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A Review on Spectrum Efficient OFDM Based on Structured Compressed Sensing

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Abstract: **Spectrum efficiency is becoming increasingly important for wireless communication systems in order to avoid the congestion of users for the spectrum. OFDM has already been extensively adopted by numerous wireless communication systems like DVB-T, WiMAX, LTE, WiFi, etc, and it is also widely recognized as a prominent modulation technique for future wireless communication systems. Thus, developing spectrum efficient OFDM scheme is essential to achieve high transmission efficiency. Time domain synchronous OFDM (TDS-OFDM) has a higher spectrum efficiency than standard cyclic prefix OFDM (CP-OFDM) by replacing the unknown CP with a known pseudorandom noise (PN) sequence. Currently, TDS-OFDM can support constellations up to 64QAM, but cannot support higher-order constellations like 256QAM due to the residual mutual interferences between the pseudorandom noise (PN) guard interval and the OFDM data block. To solve this problem, break the iterative interference cancellation and propose a new idea of using multiple inter-block-interference (IBI)-free regions of very small size to realize simultaneous multi-channel reconstruction under the framework of structured compressive sensing.**

***Index Terms*—** **CP-OFDM, Iterative interference cancellation, OFDM, Spectrum efficiency, Structured compressed sensing, TDS-OFDM.**

I. INTRODUCTION

Spectrum efficiency is of great importance for present and future wireless communication systems. OFDM is a digital multicarrier modulation method which has already been adopted by many wireless communication systems like DVB-T(Digital Video Broadcasting-Television), WiMAX, LTE, WiFi, etc. Thus, developing spectrum efficient OFDM scheme is essential to achieve high transmission efficiency. OFDM is orthogonal frequency division multiplexing in which a high rate data stream is divided into number of low rate data stream. These data are transmitted by using number of subcarriers. OFDM helps to reduce ICI, ISI etc. While OFDM has several overheads that reduces the attainable spectral efficiency OFDM is considered as a multiplexing as well as a modulation scheme. So the spectral efficiency of the OFDM system is same as that of the modulation scheme used in the communication.

There are three basic types of OFDM: CP-OFDM (cyclic prefix), ZP-OFDM (zero padding), TDS-OFDM (time domain synchronous)[1]. The CP-OFDM utilizes a Cyclic Prefix as a guard interval to reduce inter-Symbol-interference (ISI) in multipath channels [2]. The CP is replaced by a Zero Padding in ZP-OFDM to tackle the channel transmission zeros problem [2. TDS-OFDM adopts a known pseudorandom noise (PN) sequence as a guard interval as well as a training sequence (TS) for synchronization and channel estimation instead of cyclic prefix. TDS-OFDM does not uses frequency domain pilots which results high spectrum efficiency [12][13].TDS OFDM is the key technology used in Chinese digital terrestrial broadcasting.

One direct way to increase spectrum efficiency is to use higher order modulations. But TDS OFDM does not support high constellation schemes like 256 QAM because the mutual interference occurs in between the PN sequence and the data block. This will cause inaccurate channel estimation and there by incorrect data demodulation. To solve the interference problem two methods are used. First one tries to enhance the performance of iterative interference cancellation algorithm without changing the basic signal structure. Another solution is the dual PN(DPN)[1] padding scheme where two PN sequences are used in every TDS OFDM symbol to avoid the interference. But the extra PN sequence reduces the spectrum efficiency.

To provide more spectrum efficient scheme here utilizing the newly emerging theory of structured compressed sensing. based on the classical sparse signal reconstruction algorithm called simultaneous orthogonal matching pursuit(SOMP)[1].

II. OFDM

OFDM is a frequency division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional single carrier modulation schemes in the same bandwidth.

OFDM [2] has been used in many high data rate wireless communication systems because it provides many advantages.

- Immunity to selective fading: OFDM is highly resistant to frequency selective fading. Because in OFDM , it divides the whole cannel into multiple narrowband signals. These narrow band signals are affected individually as flat fading sub channels.

- Resilience to interference: Interference appearing on a channel may be bandwidth limited and in this way will not affect all the sub-channels. This means that not all the data is lost.

- Spectrum efficiency: Using close-spaced overlapping sub-carriers, a significant OFDM advantage is that it makes efficient use of the available spectrum.

- Resilient to ISI: Another advantage of OFDM is that it is very resilient to inter-symbol and inter-frame interference. This results from the low data rate on each of the sub-channels.

- Resilient to narrow-band effects: By using adequate channel coding and interleaving it is possible to recover symbols lost due to the frequency selectivity of the channel and narrow band interference. All the data will not lost.

- Simpler channel equalization: In the channel accessing technique, it is important to attain channel equalization. But in CDMA system, acquiring channel equalization which had to be applied across the whole channel is very complex. OFDM has an advantage that it using multiple sub-channels, and this helps in the channel equalization becomes much simpler.

OFDM has been adopted in the Wi-Fi arena where the standards like 802.11a, 802.11n, 802.11ac and more. It has also been chosen for the cellular telecommunications standards like LTE / LTE-A, and it has been used by other standards such as WiMAX and many more.

Orthogonal frequency division multiplexing has also been adopted for a number of broadcast standards from Digital Audio Broadcasting(DAB) , Digital Radio to the Digital Video Broadcast standards (DVB).

A. CP-OFDM

In telecommunications, the term **cyclic prefix** refers to the prefixing of a symbol with a repetition of the end. the receiver is typically configured to discard the cyclic prefix samples. cyclic prefix serves two purposes:

- As a guard interval, it eliminates the inter symbol interference from the previous symbol.

- As a repetition of the end of the symbol, it allows the linear convolution of a frequency-selective multipath channel to be modeled as circular convolution, which in turn may be transformed to the frequency domain using a discrete Fourier transform. This approach allows for simple frequency-domain processing, such as channel estimation and equalization.

In order for the cyclic prefix to be effective (i.e. to serve its aforementioned objectives), the length of the cyclic prefix must be at least equal to the length of the multipath channel.

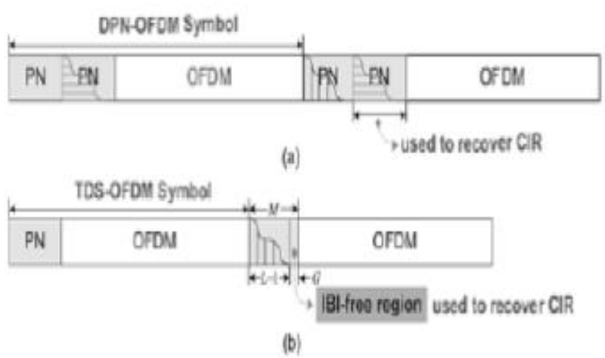
The cyclic prefix orthogonal frequency division multiplexing (CP-OFDM)[13] is widely used to deal with problem of inter-symbol interference (ISI) in wireless communications. Many broadcasting systems use CP-OFDM as their modulation scheme. The broadly used CP-OFDM scheme utilizes the CP to eliminate the inter block interference (IBI) as well as the inter-carrier interference (ICI). The role of the cyclic prefix is to turn the linear convolution into a set of parallel attenuations in the discrete frequency domain. Particularly, cyclic prefixes that are longer than channel duration should be added as guard intervals between consecutive OFDM data blocks which are inverse discrete Fourier transformed (IDFT).

B.ZP-OFDM

Zero padding sequence is used in ZP-OFDM [2] to tackle the channel transmission zeros problem. Zero padding can be used in achieve the same effect when a higher resolution is needed in the frequency domain. Zero padding in the time domain gives what is called spectral interpolation. In the time domain, zero padding at the end of a signal results in the increase in spectral samples which are samples of the true Fourier transform. This provides higher resolution.

Zero padding in the frequency domain has two distinct differences. Firstly doing zero pad after the Nyquist frequency at N/2 samples. This is because it is the highest positive frequency and can maintain spectral symmetry in doing so. Secondly obtain a time domain sequence which has reduced amplitude. This can be fix by a multiplication of a constant gain of Mu.

C.TDS-OFDM



Time domain synchronous orthogonal frequency division multiplex (TDS-OFDM)[1][12] is an effective multi-carrier modulation scheme to improve the spectrum efficiency. Instead of inserting cyclic prefix, training symbols are inserted as guard intervals. The training sequence could be any known pseudo random sequence. TDS OFDM has been adopted into the Chinese digital television/terrestrial multimedia broadcasting (DTMB)[11] standard. The training sequence could be used for synchronization as well as channel estimation. Furthermore, the inserted training sequence could be removed by the receiver and thus causes little interference to the frame body. Therefore, training pilots in the frequency domain are saved in order to improve the spectrum efficiency. The synchronization algorithm based on the cross-correlation between the local PN sequence and the received signal only works well under small range of carrier frequency offset (CFO).

III. COMPRESSED SENSING

Compressed sensing (CS)[3] is an emerging field that has attracted considerable research interest in the signal processing field. Most of the analog to digital convertors follow Shannon's theorem which says the sampling rate must be at least twice the maximum frequency present in the signal (the so-called Nyquist rate).

A. Shannon-Nyquist Theorem

Analogy to digital converters provide the interface between an analog signal being recorded and a suitable discrete representation. A common approach is to assume that the signal is band limited, meaning that the spectral contents are confined to a maximal frequency B. Band limited signals have limited time variation, and can therefore be perfectly reconstructed from equispaced samples with rate at least 2B, termed the Nyquist rate[3][4]. This basic principle uses the majority of digital signal processing (DSP) applications such as audio, video, radio receivers, radar applications, medical devices and more. The growing demand for data, as well as advances in radio frequency (RF) technology, have promoted the use of high-bandwidth signals, for which the rates dictated by the Shannon- Nyquist theorem[9] impose severe challenges both on the acquisition hardware and on the subsequent storage and DSP processors. CS was motivated in part by the desire to sample wideband signals at rates far lower than the Shannon-Nyquist rate, while still maintaining the essential information encoded in the underlying signal.

B. Compressed Sensing Basics

In the compressive sensing (CS) framework, an unobserved signal x, L = dim(x), has a K-sparse basis expansion: $x = \phi a$.

The columns of ϕ form an orthonormal basis and 'a' are the expansion coefficients. To be K-sparse, the coefficient vector a has only K nonzero entries at unknown locations. M inner-product-type measurements are made with the $M \times L$ measurement matrix Y: $y = \psi x$. From these $M \ll L$ measurements, we want to construct x.
According to CS theory, the number of measurements needed to construct x with high probability is of the order '$O(K\log(L/K))$' when a "random" measurement matrix is used[8]. The coefficient vector 'a' is found as a solution of the l1 optimization problem $\min\|a\|_1$ subject to $\psi\phi a = y$

IV. RECONSTRUCTION ALGORITHMS

Several signal reconstruction algorithms in standard CS theory have been extended to the SCS framework to achieve jointly sparse signals reconstruction. Among them, SOMP derived from the well-known OMP algorithm. Orthogonal Matching Pursuit(OMP)[7] is an iterative greedy[10] algorithm. The key idea of SOMP is to find the solution to by sequentially selecting a small subset of column vectors of **Φ** to approximate the observation matrix **Y** in an iterative manner. However, SOMP requires in advance the known sparsity level *S* and the number of observations, both of which will be variable and unavailable in practical applications. Moreover, since matrix inversion is required in each iteration step, SOMP has a high computational complexity for hardware implementation. To alleviate these problems of SOMP, we propose an adaptive SOMP (A-SOMP)[1] algorithm based on the basic principle of SOMP.

V. CONCLUSION

This review successfully described about different spectrum efficient OFDMs. Familiarized with the sparse sampling techniques and the sparse sampling reconstruction algorithm for save more band width as well as the memory of the hardware device. The compressed sensing TDS OFDM is 10% more spectrum efficient than the conventional OFDM systems. It is very much useful in HDTV delivery and the applications with very high constellations.

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