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MULTI-USER MOCZ FOR MOBILE MACHINE TYPE COMMUNICATION

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ABSTRACT

We introduce multiple access schemes for a novel non-coherent single-carrier (SC) modulation, called modulation on conjugate-reciprocal zeros (MOCZ), to enable a high-spectral efficient and mobile machine-type-communication for up- and downlink transmissions. The modulation can be used for a time-division and frequency-division multiple access (FDMA). To utilize FDMA we will adapt SC-FDMA techniques and demonstrate that a time-overlay of multiple users (MU) can significantly reduce the peak-to-average-ratio (PAPR) in the downlink. Furthermore, we compare the MU-MOCZ schemes to standard modulations in narrow-band-Internet-of-things (NBIoT) scenarios with smallest transport block size in the LTE bands. To adapt the standard numerology of the transport channel we introduced soft decoding for higher order MOCZ designs. We demonstrate that our proposed scheme outperforms the standardized scheme in highly mobile and frequency-selective fading channels by a slight PAPR reduction in the downlink.

1. INTRODUCTION

As the industry move towards developing 5G, new vertical cellular internet of things (C- IoT) services, such as smart vehicles, smart factories, smart cities, car-to- car/infrastructure communication, and other, types of automation, are becoming more and more important in our daily lives [1]. Consequently, starting from LTE-advance pro, a new narrow-band internet of-things (NB-IoT) standard was introduced by the 3GPP consortium in Release 13 [2] to tackle such machine-type communications (MTC). This demand of C-IoT services massively increased in 5G to hundreds of thousand devices, served by only one single cell in an urban or industrial environment, which pushes existing multiple access schemes to their limits [3]. To handle the massive access, user packets are bundled to the smallest possible size of only 180kHz bandwidth by reducing the packet data size to its minimum [4]. However, since every user will have an independent wireless link to the base-station of its serving cell, the standardized coherent signaling schemes suffer from a huge overhead due to channel estimation, which leads ultimately to pilot-contamination [5]. If additionally, the link is fast time-varying, due to large mobility of the users, pilot overhead will even further increase. Industry, consequently, seeks more efficient signaling schemes. Recently, a novel non-coherent single-carrier (SC) modulation for frequency-selective fading channels in a single-input single-output (SISO) system, called modulation on conjugate reciprocal zeros (MOCZ),we introduce in [6], [7]. Here, the digital information is modulated onto the K zeros (roots) of the z−transform (polynomial) of the K + 1 consecutive samples of the time-discrete baseband signal. Since the K zeros can be treated independently, one can introduce an M−ary modulation scheme by allowing M distinct constellations for each transmitted zero to encode log M bits per zero and hence K log M bits for a sequence of K + 1 time samples, defining the time-discrete baseband signal block. Since a linear-convolution with an unknown time-invariant Channel Impulse Response (CIR) adds only further zeros randomly to the complex plane, an easy separation of data zeros and channel zeros can be obtained almost surely, which solves efficiently and elegantly the channel equalization in the zero-domain without knowledge of the CIR realization at receiver and transmitter. Hence, MOCZ enables a high spectral efficiency without the need of pilot transmissions.

However, a unique separation of channel and user signals is only applicable if different MOCZ symbols from other users are not overlapping in time, which would otherwise result in the addition of polynomials and hence in merging of zeros from other users. We, therefore, propose in this work multiuser schemes which utilize single-carrier FDMA techniques to separate K users on K distributed virtual subcarrier sets generated by the discrete Fourier transform (DFT) of the received baseband samples. This paves the way for MOCZ to utilize time and frequency resources in a more controllable and flexible manner.

2. LITERATURE REVIEW

The future generation of wireless networks faces a diversity of new challenges. Trends on the horizon – such as the emergence of the Internet of Things (IoT) and the tactile Internet – have radically changed our thinking about how to scale the wireless infrastructure. Among the main challenges new emerging technologies have to cope with is the support of a massive number (billions) of devices/machines ranging from powerful smartphones and tablet computers to small and low-cost sensor nodes. These devices come with diverse and even contradictory types of traffic including high-speed cellular links, machine-to-machine (M2M) connections, and wireless links which carrying data in short-packets. Such short messages of sporadic nature [1] will dominate the future communication and the conventional cellular and centrally managed wireless network infrastructure will not be flexible enough to keep pace with these demands. Although intensively discussed in the research community, the most fundamental question here on how we will communicate in the near future under such diverse requirements remains largely unresolved. A key problem is how to acquire, communicate, and process channel information. Conventional channel estimation procedures require a substantial amount of resources and overhead. This overhead can dominate the intended information exchange when the message is short and the traffic sporadic. Noncoherent and blind strategies, provide a potential way out of this dilemma. Classical approaches like blind equalization have been already investigated in the engineering literature [2]-[4], but new blind modulation ideas which explicitly account for the short-message and sporadic type of data are required [5]. In many wireless communication scenarios, the transmitted signals are affected by multipath propagation and the channel becomes frequency-selective if the delay spread exceeds the sample period. [6]Additionally, in mobile and time-varying scenarios one also encounters time-selective fast fading channels. In both cases, channel parameters typically have a random flavor and potentially cause various kinds of interference. From a signal processing perspective, it is therefore necessary to take care of possible signal distortions, at the receiver and potentially also at the transmitter. A well-known approach to deal with such channels is to modulate data on multiple parallel waveforms which are well-suited for the particular channel conditions. [7]One of the most simple and common approaches for frequency-selective channels is orthogonal frequency division multiplexing (OFDM). If the maximal channel delay spread is known, inter-symbol-interference (ISI) can be avoided by a suitable guard interval. Orthogonality of the subcarriers can be achieved by a cyclic prefix preventing inter-carrier-interference. On the other hand, multiple channel paths introduce diversity which should be beneficial from an information theoretical point of view. [8]To exploit diversity in a frequency-selective fading channel data has to be spread over subcarriers. But to coherently demodulate the data symbols at the receiver, the channel impulse response (CIR) has to be known at least at the receiver. To gain knowledge of the CIR, training data (pilots) have to be added to the information data (modulated on the samples) and will lead to a substantial overhead when the number of samples per signal is in the order of the channel taps.[9] If the number of samples is even less than the number of channel taps, it is mathematically impossible to accurately estimate from any pilot data the channel (assuming full support). Hence, one is either forced to increase the signal length by adding more pilots or assume some side-information on the channel. Furthermore, pilot density has to be adapted to mobility and, in particular, OFDM is very sensitive to time varying distortions. Dense CIR updates are therefore required in mobile scenarios, which may result in complex transceiver designs. There are only a few works on noncoherent OFDM schemes in the literature. The classical approach is given by orthogonal signaling, as for example with pulse-position-modulation (PPM) [6] or special code division multiplexing approaches.

3. EXISTING SYSTEM

The future generation of wireless networks faces a diversity of new challenges. Trends on the horizon – such as the emergence of the Internet of Things (IoT) and the tactile Internet have radically changed our thinking about how to scale the wireless infrastructure. Among the main challenges new emerging technologies have to cope with is the support of a massive number (billions) of devices/machines ranging from powerful smartphones and tablet computers to small and low-cost sensor nodes. These devices come with diverse and even contradictory types of traffic including high-speed cellular links, machine-to-machine (M2M) connections, and wireless links which carrying data in short-packets. Such short messages of sporadic nature will dominate the future communication and the conventional cellular and centrally managed wireless network infrastructure will not be flexible enough to keep pace with these demands. Although intensively discussed in the research community, the most fundamental question here on how we will communicate in the near future under such diverse requirements remains largely unresolved. A key problem is how to acquire, communicate, and process channel information. Conventional channel estimation procedures require a substantial number of resources and overhead. This overhead can dominate the intended information exchange when the message is short and the traffic sporadic. Noncoherent and blind strategies, provide a potential way out of this dilemma. Classical approaches like blind equalization have been already investigated in the engineering literature, but new blind modulation ideas which explicitly account for the short- message and sporadic type of data are required. In many wireless communication scenarios, the transmitted signals are affected by multipath propagation and the channel becomes frequency-selective if the delay spread exceeds the sample period.

4. PROPOSED SYSTEM

Let us consider a frequency band [fc – W/2 , fc + W/2] with bandwidth W > 0 centered at a carrier frequency fc > W/2. In a single-carrier (SC) modulation, a block of K˜ consecutive complex-valued symbols sn will modulate shifts pn(t) = p(t− nTs) of a baseband pulse p(t) of bandwidth W at a sampling which is then up-converted to the carrier-frequency fc to form the real-valued transmitted passband signal.

$$s(t) = \sum_{n=0}^{N-1} s_n p_n(t),$$

If the convolution of transmitter and receiver pulse (filter) q(t)=(p∗g)(t) satisfy the Nyquist criterion, the noise-free received time-samples, in an ideal channel, r(nTs)=(s ∗ q)(nTs) will equal the symbols sn, since q(mTs)=0 for any integer m = 0 and 1 for m = 0, see for example [8], [9]. Since a perfect band-limited pulse is not realizable, a time- limited square-root raised cosine (RRC) pulse can be taken as transmit and receive pulse. Using an M−ary modulation for each symbol, allows to encode log M bits per symbol and hence NlogM bits per block. In a pure SC system, the information is encoded in each symbol independently. If we code the information over multiple symbols in a block, such as in (1), the signal duration will be at least T > NTs = N/W, which is called a spread spectrum system. Note, that each sample occupies the same bandwidth W, hence MOCZ can be seen as a type of spread spectrum modulation.

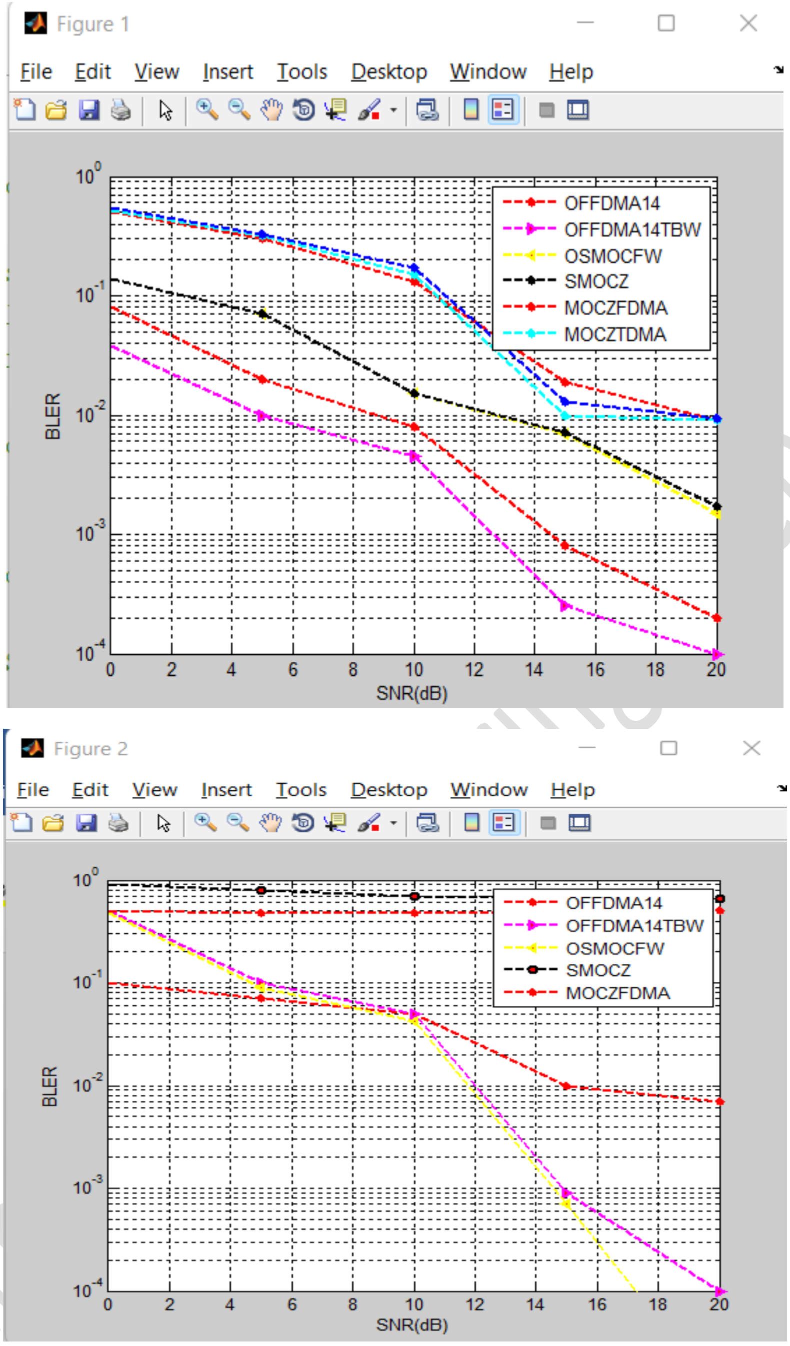

Fig. 2: BLER for EVA channel with maximal Doppler

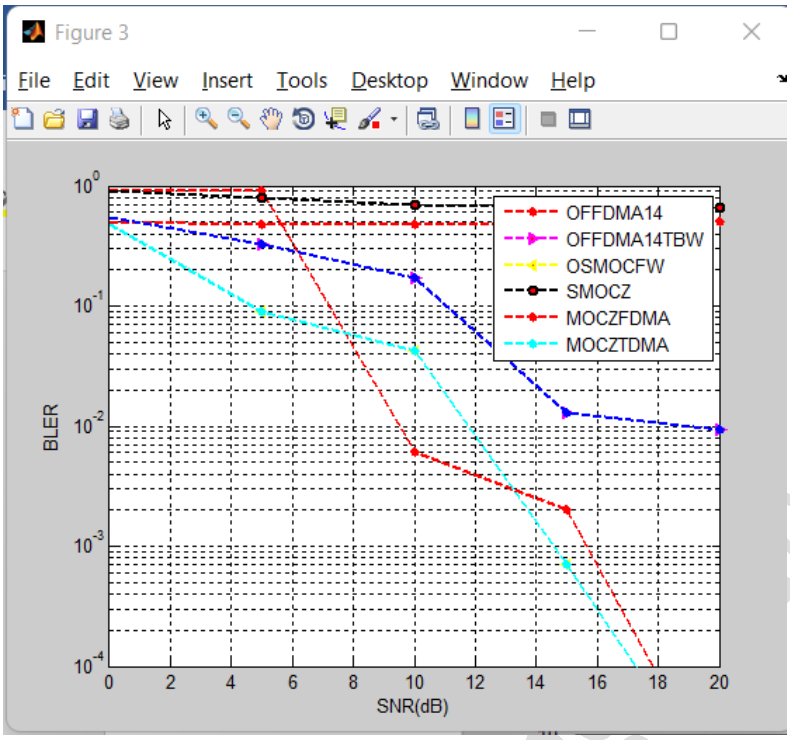

Fig-3 CDF of PAPR in DL for 6UE

5. CONCLUSION

We introduced TDMA and FDMA schemes for the novel non-coherent MOCZ scheme introduced in [6], [13] and compared with NB-IoT for 1MHz bandwidth in frequency selective fading channels. For static channels MOCZ-FDMA achieves similar performance as the standardized OFDMA in high SNR, whereas in time-variant channels with Doppler spreads of 300Hz, representing relative speeds of up to 162km/h at a carrier frequency of 2GHz, MOCZ-TDMA and FDMA are the superior multiple-access scheme and outperforms OFDMA. Hence, for high mobile scenarios, such as carto- car/infrastructure communication or industry applications with fast-moving machines/robots, MOCZ can be a viable alternative. Moreover, the PAPR of MOCZ- TDMA is the lowest of all multiple-access DL scenarios The 5G-NR and 6G standardization in the FR2 band (mm Wave) will allow the use of more than 400Mhz bandwidth, which would increase the number of users in our example from 6 to 2400 in only one single TTI. Given the increase of multipath resolution and Doppler at higher frequencies, robust and blind multi-user schemes like our proposed MU-MOCZ schemes, will prove to be even more superior in this regime. Moreover, the SC block transmission MOCZ will profit in a blind-fashion from the frequency diversity of wideband system without causing additional pilot overhead.

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