Interference Reduction in Overlaid WCDMA and TDMA Systems

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Abstract — In this paper, the performance of WCDMA uplink system for UMTS mobile communications is evaluated. Also, the possibility of increasing mobile communication cell capacity through merging WCDMA and TDMA systems in one cell is investigated. An interference canceller is proposed to reduce, or even completely cancel, the interference between WCDMA and TDMA, hence enabling them to work together. This results in a considerable increase in the cell capacity. The coexistence of WCDMA and TDMA systems in one cell is proven to be possible via computer simulations.

Index Terms—Cell capacity, WCDMA, TDMA, interference.

I. INTRODUCTION

Wideband CDMA (WCDMA) is a wideband Direct-Sequence Code Division Multiple Access (DS-CDMA) system, where user information bits are spread over a wide bandwidth by multiplying the user data with quasi-random bits (chips). In order to support very high bit rates, variable spreading factors and multicore connections are used.

Increasing cell capacity in mobile communication systems is one of the important objectives for those systems. Given the constraints of the high cost and the limited availability of radio spectrum, efficient spectrum usage is fundamental to the economic success of new generations of cellular systems. One novel concept to use available resources more efficiently is the combination of existing radio systems into coordinated, hybrid systems, in order to support very high bit rates, variable spreading factors and multicore connections are used.

The effect of using notch filters to enhance capacity of the hybrid system was studied in [4], whereas the effect of power control mechanism on the bit error rate of the combined schemes was investigated in [5]. A simplified model to investigate the capacity implications when both GSM and CDMA systems operate at the same band was used in [6].

In [7], a system was proposed to combine a TDMA based cell structure with CDMA using direct sequence spread spectrum communication to increase the capacity by time multiplexing cell operations between forward and reverse links. In another investigation [8], a new system for cellular mobile applications was proposed by utilizing TDMA to multiplex users within each cell and CDMA to control inter-cell interference. It was revealed, by comparative simulations, that the proposed system increased the total system capacity. The performance of two spread spectrum systems has also been compared in [9]; the first is a WCDMA system in the classical sense, while the second system employed spread-TDMA for the reverse link. It was suggested that TDMA and WCDMA should be used in indoor and outdoor cells, respectively. A theoretical investigation into the possibility of using a frequency overlay of a narrowband CDMA system and a TDMA system to provide a greater spectral efficiency was presented [10]. It was shown that under certain conditions the two systems can operate in the same frequency band and in the same area with a considerable improvement in the overall capacity of the whole system.

In this paper, a simulator for the uplink UMTS system is implemented using MATLAB, and the effect of dispersive and AWGN channels on system performance is investigated. The investigation is extended to consider the coexistence of TDMA and WCDMA and its impact on system Bit Error Rate (BER). The main aim for the proposed approach is to increase cell capacity through the joint operation of the two systems within the same cell. Also, we propose a simple interference canceller (IC) to reduce the interference between the TDMA and the WCDMA systems.
This paper is organized as follows: Section II gives a preliminary description of the WCDMA uplink simulator, and its BER performance under the effect of AWGN and dispersive channels. Section III presents the proposed joint WCDMA-TDMA approach, while section IV considers interference cancellation. Section V discusses the obtained results, and finally the conclusions are drawn in section VI.

II. DESCRIPTION OF WCDMA UPLINK SYSTEM

In the WCDMA (UMTS) uplink communication system, two physical channels are dedicated for every mobile station; the data channel and the control channel. The data channel is used to convey information data like voice and images, while the control channel is used to carry control signals. A simple schematic diagram for uplink WCDMA system is shown in Fig. 1.

First, the data and control channel bits are modulated using BPSK modulator, and then they are spread with Orthogonal Variable Spreading Factor (OVSF) short codes. After that the two channels are orthogonally related using the complex property. The resultant signal is then scrambled by multiplying with long Golden code. The Golden codes are complex long sequences with low cross correlation, and relatively high autocorrelation. The scrambled signal is then transmitted and propagated over channel.

At the base station receiver, a reciprocal process is achieved. After descrambling the received signal, the data and control channels are separated simply as shown in Fig. 1. Then a matched filter is used to estimate the transmitted BPSK symbols through using integrate and dump (matched filter).

A. Uplink System Simulator

We have built the baseband WCDMA system simulator using MATLAB/SIMULINK. The simulator consists of number of mobile stations (users), the dispersive channel and/or Additive White Gaussian Noise (AWGN) channel, and the base station receiver.

In this simulator, we consider some assumptions for the sake of simplicity. Firstly, a one cell model is used, and hence there is no co-channel interference; secondly a perfect power control is adopted so that all users have the same signal power at the base station receiver; thirdly, every user has its own Orthogonal Variable Spreading Factor (OVSF) and scrambling codes; and finally, full synchronization is assumed between the transmitter and receiver spreading codes.

In our simulation, we select the received Bit Error Rate (BER) as a criterion for system performance evaluation. Each result for BER is obtained through running the simulator for ~10^4 symbols.

Fig.1. The WCDMA uplink system

B. Simulation Results for Uplink system

After running the simulator, the resulting signal waveforms are displayed for each system stage. Fig. 2 illustrates these waveforms and their locations according to diagram shown in Fig. 1.

Fig. 3 shows variation of the received BER with respect to number of users, when the transmitted signal is propagated over dispersive and dispersive AWGN channels. The spreading factor (SF) is taken to be equal to (8). Also, the information bit rate is 480 kbps. It is obvious that the BER increases with the increase of number of users, and it is also clear that for the same number of users, an addition of AWGN will slightly increase the BER because the effect of the dispersive channel dominates.
Fig. 2: Signal waveforms taken from selected test points.
The behavior of the system BER over dispersive channel when varying the spreading factor is depicted in Fig. 4. It is clear that the system BER is improved when the spreading factor is increased from 8 to 16 for the same number of users. This is because increasing SF reduces the noise power per Hz; which leads to an improvement in SNR at the receiver and hence reduces the BER. The effect of AWGN variance on the system performance is shown in Fig. 5. The increase in noise variance increases the probability of receiving error bits. Also, the system becomes more robust against noise when increasing the spreading factor.

III. EFFECT OF COEXISTENCE OF WCDMA AND TDMA SYSTEMS ON CELL CAPACITY

The aim of this work is to enable two different mobile communication systems to operate in the same cell, and thus increasing the cell capacity to make it ideally equal to the sum of the two systems’ users. The two candidate systems are WCDMA and TDMA, since the two systems are relatively robust to interference from each other.

A. Description Of The Hybrid System Operation

In this subsection, we explain how the CDMA and TDMA systems behave when they operate in the same cell. Fig. 6 shows the principle of the spreading and the de-spreading process. The useful signal is spread and then transmitted over a wideband channel and de-spread in the
receiver. As can be seen in Fig. 6, the de-spreading process in the CDMA receiver operates as spreading process for a narrowband interfering signals. In terms of coexistence of TDMA and CDMA systems, the narrow band TDMA channels act as narrowband interferer for the CDMA system if they exist in the same frequency band. From the TDMA system's point of view, the CDMA system acts like a noise-like interferer with a low power spectral density. The receiver filter in the TDMA receiver will ensure that the noise-like interfering signal will only be received in the narrow bandwidth of the TDMA system. Thus, only a small part of the CDMA interference power will be received [10], see Fig. 7.

**B. the Baseband WCDMA/TDMA System**

Time-division multiplexing (TDM) is the interleaving of several digital messages into one digital message with a higher bit rate; as an example, we consider the generation of TDMA wireless system which is similar to that of the European base group, called E1, at 2.048 Mbit/s, which is obtained by multiplexing 32 PCM coded speech signals that are belonging to 32 users at 64 kbit/s [11].

As an example of WCDMA system, we used the UMTS system [8], where the bit rate is chosen to be 240 kbps, and the spreading factor is 16. Hence, the chip rate would be 3.84 Mchip/s, which is the same chip rate for the scrambling codes. More detailed informations about UMTS system can be found elsewhere [12].

However, we propose a one cell model which has both TDMA and WCDMA mobile station transmitters, and a base station which contains two receivers; one for the WCDMA and the other for the TDMA. It is worth to mention that for the sake of simplicity, our simulation is concerned with the uplink system only.

Fig. 8 shows a simple schematic diagram for the proposed model.

![Fig. 8. Schematic diagram of the uplink WCDMA/TDMA system.](image-url)
IV. DESCRIPTION OF THE PROPOSED INTERFERENCE CANCELLER (IC)

Fig. 9 illustrates a schematic diagram of the proposed interference canceller. The idea is to extract the TDMA interference through the use of a low pass FIR filter which is matched to the TDMA bandwidth (2.048 MHz), and then subtract the extracted TDMA signal from the received composed signal (TDMA+WCDMA). Hence, it is possible to get a WCDMA signal with approximately no TDMA interference.

![Fig. 9. A schematic diagram for the proposed IC.](image)

A threshold circuit is used to eliminate the residual WCDMA signal which passes with the extracted TDMA signal as shown in Fig. 9. The filter has a cutoff frequency of 2.048 MHz which is matched to the TDMA system bandwidth. Also, when designing the filter, the group delay of the filter is to be taken into consideration. It must not have a large group delay (group delay= \{filter order – 1\}/2). In our design, we select a reasonable filter order of seven; which gives a group delay of three sample periods. Table 1 shows the parameters of the designed FIR low pass filter.

| TABLE I  
FIR FILTER PARAMETERS |
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Since the signal will suffer a group delay of three sample periods when it passes through the designed FIR filter, this delay must be compensated by adding a delay line (z^{-3}) for the purpose of signals alignment. Also, it is worthwhile to mention that all the delays and their compensations are taken into account throughout the simulation.

V. SIMULATION RESULTS AND DISCUSSION

The simulation is run under enough number of data symbols, and we neglected the effect of the additive white Gaussian noise in order to study the effect of TDMA interference more clearly.

Fig. 10 illustrates the variations of the BER at the WCDMA receiver with respect to the number of TDMA users (N_t) for two cases: one by using the proposed interference canceller (IC), and the other without using the IC. Also, the simulation is run for one WCDMA user (N_c=1). It is clear that increasing N_t will increase the BER due to the increase in the number of TDMA interferers. Also, the use of the proposed IC has reduced the BER by about three times compared with the case of not using the IC. The increase in the BER by increasing N_t gives an indication that some of the TDMA signal power is still passing through the IC and causes an increase in the BER. This is considered as a disadvantage, since we expect a nearly constant BER by increasing N_t as an ideal case. It is possible to justify this by the non ideal characteristics of the FIR filter.

![Fig. 10: Variation of BER with N_t at the WCDMA receiver, for one WCDMA user.](image)

The relation between the BER at the WCDMA receiver and P_t/P_c, is shown in Fig. 11, where P_t is the TDMA transmitted power and P_c is the WCDMA transmitted power from the mobile station. The simulation is run for one WCDMA user, and for 32 TDMA users. It is clear...
that, in general, increasing $\frac{P_t}{P_c}$ will increase the BER. But on the other hand, we can observe a reduction in the BER by a factor of one-fourth in average because of using the proposed IC.

Now, to get a clear vision about the performance of our proposed IC, we define an improvement factor as the ratio of the BER without using the proposed canceller to that when using the canceller. Fig. 13 shows the effect of $N_c$ and $\frac{P_t}{P_c}$ on the improvement factor, keeping the number of TDMA users constant (i.e $N_t=32$). It is possible to observe that the improvement factor increases with decreasing $N_c$. This can be interpreted as follows: decreasing the WCDMA interferers makes the TDMA interference the dominant interference, and hence suppressing the TDMA interference (using the proposed IC) will cause a considerable improvement in the BER. Also, it is observed that the maximum improvement factor is achieved at $\frac{P_t}{P_c}=2$.

**VI. CONCLUSIONS**

It has been shown that the WCDMA and TDMA systems can work in the same cell and hence, it is possible to increase the cell capacity as the problem of cross interference between the two systems can be reduced using the proposed interference canceller. In WCDMA base station receiver, the BER can be considerably reduced by using the proposed interference canceller. On the other hand, in TDMA base station receiver, the effect of WCDMA interferers can be reduced by increasing the transmitted power of the TDMA mobile station.

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**REFERENCES**