Employing A Suppression Filter for MC-DS-CDMA Overlay

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Abstract: In this paper, the performance of multicarrier direct sequence code division multiple access (MC-DS-CDMA) system equipped with a suppression filter is analyzed. A suppression filter is used in the MC-DS-CDMA receiver for suppressing narrowband interference (NBI) over a Rayleigh fading channel. The NBI is assumed to be multi binary phase shift keying narrow band (BPSK NB) signals which exist in all subcarriers of the MC-CDMA system. The effect of suppression filter coefficients, MC-DS-CDMA system parameters, and the NBI parameters on the performance of the system is studied. The analysis shows that, the suppression filter can improve the MC-CDMA system performance significantly, and then increases the MC-CDMA system capacity. It is shown that, increasing the number of taps to be more than nine taps increases the complexity of the filter and does not add any performance gain to the system. The system with a suppression filter has better performance than the system without a suppression filter at a range of values of the ratio of the offset of the interference carrier frequency existing in a subband to the half spread spectrum bandwidth of this subband, (q), which varies from zero up to a greater value of (q) at which using the suppression filter is useless. This value of q at which the system with and without a suppression filter have the same performance depends on the level of the signal to interference power ratio.

Keywords: Multicarrier CDMA; narrowband interference; suppression filter

1. Introduction

In recent years, code division multiple access (CDMA) has become a technology of choice for wireless communication networks due to high security, high spectral efficiency and greater capacity. This multiple access method offers distinct advantages in suppressing interference and intentional jammers [1]. It is well known that the DSSS systems have inherent interference suppression capabilities. However, when the spreading gain is restricted and the interfering signal is very strong, the spreading gain cannot provide sufficient degree of interference suppression capability. To solve this problem, some signal processing techniques must be employed to further improve the system performance [2]. Under such circumstances, an effective NBI suppression scheme is required. NBI suppression before despreading in the receiver can improve the performance significantly. Many NBI suppression techniques in DSSS systems have been proposed in the previous research and are generally classified into three categories, which are time-domain methods, transform domain methods and multiuser detection (MUD) methods [3]. In [4] a linear suppression filter at a receiver of the single carrier DS-CDMA system is employed to reduce the NBI. In [5], an adaptive linear prediction

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version of least mean square (LMS) filter is applied to reject NBI. In [6], a non linear prediction technique is introduced and the dynamic convergence behavior of the adaptive nonlinear prediction filters is analyzed. In [7] a new kind of nonlinear filter called nonlinear Lattice and Transversal Joint (LTJ) filter is proposed. A discussion was introduced of their SNR improvement and convergence speed in NBI suppression in DS-SS communications and their complexity. For the transform-domain NBI suppression schemes the commonly used transforming schemes are Fourier transform, discrete cosine transform and Karhaunen-Loeve Transform (KLT) [8–10]. In [11] a new and powerful method for suppressing narrowband interference (NBI) in direct sequence spread spectrum (DS/CDMA) communication system is developed. This technique is based on the linear minimum mean square error (MMSE) algorithm for multiuser detection. The performance of the proposed method against NBI is compared with the performance of some previous linear and nonlinear NBI suppression methods. It is seen that this method outperforms all these previous techniques of NBI suppression. In [12] it is shown that the non-linear predictor have not proven as successful in CDMA systems as in single-user SS communication systems because the effectiveness decreases for the increasing number of users. Also, the NBI rejection in synchronous DS-CDMA systems based on zero-forcing (ZF) code-aided techniques is analyzed. In [13] linear predictor and adaptive NBI Re-estimation algorithms are combined with code-aided method. This proposed approach shows that a much better performance can be achieved than the pure code aided approach. Compared with the transform-domain methods, the time domain filtering can eliminate the interference thoroughly with less impairment to useful signals. On the other side, time-domain filtering is of less complexity than the MUD scheme with some penalty of performance [3].MC-CDMA has recently been proposed as an efficient multicarrier transmission scheme for supporting multiple access communications, which combines CDMA and orthogonal frequency division multiplexing (OFDM) techniques. It receives considerable attention because of its advantages in frequency diversity and multipath fading resilience [14]. The parallel transmission of data over multiple simultaneous carriers makes the OFDM system to be more robust against frequency selective fading or narrowband interference, some subcarriers may be degraded, others will be unaffected [15]. In [16] the performance of a MC-DS-CDMA system is investigated under the effect of multipath fading and narrowband interference. It is shown that this approach exhibits a NBI suppression effect, along with robustness to fading, without requiring the use of either an explicit RAKE structure or an interference suppression filter. But this reference assumes that the NBI does not exist in all subbands of the MC proposed system. In [17] closed form expressions of the average bit error probability of the MC-DS-CDMA system with channel estimation errors in the presence of partial band, broadband and multitone jamming are derived in Rayleigh fading channel. It is concluded that the MC-DS-CDMA system under jamming has a superior performance than the single carrier DS-CDMA system. It is also deduced that in partial band jamming the smart jammer should be present in all subbands of the system in order to be effective. So in [17] the performance of the MC-DS-CDMA system with channel estimation errors is studied in presence of different types of interference. But this reference does not investigate any suppression techniques to these interferences. In [18], the performance of MC-CDMA ultra-wideband (UWB) communication system is studied in the presence of NBI and with the employing of a suppression notch filter in each subband. It is shown that when the number of subcarriers jammed by NBI is small, the MC receiver without notch filters can work well, on the other hand for large number of subcarriers jammed by NBI, using notch filters can improve the MC system performance. But this reference assumes the existence of the suppression filter in each subband and does not study the effect of the number of tapes of the notch filter on the performance of the MC system. However, this reference considered the NBI as a Gaussian random process with a flat spectrum. In [19], the performance of MC-CDMA overlay in UWB application is studied. It is shown that, the NBI reduction can be done by using notch filters at the transmitter. At the receiver, the NBI suppression is fulfilled by minimum mean square error detection technique. Also this reference considers the NBI as a Gaussian random process with a flat spectrum.

In this paper we consider the NBI as multi BPSK NBI. Moreover, the average bit error probability of the MC-DS-CDMA system subjected to multi BPSK NBI and equipped with a suppression filter is derived. The effect of suppression filter coefficients, MC-DS-CDMA system parameters, and the NBI parameters on the performance of the system is studied.

The paper is organized as follows. In Section II, the system model is presented. In Section III, the performance of the MC-DS-CDMA system with the use of a suppression filter in presence of multi BPSK NBI is derived. Section IV the determination of the suppression filter coefficients is deduced. Section V provides the numerical results and the conclusions are given in Section VI.

2. System Model

The transmitter block diagram of the MC-DS-CDMA system of user k is shown in Figure 1 [20, 547]. The binary source data sequence $b_k(t)$ of the kth user is first spread by random binary sequence $c_k(t)$ with processing gain $N = T_b / T_c$, where $1/T_b$ and $1/T_c$ stands for the bit and chip rates, respectively. After that, the spread signal modulates U different subcarriers. Finally, the U binary phase shift keying (BPSK) carrier-modulated signals are added together to form the transmitted signal. The transmitted signal of user k in the MC-DS-CDMA system can be expressed as [20]:

$$s_k(t) = \sum_{u=1}^{U} \sqrt{2P}\, b_k(t) c_k(t) \cos\left(2\pi f_u t + \phi_{ku}\right)] \tag{1}$$

where P is the transmitted power of the MC-DS-CDMA signal, U is the number of subcarriers, $b_k(t)$ is the baseband data sequence of user k, and $c_k(t)$ is the spreading waveforms of user k. The autocorrelation function $\rho_{T_c}(\tau)$ of $c_k(t)$ is given by

Finally, f_u ; u = 1, 2, …, U, are the subcarrier frequencies and ϕ_{ku} ; u = 1, 2, …, U are the initial phases of subcarriers. In the MC-DS-CDMA system the subcarrier spacing between two adjacent subcarriers is $1/T_c$ where T_c is the chip duration. When the spacing frequencies are usually chosen to be orthogonal to each other after spreading. Therefore, the minimum between two adjacent subcarriers is assumed to be $2/T_c$, there exists no spectral overlap between the spectral main-lobes of two adjacent subcarriers [16]. In this case, the total spreading bandwidth of the MC-DS-CDMA system W_{ss} is divided into U disjoint subbands, each subband has bandwidth (B_s) equals to $2/T_c$.

$$\rho_{T_c}(\tau) = \begin{cases} 1 - \dfrac{|\tau|}{T_c}, & |\tau| \le T_c \\ 0 & |\tau| \ge T_c \end{cases} \tag{2}$$