Review on Performance Analysis of Detection of Single Carrier FDMA

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***Abstract*— This paper incorporates different approaches used to check the performance on detection of single carrier frequency division multiple access (SC-FDMA). Primarily four different techniques have been compared to study the effect of phase noise on the performance of linear receivers that are often used in practice. It identifies the association of the significant phase noise components with the components of multi-user interference to be the fundamental reason behind the performance gap between interleaved and localized SC-FDMA.**

Keywords—SC-FDMA, localized FDMA, OFDMA, LTE, PAPR, DFT, MMSE equalizer, IFFT, BICM-aided SC-FDMA, MMSE FD-LE, STSK-MIMO architecture, ISI, SCM system, DFE.

I. INTRODUCTION

The frequency division schemes that serve multiple users in a network both ways i.e. downlink as well as uplink have been adopted by many standards in recent years e.g. OFDMA and SC-FDMA. It is quite a fact that difficulties in the transceiver design is caused by the high peak to average power ratio of OFDM. In order to solve this problem, in the LTE standard, for uplink of the transmission, SC-FDMA has been adopted [1].

SC-FDMA scheme is having a much smaller peak-to-average power ratio as compared to OFDMA and is essentially a Discrete Fourier Transform that has been precoded as OFDMA scheme. In both the schemes the allocation of sub carriers can be done in different ways so that varying degrees transmitters are having the channel knowledge. Apart from that some metrics of performance like outage probability or capacity get optimized by solving a resource allocation problem and is quite meaningful in this context [2].

In this comparative research paper, to check the performance, two allocation approaches have been adopted in LTE which are of our prime focus. These approaches dispenses with the requirement of any form of transmitters channel knowledge whether interleaved or localized. In the latter approach, the isolated sub carriers are allocated to the users. The isolated subcarriers are evenly spaced with the transmission bandwidth. Whereas in the former approach, a set of contiguous sub carriers is allocated to each user.

II. INTERLEAVED SC-FDMA

Interleaved SC-FDMA has some benefits of diversity over the localized SC-FDMA. The linear frequency domain MMSE equalizer which is at the receiver end for the purpose of compensating the channel / carrier basis is also included for performance checking [3]. Due to low level of complexity involved and ease in the process of implementation, this kind of structure is being widely used in a receiver design. So the prime focus is on this kind of recievers in this paper. Since multi carrier systems are being adopted widely, it is important for to study the performance of multi carrier system under the realistic scenarios where the impairment of receiver plays a very critical role. Impairment, particularly the phase noise (PHN) requires special attention because over the duration of multi carrier symbol, it changes substantially unlike other impairments and for the training stage, it cannot be compensated at all.

This paper is intended for analyzing in detail regarding the effect put on the SC-FDMA signal by phase noise. Also the effect of the phase noise in altering the performance of linear receiver present is also been analyzed in detail in this paper. There can be generalization of results to OFDMA by using the framework. Due to imperfections in the frequency synthesizer, the phase noise rises. As a result, in the phase of frequency synthesizer sinusoidal signal, random fluctuations take place. Under the ideal conditions, the initial studies suggests that the while using the frequency domain MMSE equalizers, both OFDMA and SC-FDMA performs well. The performance of the SC FDMA has also been analyzed by the recent studies on which the RF impairments like, IQ imbalance, timing offsets; frequency offsets etc. have made their influence. In the presence of power amplifiers, the review on performance of both SC-FDMA and OFDMA has been presented and the results have shown that SC-FDMA has performed better over OFDMA [4] [5].

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III. Review on Detection of Single Carrier FDMA Methods

A. SC-FDMA and IFFT

On the basis of the structure of SC-FDMA, the explanations for several of its names, like DFT-spread OFDM or DFT pre-coded OFDM, are understood to some extent. But for using the 'Single Carrier' in its name, SC-FDMA, is not as evident and is frequently the reason why is not described, Whereas in the standard OFDM, every data symbol is passed by the specific subcarriers, the transmitter of SC-FDMA carts data symbols over a set of subcarriers which are transmitted concurrently. SC-FDMA is basically the set of subcarriers that cart each data symbol can be observed as one frequency band carrying data successively in a standard FDMA. In the Fig. 1, the IFFT output's time domain representation is shown for certain subcarrier mappings, which will provide additional vision on the SC-FDMA signal. Mathematically it can be shown that the samples in time domain of the SC-FDMA baseband signal afterward IDFT or IFFT is the data symbol set which is original and is repetitive in time domain over the symbol period. [6]. This type of setup of SC-FDMA can be used as base for checking the performance of the carrier.

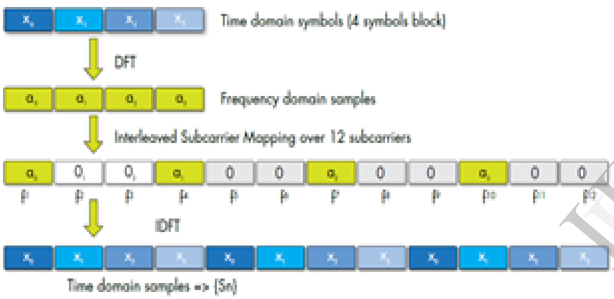

Fig. 1 Domain representation of interleaved SC-FDMA (Wang et. al, 2006)

B. Frequency-domain turbo equalization

In another method, the BS's receiver conceived for BICM-aided SC-FDMA systems is shown in Fig. 3, which invokes the complex-valued MMSE turbo FD-LE using the iterative decoding (ID) scheme. The corresponding iterative equalisation and decoding philosophy was detailed in [7]. Following the initial equalisation by the classic MMSE FD-LE and the BICM decoding, these blocks exchange extrinsic information in a number of consecutive iterations, in order to improve the attainable performance. It is generated by the bit-probability-to-symbol-probability conversion using a-priori LLRs, which are generated by appropriately ordering them by the interleaving based on the feedback of the BICM decoder. Therefore, by applying soft-information exchange between the equaliser and BICM decoder, the weight matrix of the MMSE FD-LE is updated based on the *a-priori* information gleaned during each iteration, which results in a high complexity. ISI imposed on the estimated symbols, but the required number of iterations may be increased.

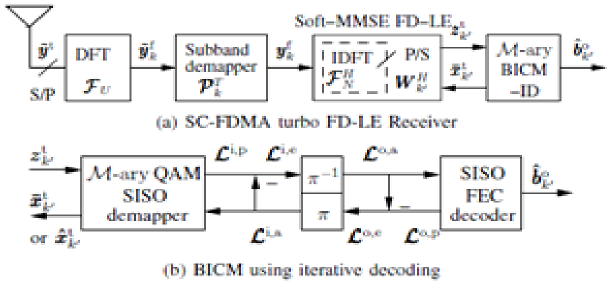

Fig. 2 SC-FDMA turbo FD-LE Reciever and BICM using iterative decoding(Berardinelliet, al, 2008)

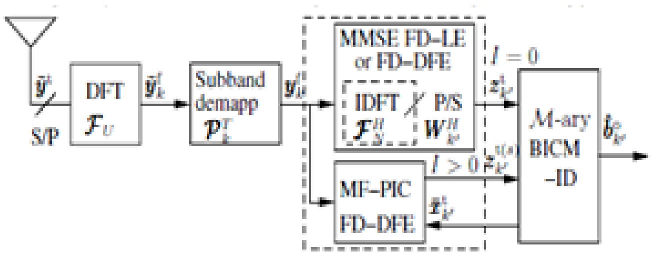

Fig. 3 PIC or HIC added turbo for BICM-aided SC-FDMA (Berardinelliet, al, 2008)

C. OFDMA/SC-FDMA-aided STSK MIMO Architecture

A novel OFDMA/SC-FDMA-aided STSK MIMO architecture is proposed, which is capable of efficient operation in frequency-selective wireless channels to strike a flexible diversity versus multiplexing gain trade-off. The transmitted signal of each subcarrier the parallel modem experiences a non-dispersive narrowband channel, and the overall STSK-based MIMO scheme manifests a performance similar to that in narrow-band channels, despite operating in a wideband scenario. The appropriate mapping of the users' symbols to subcarriers results in a flexible multiuse performance while benefitting from our low-complexity. [8].

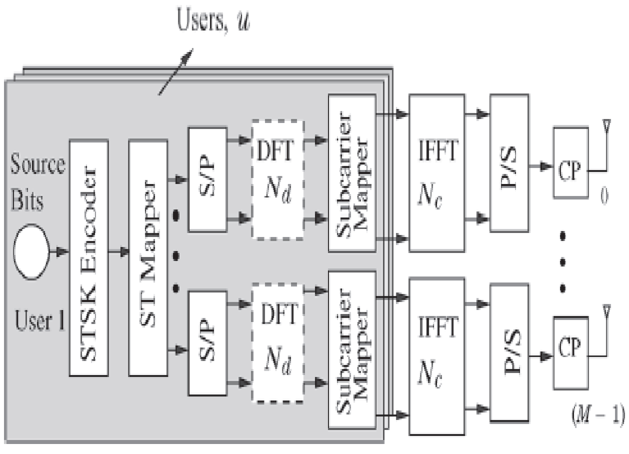

Fig. 4 OFDMA/SC-FDMA-aided STSK MIMO transmitter (Yune et. al. 2010)

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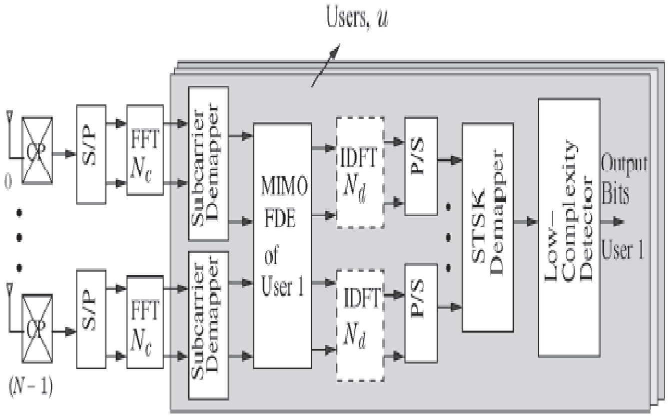

Fig. 5 OFDMA/SC-FDMA-aided STSK MIMO Receiver (Yune et. al. 2010)

D. Modulation of Single Carrier with Nonlinear Frequency Domain Equalization:-

In the initial 1970s, the key progress was accepting that for the facilitating and simplification of the equalization of SCM system, various techniques of frequency domain processing can also be used [9] [10]. Recently, as an alternate of the first OFDM applications in standards of wireless, figured out that by moving the inverse DFT at the receiver side for highly frequency selective channel, the traditional SCM can perform an execution ease/performance compromise analogous to that of OFDM . But, this is only correct for a nonlinear frequency domain equalizer. But according to facts, only DFE can perform equally or better than that of OFDM [8]. An another advantage of SCM waveforms is that the amplitude range for a prearranged signal power, which is calculated by using the peak-to-average ratio, and is expressively less in comparison to that of multicarrier signals. As an outcome, the power amplifier nonlinearities of the transmitter have less effect on the performance and their transmitted spectra. This permits that the transmitting SCM signals could use inexpensive and more effective high power. The advantage of SCM in comparison to OFDM is superior strength to phase noise and frequency offset [7]. Thus the single carrier with frequency domain equalization is preferable alternate for OFDM because of its greater robustness to radio frequency hardware impairments, mainly for wireless user terminals of next generation which are sensitive to price and power consumption and transmit uplink signals to base stations. Thus the time of the idea of implementing SCM receivers in frequency domain has come once again after 2 decades.

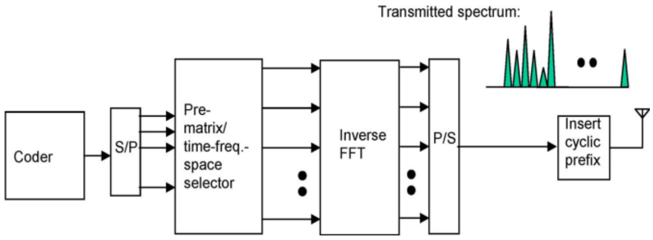

Fig. 6 Generalized multicarrier transmitter (Benvenuto et. al., 2010)

IV. Conclusion

In this paper, various architecture techniques of FDMA have been incorporated to illustrate the basic principles of this scheme. Suppressed carrier frequency modulation is an efficient technique of signal transmission and reception. This technique is robust and the phase noise interference is very less that makes it better than other modulation techniques. Four different techniques have been discussed and evaluated in FDMA in this paper. The results obtained are very much useful and promising in the field of communication.

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