939

7. Conclusions

CI-OFDM for cooperative diversity realized by using of wavelet transform and proposed system's PAPR performance is investigated. Combining method is essential for the cooperative network system. In this work, we used ERC, FRC and SNRC. The results show, that the proposed system has its best performance when using SNRC. OFDM has high PAPR problem. The high PAPR causes the interference and performance loss. The results show that the proposed system is successful on reduction of PAPR compared to traditional systems. Despite proposed system has better performance than the original system, the proposed system has computational complexity disadvantage.

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