Robust Diversity Technique and New MCFH-SS System

Othman Sidek ,Abid Yahya and Mohd Fadzli Mohd Salleh

Abstract— **This paper presents new multicarrier frequency hopping spread spectrum (MCFH-SS) system by employing our newly developed large girth Quasi-Cyclic low density parity check (QC-LDPC) codes [10]. The newly obtained codes are employed as a forward error correction codes in MCFH-SS system to cater for some anti-jamming (AJ) competences with DPSK modulation. The bit error rate (BER) of MCFH-SS system with newly obtained codes significantly outperforms a fast frequency hopping spread spectrum (FFH-SS) system with a difference of BER =** 10^{-1} **at fraction bandwidth (** $\rho = 1$ **).**

Index Terms—- **MCFH-SS, FFH-SS, Fractional bandwidth, QC-LDPC, PBNJ.**

I. Introduction

Low-density parity-check codes [1] have acquired considerable attention due to its near-capacity error execution and powerful channel coding technique with an adequately long codeword length. The performance of LDPC codes has been investigated in [2, 3], at many events of interests and are encountered to outperform turbo codes.

The potency of LDPC codes is outclass over the AWGN channel, where coherent detection employing phase shift keying (PSK) can be carried out with carrier phase estimation. Precise phase tracking and high-quality estimation of channel state information (CSI) is required for the appropriate execution of coherent detection.

Wireless communications experience from respective channel imperfectnesses that considerably degrade system execution. One of the aftermaths is the loss of carrier phase synchronization. Differential and noncoherent techniques do not entail a phase reference and, for this reason, have acquired esteem recognition in wireless communications.

To get rid of CSI, authors in work [4] have employed frequency shift keying (FSK) modulation scheme for noncoherent detection with LDPC codes. Nevertheless, the power efficiency of FSK is less than PSK.

No channel estimation or equalization is expected if DPSK modulation is employed. Accordingly, the receiver can be more elementary and pilot symbols can be neglected at the cost of higher SNR.

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The FHSS system with partial band interference requires appropriate compounding of spread spectrum modulation, error correcting codes, diversity technique and decoding method in order to improve the signal transmission. It has been recognized from the work in [5], the combination of a diversity technique and forward error correction codes for FHSS communications system offers the most reliable means of crossing the partial-band noise jammer.

There have been limited research efforts to date, that incorporate FHSS system with LPDC channel coding scheme. The work in [6] investigates the applicability of irregular LDPC codes which exhibit good waterfall and error floor performances with FHSS system in partial jammed environment. The work reveals that LDPC codes can be used as the alternative to Turbo codes for forward error correction scheme in FHSS system.

A robust diversity-combing technique based on the generalized maximum-likelihood ratio test (GMLRT) for mitigating partial-band interference is presented in [7]. The authors incorporate the GMLRT technique and LDPC codes for channel coding into their FFH-SS system. The performance of the proposed FFH-SS receiver is somewhat worse than the self-normalizing receiver when the diversity level is greater or equal to 2 $(L \geq 2)$. The work in [8] finds that FFH-SS is not feasible for high data rates system. Therefore, a multicarrier frequency hopping spread spectrum (MCFH-SS) system is introduced as the alternative. Flam in [9] introduces a channel prediction algorithm with the purpose to avoid the selection of the unwanted channels for communication. Therefore, there is no need for data retransmission.

In our work, a new MCFH-SS system is introduced which employs a diversity technique, channel prediction algorithm as presented in [9] together with the newly obtained large girth QC-LDPC codes [10]. The system is evaluated in the presence of partial band noise jamming (PBNJ) environment. The performance of the new MCFH-SS system with the newly obtained codes is compared to FFH-SS system in term of their BER for given value of fraction bandwidth and signal noise ratio.

II. MCFH-SS System Model

The new MCFH-SS system block diagram is shown in Figure 1. The transmitter consists of LDPC encoder, inverse fast Fourier Transform (IFFT), channel interleaver, DPSK modulator and RF oscillator. The reverse operations are applicable at the receiver, except with the additional employment of a coherent detector.

The new system utilizes a diversity technique of order L, which represents the number of subbands for the system. In the aforesaid system the transmitter initially sends a test packet to receiver prior transmitting the rest of the packets. If the test packet is readable at receiver, that particular channel will be employed. Otherwise, the channel is considered to be unsuitable and will be avoided. When the system is under hostile interference, then several test packets are sent over different channels in order to find the good one. This selection process is handled by the channel prediction algorithm as proposed in [9].

The new MCFH-SS system utilizes a total bandwidth of W, and it is divided into L number of segments. These small segments are called the subbands, and each subband has L_h frequency bins. In each signaling interval, there are L_h subcarriers chosen from the L frequency subbands. This is achieved by using the inverse discrete Fourier transform (IDFT), or can easily be implemented using IFFT operation.

The baseband equivalent of the transmitted signal can be written as follows;

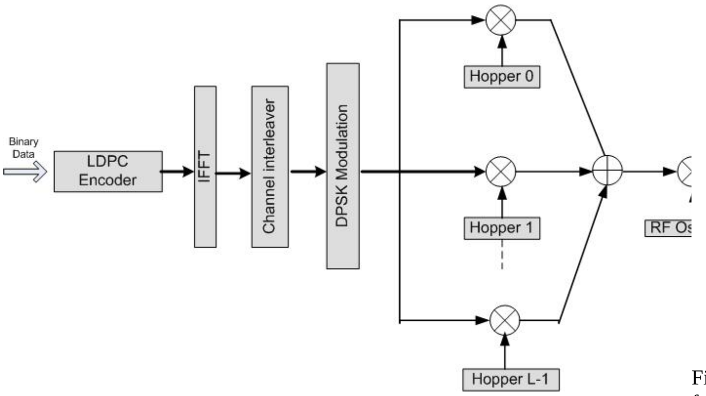
$$x(t)=\sum_{q=0}^{\infty}\sum_{l=1}^{L}\sqrt{2X}\,b_q e^{j2\pi(f_{l,q}+r_q f_d)m}\varphi_{T_h} m \tag{1}$$

where X represents the transmitted power for each diversity transmission. The parameter b_q is the independent identity distributed (i.i.d) transmitted sequence bits. The sequence bit values are set to $\{+1,-1\}$ since the system employs DPSK modulation scheme. The parameter $f_{l,q}$ is the hop frequency for each l_{th} diversity transmission of q_{th} symbol. The reciprocal of the bit duration (f_d) separates the subchannels. The parameter r_q is the i.i.d random variable uniformly distributed in the interval [1, L]. The parameter m is defined as $m=t-qT_h$ where T_h is the hop duration of q_{th} symbol and the variable φ_{T_h} represents the rectangular pulse of duration of T_h.

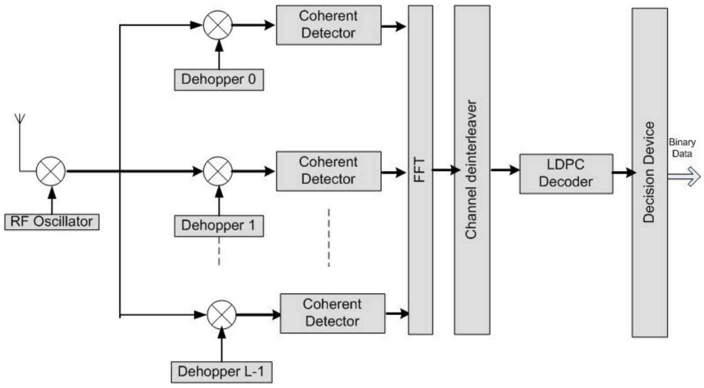
At the receiver, the received signals undergo the reverse operations of those in the transmitter. First, the discrete Fourier transform (DFT) is used for reconstruction. In practice, this process is done by FFT operation in order to reconstruct the original information. Assuming a perfect synchronization for the system, the total received signals can be expressed as the following;

$$S=\sum_{g=1}^{G} y(t)+N \tag{2}$$

where G is the number of user and $y(t)$ is the equivalent baseband received signal. The parameter N represents the effect of PBNJ over AWGN channel.



(a)



(b)

Figure 1. (a) Transmitter and (b) Receiver of New MCFH-SS system with LDPC Encoder and Decoder

III. Results

We evaluate the performance of newly proposed MCFH-SS system by employing the newly obtained codes and then compare the BER rates with FFH-SS system.

In this work, the two girth-twelve QC-LDPC codes with a group size 7 are utilized as a forward error correction codes for MCFH-SS system. Figure 2 shows the performance comparison between the MCFH-SS with two girth-twelve QC-LDPC codes and FFH-SS systems for a given value of ρ at L=4. The curves exhibit that the MCFH-SS system with a newly obtained codes outperforms FFH-SS system with a difference of 10^{-1} BER at $\rho=1$. The similar performance have been accomplished by MCFH-SS system against FFH-SS system in term of their BER for given values of E_b/N_o in dB. Figure 3 reveals that 35dB gain is established at bit error rate of 10^{-5} in FFH-SS system while MCFH-SS system has achieved 26dB gain at BER= 10^{-8}. The BER curves show that large girth and diversity level robust the system performance.

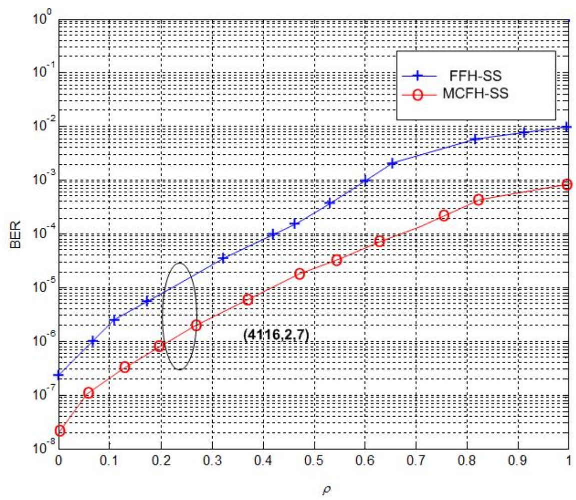


Figure 2. BER of MCFH-SS and FFH-SS systems for a given values of fractional bandwidth at diversity level L=4

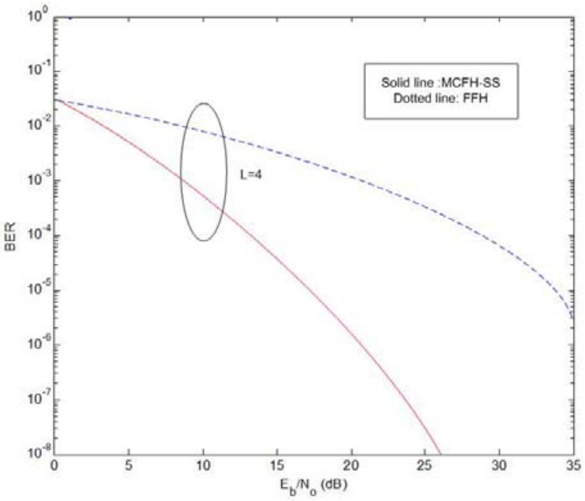


Figure 2. BER of MCFH-SS and FFH-SS systems for a given value of E_b / N_o.

IV. Conclusion

This paper introduces a new multicarrier frequency hopping spread spectrum system which consists of a diversity technique, channel prediction algorithm and two girth-twelve QC-LDPC codes. The potentiality of the system has established by finding the BER for a given value of E_b / N_o in the presence of PBNJ. The development of two girth-twelve QC-LDPC codes incorporates with MCFH-SS system and DPSK modulation scheme furnishes information on the design of robust system.

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