Abstract of Ph.D. Thesis
"OTFS Based Orthogonal Multiple Access in High Delay and Doppler Wireless Channels"

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The tremendous growth in cellular telephone subscribers proves that wireless communications is an effective and practical means of transmitting both voice and data. There have been successful rollouts of cellular networks at every generation from 1G to 4G. To accommodate the ever-increasing number of customers and the exponentially rising demand for data throughput, the future 5G cellular networks have more work to do. In cellular wireless systems prior to the fourth generation (e.g. long term evolution (LTE), LTE-Advanced (LTE-A), etc.), increasing spectral efficiency within a limited frequency range was a primary design goal. To address the growing need for spectrum resources and the challenge of constrained energy resources, 5G cellular networks integrate existing 4G-LTE technology and Wi-Fi standards. The Third Generation Partnership Project (3GPP) recommends that 5G networks include the Enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communications (URLLC), and Massive Machine Type Communications (mMTC) categories of applications. Furthermore, 5G networks should be able to allow improved vehicle-to-everything communications. Modulation and multiple-access (MA) systems will need to be investigated further in order to accommodate these tweaks.

Orthogonal Time Frequency Space (OTFS) is a novel modulation scheme in which each transmitted symbol experiences a nearly constant channel gain even in channels with high Doppler or carrier frequencies. In this dissertation, we examine OTFS modulation based Orthogonal MA (OMA), where each user terminals (UTs) are allotted non-overlapping physical resources in the delay-Doppler (DD) and/or time-frequency (TF) domain. In the uplink of an orthogonal time frequency space modulation-based wireless communication system with significant Doppler and delay spread, we present a unique OMA approach called Interleaved Delay Doppler Multiple Access (IDDMA) where each UT is allocated delay-Doppler (DD) resource elements that are evenly spaced throughout the DD domain. This restricts the time frequency (TF) transmit signal to a sub-domain of the whole TF domain. Multi-user interference (MUI) is eliminated by assigning non-overlapping portions of the TF transmit signal to different UTs. Analytical results demonstrate that the proposed MA technique (IDDMA) is MUI-free with ideal transmit and receive pulses and has a much better sum spectral efficiency than previous OMA approaches, Guard Band(GB) based MA (GBMA), and Interleaved Time Frequency MA (ITFMA), reported in the literature.

As ideal pulses are not realizable, in this thesis, we study the SE performance of the OMA methods with practical rectangular pulses. For these OMA methods, we derive the expression for the received DD/TF domain symbols at the base station (BS) receiver

and the effective DD domain channel matrix when rectangular pulses are used. Study of these expressions demonstrates the existence of MUI when rectangular pulses are used, although the quantity of MUI in IDDMA is substantially less than in ITFMA. We also derive the expression for the achievable sum SE. Through simulations, for practical values of the received signal-to-noise ratio, we observe that with rectangular pulses the sum SE achieved by the IDDMA method is significantly higher than that achieved by the ITFMA and GBMA methods. The uncoded BER performance of various OMA techniques for BPSK and QPSK modulations is also studied in this thesis, and it is shown that our proposed IDDMA method has lower BER than the other existing OMA methods.

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