

Chapter 15

Single-Carrier Frequency Domain Equalization for Broadband Cooperative Communications

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ABSTRACT

Cooperative diversity is an effective technique to combat the fading phenomena in wireless communications without additional complexity of multiple antennas. Multiple terminals in the network form a virtual antenna array in a distributed fashion. Even though each of them is equipped with only one antenna, spatial diversity gain can be achieved through cooperation. In this chapter, we discuss relay-assisted single carrier transmissions extending conventional transmit diversity schemes. We focus on distributed space-frequency block coded single carrier transmission, in order to operate over fast fading channels. A pilot design technique is also discussed for channel estimation of this single carrier cooperative system, which shows better channel tracking performance than conventional block-type channel estimations. In addition, spectral efficient cooperative diversity protocols are presented, where the users access a relay simultaneously or transmit superposed data blocks. Interference from the other user is effectively removed by using an iterative detection technique.

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INTRODUCTION

Single carrier frequency-domain equalization (SC-FDE) has similar performance and essentially the same overall complexity as orthogonal frequency division multiplexing (OFDM) (Falconer, 2002; Prasad, 2004). This SC-FDE is preferred for the uplink transmission, because its transmit structure at mobile equipment is very simple. Moreover, the peak-to-average power ratio (PAPR) of transmitted sequences of SC-FDE is much lower than that of OFDM, and thus the required dynamic range of power amplifier is smaller and the battery life time is longer than that of OFDM (Kwon, in press). SC frequency division multiple access (SC-FDMA), which is a combination of FDMA and SC-FDE, is currently a strong candidate for the uplink multiple access scheme in 3rd Generation Partnership Project Long Term Evolution (3GPP-LTE) (Myung, 2006).

Space-time coding is a communication technique for wireless systems, which realizes spatial diversity by introducing temporal and spatial correlations into the signals transmitted from different antennas (Alamouti, 1998; Agrawal, 1998; Al-Dhahir, 2001; Choi, 2007). Most significantly, Alamouti (1998) proposed a simple space-time block code (STBC) for two transmit antennas, guaranteeing full spatial diversity and full rate over frequency-flat channels. Since Alamouti coded system does not require any channel state feedback information, it has been widely adopted in wireless standards such as IEEE 802.11n WLAN and 802.16e mobile WiMAX. STBC combined with SC-FDE was presented by Al-Dhahir (2001), which is based on the Alamouti scheme for frequency selective channels. The major drawback of the STBC SC-FDE, however, is that the channel is assumed to be constant for two consecutive symbol intervals (Jang, 2006; Bauch, 2003). Therefore, the system breaks down when used in a time-varying mobile environment. In order to mitigate the fast fading distortion caused by high-speed mobility, Jang *et al.* (2006) recently proposed space-frequency block code (SFBC) combined with SC-FDE. Although the SFBC SC-FDE achieves spatial diversity gain over fast fading channels, it introduces 3dB PAPR increase over two transmit antennas and additional computational complexity at the transmitter.

Employing multiple antennas in uplink communications is restricted, due to the limitation of size and complexity of the mobile equipment. Cooperative diversity overcomes these problems without additional complexity of multiple antennas and provides an effective means of improving spectral and power efficiencies (Sendonaris, 2003; Pabst, 2004). Recently, relay and cooperative networks have been proposed for applications of several emerging systems. IEEE 802.16j (LMSC, 2008) is a developing standard for 802.16-based multihop networks. The multihop relay is a promising solution to expand coverage and to enhance throughput and system capacity. It is expected that the complexity of relay stations will be considerably less than the complexity of legacy base stations. The gains in coverage and throughput can be leveraged to reduce total deployment cost. Relaying is also considered in IEEE 802.11s, a developing mesh networking standard. There have been extensive works on cooperative diversity, but most of them assume frequency-flat fading environment. For broadband wireless applications, frequency-selective channels must be considered. Mheidat *et al.* (2007) extended conventional STBC SC-FDE in a distributed fashion, so called D-STBC SC-FDE, for practical implementation of cooperative networks. They have considered all underlying links experience frequency selective fading. For fast fading channels, the conventional SFBC SC-FDE can also be extended in a distributed fashion, but still holds the disadvantages of increased PAPR and computational complexity. In practice, the relay works in the half-duplex mode, i.e., the relay cannot simultaneously transmit and receive in the same frequency channel. It means that the transmission of one information symbol from source to destination requires two channel uses (Rankov, 2007).

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