Form 2

Dissertation Abstract

Report no.	(Course-based) No.1178	Name	MD. NAJMUL HOSSAIN
Dissertation title	Reduction of Peak-to-Average Power Ratio and Out-of-Band Power Emission for OFDM and OTFS Systems (OFDMとOTFSシステムにおけるピーク対平均パワー比と帯域外パワー発射の抑圧)		

Abstract

※ The abstract should be in keeping with the structure of the dissertation (objective, statement of problem, investigation, conclusion) and should convey the substance of the dissertation.

The upcoming fifth-generation (5G) and beyond 5G (B5G) mobile communication systems are highly intended to deal with comprehensive services viz. enhanced Mobile Broadband (eMBB), Ultra-Reliable, and Low Latency Communications (URLLC) and massive Machine Type Communications (mMTC) including explosively increasing high data rates. To meet the unprecedented growing demand, orthogonal frequency division multiplexing (OFDM) is an attractive technology for wireless communications, which is also a multicarrier modulation technique, offers a considerable high spectral efficiency, multipath delay spread tolerance and immunity to the frequency-selective fading channels. As a result, OFDM system has been chosen for high data rate communications and widely deployed in many wireless communication standards. However, a main weakness of OFDM system is the high peak-to-average power ratio (PAPR) that promotes nonlinear distortion in a high power amplifier (HPA) and reduces power efficiency in communication systems which leads to operational expenses (OPEX). Especially for the hand-held device's uplink transmission efficiently, low PAPR plays an important role in wireless communication systems. OFDM also has another drawback, such as high out-of-band (OOB) power emissions. In particular, excessive OOB power emissions create adjacent channel interference (ACI) and degrade communication quality. OFDM uses a wide guard interval (GI) in order to avoid ACI. It decreases spectral efficiency when a number of mobile devices simultaneously access a base station. For the next-generation mobile communication systems, a novel physical (PHY) layer should be developed to overcome such drawbacks.

In this research, a promising new approach is proposed for the PAPR and OOB power emission reductions of the OFDM system, which is based on a synergistic combination of DFT-IFFT concatenation and windowing technique, that is, DFT precoding is used prior to inverse fast Fourier transform (IFFT) operation and well-known windowing

technique is applied after the cyclic prefix (CP) insertion stage. The proposed DFT-Spread WR-OFDM system takes the benefit from the fact of single (quasi) carrier property and has the same overall complexity as the OFDM system. DFT precoding aims to lessen the PAPR of the system, and the windowing technique aims to lower OOB power emission and a very short window length is enough to meet the conventional spectral mask. That is, DFT precoding deals with the large peak of the OFDM signals, and windowing deals with the high OOB power emission. We implemented a time-domain window function named Tukey (tapered cosine) to reduce the OOB power emission. Also, subcarrier mapping has been implemented to obtain the multiuser diversity. Compensation for HPA nonlinearity becomes a difficult task for wireless communication systems. In practical wireless communications systems, power spectrums and bit error rate (BER) performance are highly affected by the HPA nonlinearity features. HPA nonlinearity increases the OOB power emission by means of spectral spreading, which causes ACI. Moreover, it degrades the communication quality. So, by reducing the PAPR, the efficiency of the HPA can be significantly improved and the nonlinear distortion caused by HPA can be decreased, too. In this research, we have emphasized on the spectrum characteristics, that is, OOB power spectrums and BER performance evaluation of each scheme in HPA linear and nonlinear environments. The simulation results reveal that the proposed system can consistently achieve very low-level OOB power emissions in HPA linear and nonlinear cases. Low-level OOB power emission is very crucial to save frequency resources. Also, the proposed system reduces PAPR significantly. At a level of 10^{-4}, the PAPR of the proposed system is 2.6 dB and 3.2 dB smaller than the conventional OFDM and WR-OFDM systems, respectively. BER performance for different modulation orders was analyzed over AWGN and multipath fading channels. To cancel the effect of the fading channel, frequency-domain channel equalization is used. The uncoded BER performance of the proposed system is similar to the other schemes under the HPA linear condition. The BER performance of each system is degraded by increasing the strength of HPA nonlinearity; however, our proposed system outperforms OFDM and WR-OFDM systems, and performance is the same as the DFT-Spread OFDM system. The combined effects of using DFT precoding technique significantly reduce the PAPR and enhance the power efficiency, and hence improved BER performance in HPA nonlinear environments. On the other hand, the time-domain windowing technique significantly reduces the OOB power emission and enhances the spectrum efficiency.

Next, we have investigated a recently proposed orthogonal time frequency space (OTFS) modulation technique. Since, it is well-known that under higher Doppler conditions, channel estimation performance, and associated OFDM modulation perfor-

mance breaks down completely. OTFS system is a 2-D modulation scheme that has superior performance in high-speed vehicle communications and high-level dimensions of multiple-input multiple-output (MIMO) systems over the OFDM system in the delay-Doppler domain. However, the OTFS system has high PAPR, like OFDM system. In this dissertation, we analyze the PAPR characteristics of OTFS signal and propose a concept of discrete Fourier transform (DFT)-Spread OTFS system to reduce the PAPR efficiently. We evaluate the spectrum characteristics of conventional OFDM and OTFS schemes and the proposed DFT-Spread OTFS scheme; according to the different nonlinear conditions of HPA. Simulation results demonstrate that the power spectrums of the proposed system are less sensitive than the conventional schemes in HPA nonlinear environments. In addition, we compare the uncoded BER performance among the different schemes over the AWGN and delay-Doppler channels according to the several HPA nonlinear conditions for the different mobility speeds of user equipment (UE). The BER performance of the conventional OFDM system breaks down completely in high-mobility scenarios for both HPA linear and nonlinear conditions. The proposed scheme improves the BER performance over AWGN and delay-Doppler channels in HPA nonlinear environments, as compared to the conventional OTFS system. In high-mobility scenarios and at BER of 1×10^{-3}, simulation results verify that the OTFS and our proposed DFT-Spread OTFS scheme can be achieved a gain of 12.8 dB compared to OFDM scheme. Moreover, the proposed DFT-Spread OTFS scheme can be reduced PAPR by 2.2 dB and 1.8 dB compared to OFDM and OTFS schemes, respectively.