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The Reduction of PAPR of 5G Wireless Network Based on Uplink NOMA on DST Pre-coding

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Abstract: Non-Orthogonal Multiple Access (NOMA) is one of the potential candidate for the upcominga5G wireless networks because of low latency, higher spectral efficiency, system throughput, massive connectivity The major fault of uplink NOMA employing OFDM modulation is high Peak-to-Average Power Ratio (PAPR), which makes this NOMA inefficient. . The uplink NOMA can employ Orthogonal Frequency Division Multiplexing (OFDM) modulation for the developing of its basic signal waveform. Therefore, in this paper the Discrete-Sine Transform (DST) matrix pre-coding based uplink NOMA scheme is proposed to reduce the high PAPR. PAPR as compared to the Walsh-Hadamard Transform (WHT) matrix pre-coding based uplink NOMA scheme and non-pre-coded uplink NOMA scheme available in the literature Simulations indicate that the DST matrix pre-coding based uplink NOMA scheme has lower PAPR.

Keywords: Non-Orthogonal Multiple Access (NOMA); Peak-to-Average Power Ratio (PAPR); 5G Wireless Networks; Discrete-Sine Transform (DST); Walsh-Hadamard Transform (WHT).

I. INTRODUCTION

The upcoming 5G cellular wireless network has one of the preferred system i.e, Non-Orthogonal Multiple Access (NOMA). The system concept is based on implementation of superposition coding (SC) at the transmitter side and the Successive Interference Cancellation(SIC))at the receiver end, the basic signaling could be based on Single-Carrier Frequency Division Multiple Access (SCFDMA) scheme or Orthogonal Frequency Division Multiple Access (OFDMA) same like 4G cellular networks.

We consider orthogonal frequency division multiplexing (OFDM) as the modulation scheme and NOMA as the multiple access scheme. In conventional 4G networks, as natural extension of OFDM, orthogonal frequency division multiple access (OFDMA) is used where information for each user is assigned to a subset of subcarriers. In NOMA, on the other hand, all of the subcarriers can be used by each user. Fig.1 illustrates the spectrum sharing for OFDMA and NOMA for two users. The concept applies both uplink and downlink transmission.

Superposition coding at the transmitter and successive interference cancellation (SIC) at the receiver makes it possible to utilize the same spectrum for all users. At the transmitter site, all the individual information signals are superimposed into a single waveform, while at the receiver, SIC decodes the signals one by one until it finds the desired signal. Fig.2 illustrates the concept. In the illustration, the three information signals indicated with different colours are superimposed at the transmitter. The received signal at the SIC receiver includes all these three signals. The first signal that SIC decodes is the strongest one while others as interference. The first decoded signal is then subtracted from the received signal and if the decoding is perfect, the waveform with the rest of the signals is accurately obtained. SIC iterates the process until it finds the desired signal.

The success of SIC depends on the perfect cancellation of the signals in the iteration steps. The transmitter should accurately split the power between the user information waveforms and superimpose them. The methodology for power split differs for uplink and downlink channels.

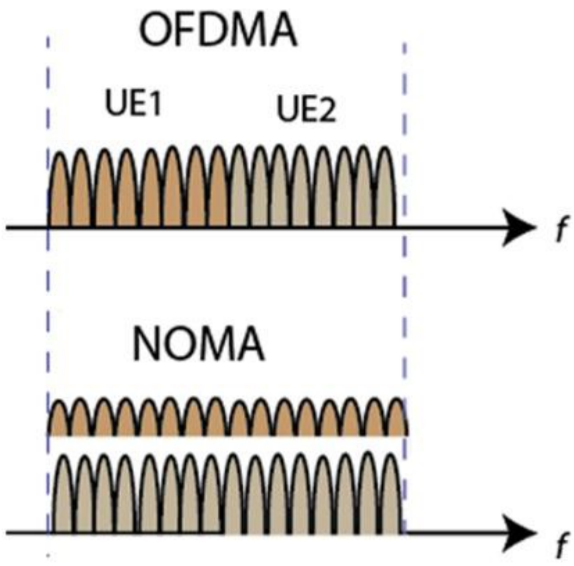

Fig 1. Spectrum sharing for OFDMA and NOMA for two users.

Fig 3 illustrates the uplink NOMA system. It is based on a single cell scenario with two users, User 1 (near to the BS) and User 22(far from the BS) distributed geographically. The NOMA implements the OFDM modulation to divide the available bandwidth into several narrowband sub-channels. Each sub-channel can hold one subcarrier which is accessed by different NOMA users. At the cost of increased intra-cell interferences, unlike OFDM, NOMA serves multiple users simultaneously using the same subcarriers [2]. Moreover, NOMA scheme based on OFDM modulation has some weaknesses which need to be addressed for its successful standardization. Among all, one of the main weaknesses of uplink NOMA systems based OFDM is its high Peak-to-Average Power Ratio (PAPR), which makes it spectrally and energy inefficient.

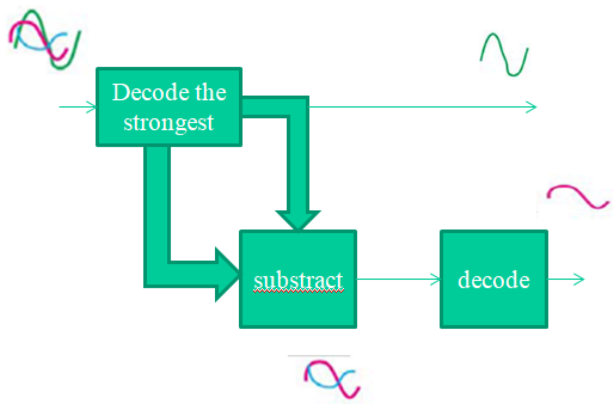

Fig 2. Successive Coding Interference cancellation

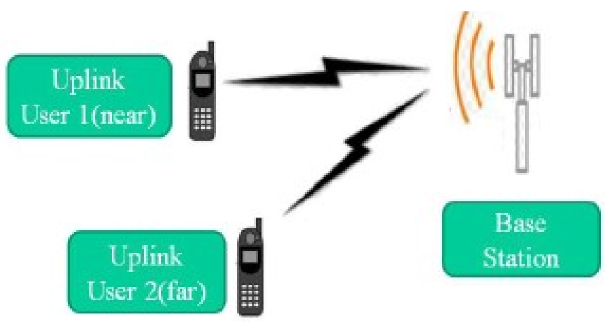

Fig 3. Uplink NOMA model with one base station and two users

Recently, many NOMA schemes have been proposed in the literature [5-8] for 5G mobile and wireless networks. Some of NOMA proposals have got significant consideration and are under the investigations. Among others, the uplink NOMA scheme presented in [7] is more attractive and seams near to be the real implementations. In the proposed scheme [7], the authors employ OFDM modulation at the transmitter side without the use of traditional coding or spreading, and on the receiver side the Multi- User Diversity (MUD) is implemented without using the spreading redundancy for user's separation. However, to get higher spectral efficiency, users are allowed to use the subcarriers without any exclusivity under certain restrictions. The main drawback of this uplink NOMA scheme [7] is its higher PAPR at transmitter side due to engagement of OFDM modulation. In literature [9-13], a number of PAPR reduction schemes have been proposed, among others, the PAPR reduction schemes based on predefined linear pre-coding matrix are more suitable due to simple linear implementations. In this paper, the uplink NOMA scheme presented in [7] has been tailored by adding a new linear pre-coding block before the subcarrier mapping and IFFT operation to lower the higher PAPR.

This paper is arranged as follows; Section II presents the Discrete-Sine Transform (DST) matrix pre-coding based uplink NOMA scheme for higher PAPR reduction, Section III presents the Monte Carlo simulations and finally, Section IV concludes the paper.

II. PROPOSED SYSTEM MODEL

A. Discrete Sine Transform (DST) and DST Matrix

Fig: 4 illustrates the proposed pre-coding based uplink NOMA scheme employing OFDM modulations and linear pre-coding at the transmitter side. The MUD-SIC and inverse of the pre-coding matrix is implemented at the receiver side to separate the superimposed users and pre-coding effects. For simplicity, a single cell scenario is investigated with User 1 i.e. near to the BS and User 2 i.e. far from the BS, these users are distributed geographically. These users can communicate simultaneously with the same BS. The DST is a unitary transform developed by [11]. According to [14], the DST can be defined as follows: -

$$S_L = \sqrt{\frac{2}{L}}\left[\epsilon_k \sin\frac{\pi(2n+1)(k+1)}{2L}\right]$$

B. DST Matrix Pre-coding based Uplink NOMA Scheme

The pre-coding based uplink NOMA system. After mapping, the pre-coding is applied on the modulated data Di of the Ith user, and we get: -

$$Y_i = PD_i = [Y_0, Y_1, Y_2 \dots Y_{L-1}]^T$$

where I = 1,2 (denotes the users), PKis a pre-coding matrix of DST, the pre-coding process can be explained by using the following equation:

$$Y_{i,l} = \sum_{m=0}^{L-1} p_{l,m} . D_{i,m}$$

C. The effect of DST Matrix Pre-coding

The contribution of DST matrix pre-coder can be verified by Aperiodic-Autocorrelation Function (AAF) of randomly generated normalized QPSK sequences of size 64. The lower side-lobe value in Fig. 5 defines low autocorrelation and vice versa. Low side-lobe sequences create low PAPR after IFFT due to non inphase alignments. In-phase addition of subcarriers at IFFT results in higher PAPR. It is obvious from the Fig. 5 that side-lobe values of the non-pre-coded sequence (i.e. original sequence) are greater than the pre-coded sequences. Therefore, it can be concluded that pre-coding before IFFT operation can reduce PAPR.

Extensive Monte-Carlo simulations have been performed to investigate the PAPR of the DST matrix pre-coding based uplink NOMA scheme with RRC pulse shaping filter. The data is generated randomly and modulated by using QPSK. The PAPR is investigated

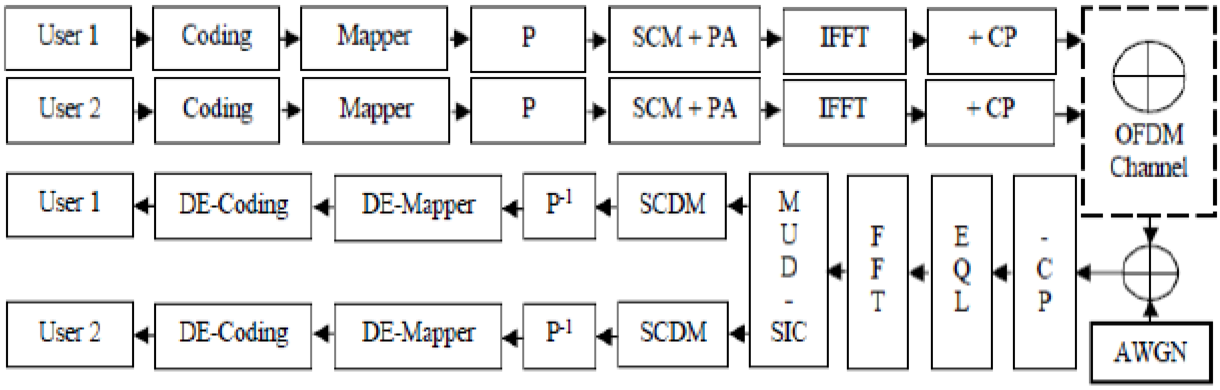

Fig 4. Pre-coding Based Uplink NOMA System; P: Pre-coding; SCM: Subcarrier Mapping; SCDM: Subcarrier De-Mapping; PA: Power Allocation; CP: Cyclic Prefix; EQL: Equalization

statistically by implementing Complementary Cumulative Distribution Function (CCDF). Simulations are carried out by using 105 random data blocks demonstrates the CCDF plot of PAPR for the DST matrix pre-coding based uplink NOMA signal, the WHT matrix pre-coding based uplink NOMA signal and the non-pre-coded uplink NOMA signal, respectively. At clip rate of 10-3, with user subcarriers M = 64 and system subcarriers N = 2048, the PAPR of DST matrix pre-coded uplink NOMA signal, WHT matrix pre-coded uplink NOMA signal and non-pre-coded uplink NOMA signal is approximately 7.8 dB, 9.9 dB, and 11 dB, respectively, using QPSK modulations.

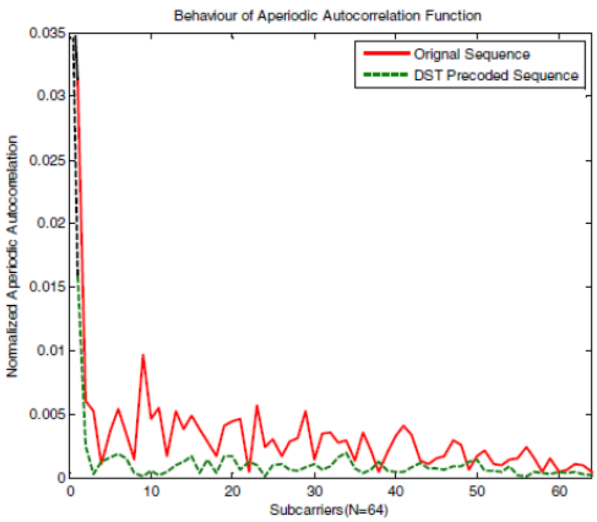

Fig 5. The normalized autocorrelation function

III. COMPUTER SIMULATIONS

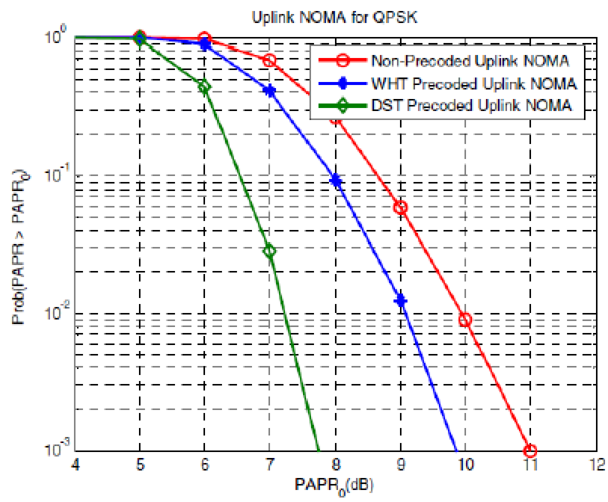

Fig 6. PAPR graph

Fig 7. PAPR ANALYSIS AT CCDF CLIP RATE OF 10^{-3}

Uplink MA Scheme	PAPR		
	QPSK	*16-QAM*	*64-QAM*
NOMA	11 dB	10.8 dB	11.1 dB
WHT- NOMA	9.9 dB	10 dB	10.1 dB
DST- NOMA	7.8 dB	8.7 dB	9 dB

At the clip rate of 10-3, the Table.1, summarizes the PAPR analysis of non-pre-coded NOMA, WHT precoded NOMA and DST matrix pre-coded NOMA, respectively with user subcarriers 64 and system subcarriers 2048. Additionally, it is also pointed out that PAPR of both users i.e. User 1 and User 2 is almost the same due to power constraints at the transmitter side.

IV. CONCLUSION

A DST matrix pre-coding based uplink NOMA scheme for high PAPR reduction has been presented and its PAPR is investigated by extensive Monte-Carlo simulations. It can be concluded from Table II that the PAPR of the DST matrix pre-coded scheme is lower than the WHT matrix pre-coded scheme and the non-pre-coded scheme, respectively. The DST matrix is a predefined pre-coding matrix, hence; do not require any kind of side information or complex optimization. Therefore, it can be concluded that the DST matrix precoding based uplink NOMA scheme is more suitable than the WHT matrix pre-coding based uplink NOMA scheme and the non-pre-coded uplink NOMA schemes for the upcoming 5G wireless networks.

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