

UWB MODULATION SCHEME “SC-CFDMA” FOR MULTI-USER COMMUNICATIONS

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Abstract: A very high-speed wireless access of 100Mbps to 1Gbps is required for the 4th generation (4G) mobile communications systems. However, for such high-speed data transmissions the channel is severely frequency-selective due to the presence of many interfering paths with different time delays. A promising wireless access technique that can overcome the channel frequency-selectivity and even take advantage of this selectivity to improve the transmission performance is code division multiple access (CDMA). There may be two approaches in CDMA technique: direct-sequence (DS)-CDMA and multi-carrier (MC)-CDMA. A lot of attention is paid to MC-CDMA. However, recently it has been found that DS-CDMA can achieve a good performance comparable to MC-CDMA if proper frequency-domain equalization is adopted. The modulation method adopted with frequency domain equalization to CDMA is called SCCFDMA. The motivation was to combine the advantages of multicarrier transmission with the ability of CDMA to accommodate a greater number of users

Keywords: Code Division Multiple Access, Single Carrier Frequency division Multiple Access

I. INTRODUCTION

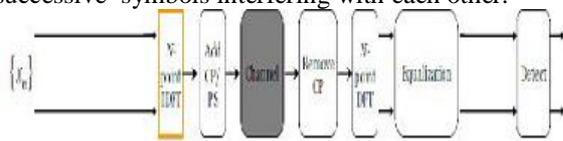
The field of wireless communications is growing at an explosive rate, covering many technical areas. Its sphere of influence is beyond imagination. The worldwide activities in this growth industry are perhaps an indication of its importance. A very high-speed wireless access of 100Mbps to 1Gbps is required for the 4th generation (4G) mobile communications systems. However, for such high speed data transmissions the channel is severely frequency-selective due to the presence of many interfering paths with different time delays. A promising wireless access technique that can overcome the channel frequency-selectivity and even take advantage of this selectivity to improve the transmission performance is code division multiple access (CDMA). There may be two approaches in CDMA technique: direct-sequence (DS)-CDMA and multi-carrier (MC)-CDMA. A lot of attention is paid to MC-CDMA. However, recently it has been found that DS-CDMA can achieve a good performance comparable to MC-CDMA if proper frequency-domain equalization is adopted. This report presents the modulation scheme that improve the performance of existing multiple access techniques proposed for fourth generation wireless communication systems, i.e., Orthogonal Frequency Division Multiplexing-Code Division Multiple Access (OFDM CDMA), Orthogonal Frequency Division Multiplexing (OFDM), Multi-Carrier Code Division Multiple Access (MC-CDMA) and Single Carrier Frequency Division Multiple Access (SC-FDMA) systems for uplink. Over the years, a vast amount of knowledge base has been built around the subject of digital modulation techniques in the technical literature. An analysis of the digital modulation technique carried out in

various article reveals that the selection of a digital modulation technique is solely dependent on the type of application and requirements. Ever increasing demand for higher data rate is leading to utilization of wider transmission bandwidth. Broadband wireless mobile communications suffer from multipath frequency selective fading. For broadband multipath channels, conventional time domain equalizers are impractical for complexity reason. Orthogonal frequency division multiplexing (OFDM), which is a multicarrier communication technique, has become widely accepted primarily because of its robustness against frequency selective fading channels which are common in broadband mobile wireless communication. The two main candidates for fourth generation (4G) mobile communication systems are WiMAX802.16e and Long Term Evolution (LTE) Advanced initially endorsed by ITU-R enabling true broadband services with transmission rates up to 100 Mbps with full mobility and 1 Gbps with limited. There have been several proposals including Orthogonal Frequency Division Multiplexing (OFDM), Multi-Carrier Code Division Multiple-Access (MC-CDMA) and Orthogonal Frequency & Code Division Multiplexing (OFCDM) for the adoption as multiple access techniques. The motivation was to combine the advantages of multicarrier transmission with the ability of CDMA to accommodate a greater number of users. The existing multicarrier modulation schemes are following

1.1 Orthogonal Frequency Division Multiplexing

Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier transmission technique. It is a low complexity technique to efficiently modulate multiple subcarriers by using digital signal processing. The principle of multi-carrier

transmission is to convert a serial high-rate data stream onto multiple parallel low-rate sub-streams. Each sub-stream is modulated on another subcarrier. Since the symbol rate on each sub-carrier is much less than the initial serial data symbol rate, the effects of delay spread, i.e., ISI significantly decrease. The transmitter user data, as a serial stream of bits, is modulated by a suitable digital modulation technique and then converted from a serial stream in to parallel substreams. Each stream will be up-converted by carriers that are orthogonal to each other. This is performed by applying the IDFT algorithm onto the parallel sub-streams. A part of the signal's tail is copied to its front, therefore prefix, before sending it through the channel. This helps in creating a guard space in the time-domain for delayed multipath signals and prevents successive symbols interfering with each other.



CP: Cyclic Prefix, PS: Pulse Shaping

Fig 1.1 OFDM Transmitter and Receiver

1.2 Multi-Carrier Code Division Multiple Access

The transmitter for MC-CDMA is similar to that of OFDM. Data bits are modulated and repeated onto N parallel streams. After that, each sub-stream is multiplied by a chip of a unique spreading sequence. This step would perform the objective of multiplexing in the frequency-domain.

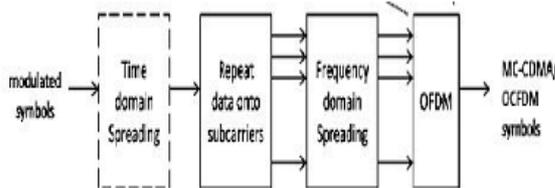


Fig 1.2 Basic MC-CDMA Transmitter

1.3 Single Carrier Frequency Division Multiple Access(SC-FDMA)

Single Carrier Frequency Division Multiple Access (SC-FDMA), is a multiple access technique that utilizes single carrier modulation and orthogonal frequency multiplexing. It has been adopted by the third generation partnership project (3GPP) for uplink transmission in the technology standardized for long term evolution (LTE) cellular systems. SC-FDMA is sometimes referred as DFT-spread or DFT-pre-coded OFDMA. C-FDMA has similar performance and essentially the same overall structure as an OFDMA system. One prominent advantage over OFDMA is that the SC-FDMA signal has lower PAPR because of its inherent single carrier structure. Therefore, we consider single carrier instead of multicarrier to combine with spreading technique. Moreover,

conventional SC-FDMA cannot operate with some terminals using localized scheduling and others using distributed scheduling because it achieves orthogonality of sources by having each sub-carrier occupied by no more than one terminal at any time. Orthogonal frequency division multiple access (OFDMA) is a multiple access scheme which is an extension of OFDM to accommodate multiple simultaneous users. FDM/OFDMA technique is currently adopted in wireless LAN (IEEE 802.11a & 11g), WiMAX (IEEE 802.16), and 3GPP LTE downlink systems. Despite the benefits of OFDM and OFDMA, they suffer a number of drawbacks including: high peak-to-average power ratio (PAPR), a need for an adaptive or coded scheme to overcome spectral nulls in the channel, and high sensitivity to frequency offset. Single carrier frequency division multiple access (SCFDMA) which utilizes single carrier modulation and frequency domain equalization is a technique that has similar performance and essentially the same overall complexity as those of OFDMA system. One prominent advantage over OFDMA is that the SC-FDMA signal has lower PAPR because of its inherent single carrier structure. SC-FDMA has drawn great attention as an attractive alternative to OFDMA, especially in the plink communications where lower PAPR greatly benefits the mobile terminal in terms of transmit power efficiency and manufacturing cost. SC-FDMA has two different subcarrier mapping schemes; distributed and localized. In distributed subcarrier mapping scheme, user's data occupy a set of distributed subcarriers and we achieve frequency diversity. In localized subcarrier mapping scheme, user's data inhabit a set of consecutive localized subcarriers and we achieve frequency-selective gain through channel dependent scheduling (CDS). SC-FDMA is currently a working assumption for the uplink multiple access scheme in 3GPP LTE.

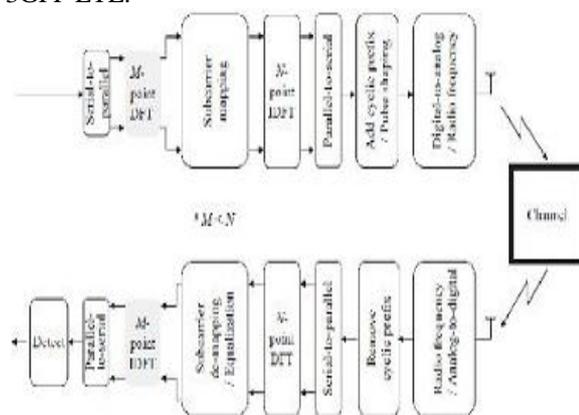


Fig 1.3 Scfdma Transmitter

II. SC-FDMA-CDMA

By using the orthogonal direct sequence spread spectrum technique prior to SC-FDMA modulation, both mappings can coexist with overlapping sub-

carrier. Hybrid subcarrier mapping scheme yields higher data throughput than the conventional subcarrier mapping schemes, we refer to this multiple access scheme as signal carrier code frequency division multiple access (SC-CFDMA), which can be viewed as a combination of DS-CDMA and SCFDMA. We can call it as SC-FDMA-CDMA, which inherits merits of SC-FDMA and DS-CDMA. Therefore, it has better PAPR performance because of single carrier structure from SC-FDMA. Different sub-carrier mapping for SC-FDMA-CDMA, i.e., localized sub-carrier mapping, interleaved sub-carrier mapping (a special case of distributed sub-carrier mapping with equidistance between occupied sub-carriers), and hybrid sub-carrier mapping (a combination of localized and distributed sub-carrier mapping). Results show that SC-FDMA-CDMA performs better than OFDM-CDMA for uplink in PAPR. Moreover, SC-FDMA-CDMA has similar BER performance as OFDM-CDMA

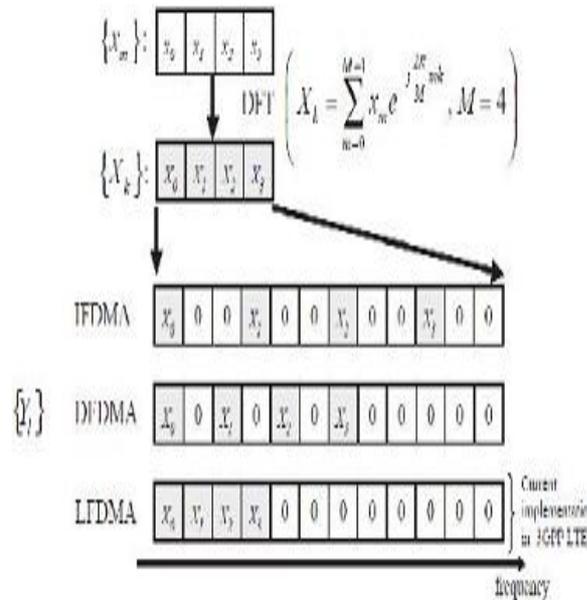


Fig.4.3 SC-FDMA-CDMA transmitter and receiver

SC-FDMA-CDMA is a single carrier spread spectrum technique. SC-FDMA-CDMA signal is similar to OFDMCDMA signal, which is generated by a serial concatenation of DS-CDMA and SC-FDMA. The key model of OFDM-CDMA and SC-FDMA-CDMA systems are OFDM model and SC-FDMA model. As the name implies, the difference of these systems is based on their modulation pattern, one is OFDM modulation, and the other is SC-DMA modulation. Moreover, OFDM and SC-FDMA have close relationship in structure and performance. In other words, the distinctions of OFDMCDMA and SC-FDMA-CDMA are based on the relationship of OFDM and SC-FDMA. From the above introduction, we know that SC-FDMA is referred as to DFT-spread or DFT-pre-coded OFDMA. Therefore, we can realize SC-FDMA-CDMA system by adding DFT

prior to OFDM modulation and adding IDFT behind OFDM demodulation in the OFDM-CDMA system. We can see difference in these The principle of OFDMCDMA is to map the chips of a spread data symbol in frequency direction over several in the parallel sub channels. It transmits a data symbol of a user simultaneously on several narrowband sub-channels. These sub-channels are multiplied by the chips of the userspecific spreading code. The principle of SC-FDMACDMA is firstly to map the chips of a spread data symbol in frequency direction, secondly to implement DFT precoded, last to map the data in parallel sub-channels. In both schemes, the different users share the same bandwidth at the same time and separate the data by applying different user specific spreading codes. The difference between OFDM-CDMA and SC-FDMACDMA are based on OFDM symbols and SC-FDMA symbols. In essence, OFDM-CDMA signal can be considered as OFDM signal, and SC-FDMA-CDMA can be viewed as SC-FDMA signal, just because the signal has been spread spectrum to transmit in wide band. Therefore, we can apply the OFDM and SC-FDMA characteristic in these novel systems. we can know that OFDMA is better than SC-FDMA 1dB when BER is 10^{-3} , without channel encoding. Therefore, we can deduce that the BER performance of OFDM-CDMA is better than SC-FDMA-CDMA. This assumption is based on the principle difference, which is reasonable. PAPR is a performance measurement that is indicative of the power amplifier efficiency of the transmitter. We can count the PAPR of these systems. We resort to numerical analysis to investigate the PAPR properties. Specifically, we numerically analyze the complementary cumulative distribution function (CCDF) of PAPR for OFDM-CDMA and SC-FDMA-CDMA. In theory, we can acquire that SCFDMA-CDMA has lower PAPR performance than OFDM-CDMA because of their single carrier structure from SC-FDMA. This is similar to the relationship of SCFDMA and OFDMA

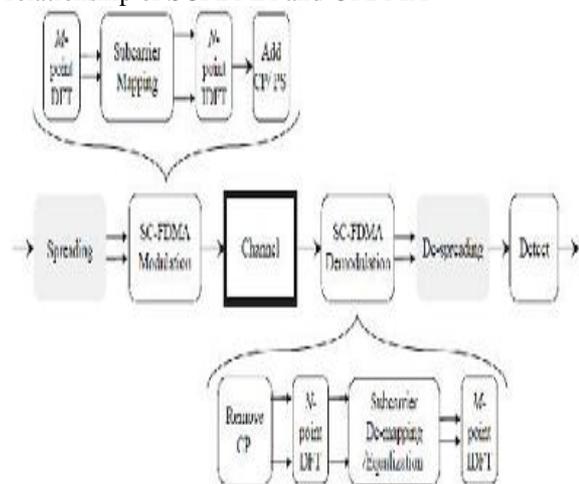
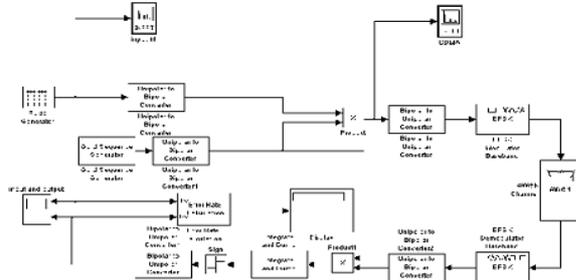


Fig.4.3 SC-FDMA-CDMA transmitter and receiver

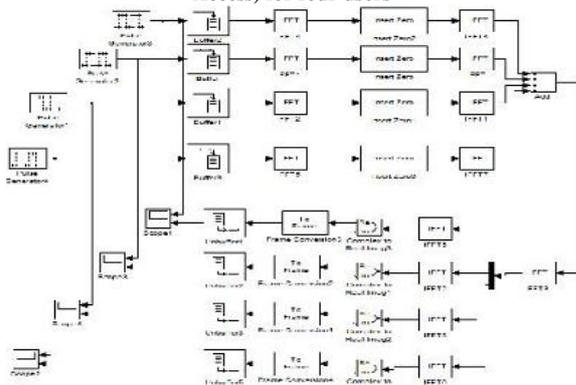
III. SIMULATIONS AND RESULTS

The design of SC-FDMA-CDMA transmitter and receiver using MATLAB SIMULINK version 7.10.0.499 (R2010a).

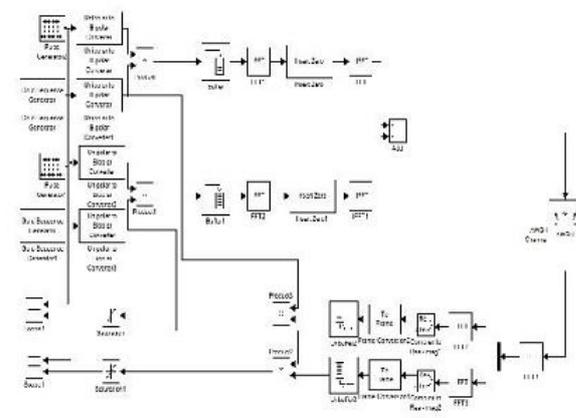
A. Spreading



B. SCFDMA (Single Carrier Frequency Division Multiple Access) for four users



C. SC-CFDMA (Single Carrier-Code Division Multiple Access)



IV. RESULT ANALYSIS

Direct sequence code division multiple access (DSSSS) with frequency domain equalization (FDE) replaces the rake receiver, commonly used in the conventional DS-SSSS, with the frequency domain equalizer. A rake receiver consists of a bank of correlators, each synchronized with one multipath component of the desired signal. As the number of multipaths increase, the frequency selectivity in the channel also increases and the complexity of the rake combiner increases. The use of FDE instead of rake combining can alleviate the complexity problem in DS-SSSS. In SC-FDMA or OFDMA, the users are separated strictly in the frequency domain whereas

SC-CFDMA separates different users in both the frequency domain and code domain. Combining multicarrier SCFDMA transmissions with code division multiple access (CDMA) allows us to exploit the wideband channel's inherent frequency diversity by spreading each symbol across subcarriers.

CONCLUSIONS

Single carrier FDMA (SC-FDMA) is a multiple access technique that utilizes single carrier modulation, orthogonal frequency multiplexing, and frequency domain equalization. It has similar performance and essentially the same overall complexity as orthogonal frequency division multiple access (OFDMA). One prominent advantage over OFDMA is that the SC-FDMA signal has better peak power characteristics because of its inherent single carrier structure. SC-FDMA has drawn great attention as an attractive alternative to OFDMA, especially in the uplink communications where better peak power characteristics greatly benefit the mobile terminal in terms of transmit power efficiency and manufacturing cost. Because of its merits, SC-FDMA has been chosen as the uplink multiple access scheme in 3GPP Long Term Evolution (LTE). Also, a modified form of SC-FDMA is used for the uplink control channel in 3GPP2 Ultra Mobile Broadband (UMB) technique SC-CFDMA. In SC-FDMA or OFDMA, the users are separated strictly in the frequency domain whereas SC-CFDMA separates different users in both the frequency domain and code domain. PAPR performance of SC-FDMA-CDMA performs better than that of OFDM-CDMA for uplink, and its BER performance is near to that of OFDM-CDMA. At the same time, the hybrid subcarrier mapping for SC-FDMA-CDMA, which is great of helpful for system sources scheduling.

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