Design and Performance Evaluation of Transmitter Receiver Structures for Broadband Wireless Communication Systems

M. Anand Kumar
PG Student
Department of Electronics & Communication Engineering
Sree vidyanikethan Engineering College, Rangam Peta, Tirupati, India

Abstract— Tremendous growth of wireless communication technology is achieved through the rapid improvements in microelectronic circuits. In future Broadband wireless internet and multimedia services requires efficient coding methodologies, simple transmitter and receiver designs. Orthogonal Frequency division Multiplex(OFDM) schemes with some encoding is used in existing broadband systems, due to their complexity of design it is not suitable for future wireless communications. The term single carrier implies a unique carrier which occupies the entire communication bandwidth, and the transmission is performed at a high symbol rate. When compared to the SC modulation, the MC modulation is just an extremely complicated system without advantage over a SC system. In this paper we present overview of the current broadband wireless communication techniques (BWC) and their limitations, channel estimation methods and designed single carrier(SC) frequency domain based equalization transmitter and receiver structures and gives comparison results with the conventional BWC. Based on the performance estimation parameters like bit error rate(BER), Signal to Noise (SNR) Ratio the proposed transmitter, receiver structures will gives better results than existing methods.

Key words: Broadband Systems, OFDM, Single Carrier, Frequency Domain Equalization

I. INTRODUCTION

Now a day's mobile internet and multimedia services increasing rapidly due to the advancement in micro-electronic circuits as well as the increasing demands for high data rates and high mobility, motivated the rapid development of broadband wireless systems over the past decade.

A major challenge in the design of mobile communications systems is to overcome the mobile radio channel effects, assuring at the same time high power and spectral efficiencies. Since in mobile communications the information data is transmitted across the wireless medium, then the transmitted signal will certainly suffer from adverse effects originated by two different factors: multipath fading and mobility. Within a multipath propagation environment waves arriving from different paths with different delays combine at the receiver with different attenuations. In addition to multipath propagation, time variations within the channel may also arise due to oscillator drifts, as well as due to mobility between transmitter and receiver [1]. The relative motion between the transmitter and the receiver results in Doppler frequency which has a strong negative impact on the performance of mobile radio communication systems since it generates different frequency shifts for each incident plane wave, causing the channel impulse response to vary in time.

The channel characteristics change depending on the location of the user, and because of mobility, they also vary in time. Hence, when the relative positions of the different objects in the environment including the transmitter and receiver change with time, the nature of the channel also varies. In mobility scenarios, the rate of variation of the channel response in time is characterized by the Doppler spread. Significant variations of the channel response within the signal duration lead to time-selective fading, and this represents a major issue in wireless communication systems. Block transmission techniques, with cyclic extensions and FDE techniques (Frequency-Domain Equalization), are known to be suitable for high data rate transmission over severely time-dispersive channels due to its reduced complexity and excellent performance, provided that accurate channel estimates are provided.

Moreover, since these techniques usually employ large blocks, the channel can even change within the block duration [2]. Fourth generation broadband wireless systems employ CP-assisted (Cyclic Prefix) block transmission techniques, and although these techniques allow the simplification of the receiver design, the length of the CP should be a small fraction of the overall block length, meaning that long blocks are susceptible to time-varying channels, especially for mobile systems [3]. Hence, the receiver design for doubly-selective channels is of key importance, especially to reduce the relative weight of the CP. Efficient channel estimation techniques are crucial onto achieving reliable communication in wireless communication systems. When the channel changes within the block duration then significant performance degradation occur. Channel variations lead to two different difficulties: first, the receiver needs continuously accurate channel estimates; second, conventional receiver designs for block transmission techniques are not suitable when there are channel variations within a given block.

As with any coherent receiver, accurate channel estimation is mandatory for the good performance of FDE receivers, both for OFDM (Orthogonal Frequency-Division Multiplexing) and SC-FDE (Single Carrier with Frequency Domain Equalization).The existence of residual CFO (Carrier Frequency Offset) between the transmitter and the receiver's local oscillators means that the equivalent channel has a phase rotation that changes within the block. That residual CFO leads to simple phase variations that are relatively easy to compensate at the receiver's side. However, that may not be the case for single frequency broadcast networks. Within a SFN (Single Frequency Networks), several receiving zones within the overall coverage location are served by more than one transmitter, meaning that multiple transmitters must broadcast the same signal simultaneously over the network [6]. Hence, each transmission will most likely have an associated frequency offset. This leads to a very difficult scenario where there will be substantial variations on the equivalent channel which cannot be treated as simple phase variations.

Traditional broadcasting systems assign different frequency bands to each transmitter, within a given region, in order to prevent interference between transmitters. Frequencies used in a cell, will not be allocated in adjacent cells. As an alternative, SFN broadcasting systems [4], where several transmitters transmit the same signal simultaneously and over the same bands, can be employed. Since the distance between a given receiver and each transmitter can be substantially different, the overall channel impulse response can be very long, spanning over hundreds or even thousands of symbols in the case of broadband broadcasting systems, this can cause severe time-distortion effects within this type of single frequency systems. To deal with the severe distortion inherent to SFN, digital broadcasting standards such as DVB (Digital Video Broadcasting) [5] and DAB (Digital Audio Broadcasting) [5] use OFDM modulations which are known to be suitable for severely time-dispersive channels. In this paper consider OFDM-based broadcasting systems with SFN operation and it is proposed an efficient channel estimation method that takes advantage of the sparse nature of the equivalent CIR. For this purpose, low-power training sequences are employed within an iterative receiver which performs joint detection and channel estimation.

In recent standardization processes, OFDM has been chosen as cellular mobile communications system, namely orthogonal frequency division multiple access (OFDMA). In conjunction with space division multiple access (SDMA) techniques it is possible to assign time-frequency-space resources to users fairly flexibly. Separate base stations and mobile terminals have to suffer from inaccuracies in terms of synchronization mismatches in time and frequency. Timing offsets are caused by propagation delays through transmission channels, but not considered throughout this paper. Carrier frequency offsets (CFOs) occur due to different unsynchronized local oscillators at each mobile terminal in the network as well as Doppler shifts in relative movements to the base station respectively [7]. In cellular systems the different mobiles have to be frequency aligned to its serving base station such as in single frequency networks. One approach is to use downlink signals as reference to estimate and track the CFO in each terminal relatively to the base station. The rest of the paper is organized as follows, section II describes the system model, related works and SC-MC approaches are discussed in section III and IV. Comparisons between OFDM –SC FDE, Receiver structures are presented in section V and VI. Finally performance evaluations and conclusions are discussed in section VII and IIX.

II. System Model Description

The SFN transmission causes time dispersion mainly induced by two factors: the natural multipath propagation due to the reflected or refracted waves in the neighborhood of the receiver, and the unnatural multipath propagation effect due to the reception of the same signals from multiple transmitters, which are added being the resulting signal equivalent to consider a transmission over a single time-dispersive channel. These signals can be seen as "artificial echoes". The receiver's performance can be compromised, since the frequency selective fading may cause very low values of the instantaneous SNR at the receiver. OFDM has been used as the modulation technique in SFN in order to prevent multipath propagation. The data rate in DVB systems is very high, which means that the overall channel impulse response can span over hundreds or even thousands of symbols. This means that we need to employ very large FFT blocks (Fast Fourier Transform) to avoid significant degradation due to the cyclic prefix. The DVB standard considers up to 8k-length blocks, corresponding to several thousands of subcarriers. Coherent receivers are usually assumed in broadcasting system, which means that accurate channel estimates are required at the receiver [8,9]. The channel can be estimated with the help of pilots or training blocks [6]. The frequency selective fading can be mitigated by employing equalization and/or coding techniques.

Assume the frame structure depicted in Fig. 2, with a training bock followed by ND data blocks, each one corresponding to an "FFT block", with N subcarriers. Both the training and the data blocks are preceded by a cyclic prefix whose duration TCP is longer than the duration of the overall channel impulse response (including the channel effects and transmit and receive filters). The duration of the data blocks is TD, each one corresponding to a size-N DFT block, and the duration of the training blocks is TTS, which can be equal or smaller than TD. To simplify the implementation we will assume that TTS = TD=L where L is a power of 2, which means that the training sequence will be formally equivalent to have one pilot for each L subcarriers when the channel is static over. The overall frame duration is TF = (ND + 1)TCP + TTS + NDTD. If the channel is almost invariant within the frame, the training block can provide the channel frequency response for the subsequent ND data blocks. When can be afforded a delay of about half the frame duration than it becomes possible to use the training block to estimate the channel for the ND=2 blocks before and after the training, grossly duplicating the robustness to channel variations.

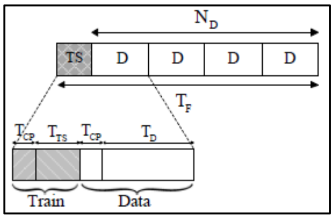


Fig. 1: Frame structure

III. Related Works

Over the decade several researchers have done different approaches for digital broadcasting systems for smooth transmission of data. Here we listed some of the contributions .S. Parkvall, et al, (2008) [2].in this paper they listed few components and their specifications in order to enhance the performance of the system. These are flexible in extended RF spectrum, solutions for placing multiple antennas, coordination between transmission/reception and they also gave idea about advanced repeaters for improving strength of the transmitted signal.

G. Okeke, W. A. Krzymie´n, et al, (1998), in this paper multiple users can communicate with multiple base stations through multiple antennas. For proper selection synchronization between base stations is required. The users can use some pre-coding and beam forming matrices at transmitter and receiver respectively. Receiver interference pre cancellation is adapted for both forward and back ward channels. They also proposed iterative alternative noise minimization algorithms to improve system transmission rate.

G. O. Okeke, Y. Jing, W. A. Krzymie´n, J. Melzer, et al, (2004),In this paper they design interference aware wireless system for mobile, personal and LAN communication networks .Simulation results shows that a significant increase in both channel capacity and transmission rate by combining the concepts of special diversity and optimum combining. They consider Rayleigh fading type of channel for evaluation of performance. Authors also shows that the gain performance of the system increases by increasing the multiple antennas at both transmit ion and reception with frequency reuse in every cell.

A. Shah, A. M. Haimovich, M. K. Simon, and M.-S. Alouini, et al, (2000), this paper derives mathematical modeling for the detection synchronous binary phase shift signals by considering at Rayleigh fading channels also give moment generating function based detection.

M. Chiani, M. Z. Win, A. Zanella, R. K. Mallik, and J. H. Winters, et al, (2003), in this paperthey investigates some approximate equations for probability of error for synchronous detection of array of symbols in presence of co channel interference and noise due to temperature for Rayleigh fading channel condition, in this system the complexity is depends on the number of antennas used and interference between two successive channels.D. A. Gore, R. W. Heath, Jr., and A. J. Paulraj, et al, (2002), in this letter they solved the problem of selection of antenna for zero forcing spatial multiplexing by knowing the statistics of channels at the transmitter. They also develop an algorithm for maximizing ergodic channel capacity and minimizing the average error probability.

M. K. Karakayali, G. J. Foschini, et al, (2006),In this article in order to provide high spectral efficiency they consider network coordination. If network coordination is employed in cellular system all base station antennas acts together as a single network antenna array, and each mobile may receive desired signals from nearby base stations antennas. The antennas responses are selected in such way that they minimize interference in inter cell regions. This leads to high efficiency in communication is possible.

IV. SINGLE CARRIER VS MULTIPLE CARRIER NETWORKS

A. Transmission Structure of MC

A MC system transmits a multicarrier modulated symbol (composed of N symbols on N subcarriers in time N=B). First, a serial to parallel conversion is implemented in order to de-multiplex the incoming high-speed serial stream and output several serial streams but of much lower speed. Subsequently, with resort to a constellation mapper, these parallel information bits are then modulated in the specified digital modulation format, each of the N modulated symbols is associated onto the respective subcarrier with resort to a bank of N sinusoidal oscillators, disposed in parallel, matched in frequency and phase to the N orthogonal frequencies (f0, f1------fN-1). Hence, each subcarrier is centered at Frequencies that are orthogonal to each other. Finally, the signals modulated onto the N subcarriers are summed forming the composite MC signal, which is then transmitted through the channel, as shown in Fig .2.

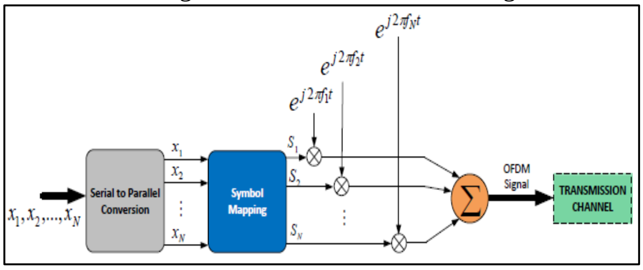


Fig. 2: Basic Multicarrier Transmission Structure

MC-modulation transmits a high speed serial stream at the input, over several streams of lower data rate[9]. As a consequence, the symbol period is extended, resulting in a significant advantage since the transmission becomes more resilient to the multipath environment. This is especially desirable in mobility scenarios, since it allows a reliable signal Reception within fast-varying channels.

B. Receiver Structure of MC

At the receiver, the received composite signal y (t) is correlated with the set of sub carriers in a sort of a matched filtering operation. The correlation of y (t) with the *l*th coherent subcarrier is a simple operation which can be expressed as

$$y(t)\left(e^{j2\pi f_l t}\right)^* = y(t)\left(e^{j2\pi l f_0 t}\right)^*$$

Where $f_o = \frac{B}{N}$ is the fundamental frequency. From the Fourier series definition it can be referred that other frequencies are in fact multiples of the fundamental frequency. When recovering the symbols, the time period of observation of the symbol corresponds to the time period of integration, which is mandatory to keep orthogonality, and it consists on the fundamental period $T_o = \frac{1}{f0} = \frac{N}{B}$.Let us consider no noise and no channel effects. Under these conditions, the received signal y(t) equals the transmitted signal s(t).

$$y(t) = s(t) = \sum_{k=0}^{N-1} S_k e^{j2\pi f_k t}$$

After correlating with the carrier signal symbol de mapping and finally parallel to serial conversion and then transmitted signal decoded. Fig shows the receiving structure for MC modulation.

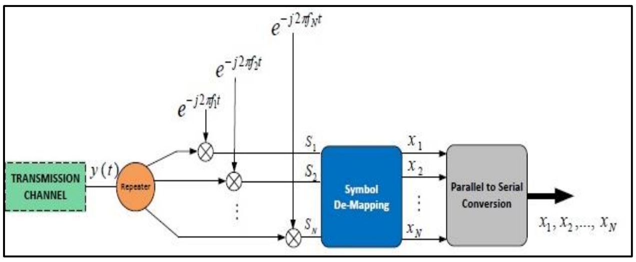


Fig. 3: Basic Multicarrier Receiver Structure

In a conventional single carrier modulation, the energy of each symbol is distributed over the total transmission band. The term single carrier implies a unique carrier which occupies the entire communication bandwidth B, and the transmission is performed at a high symbol rate [10]. We may think that when compared to the SC modulation, the MC modulation is just an extremely complicated system without advantage over a SC system (since both schemes have an overall data rate of B symbols per second). So, if from the symbol rate perspective, the MC system and the SC system are equivalent, what advantages does the much more complex MC system has to offer? In order to better understand the fundamental advantage of MC modulations, consider a scenario in which the available bandwidth for transmission is B=1024 kHz. A SC system will use the complete bandwidth of 1024 kHz, much greater than the coherence bandwidth of the channel which is assumed to be approximately 200 to 300 KHz. In this conditions, since the bandwidth is much greater than the coherence bandwidth, the channel is said to be frequency selective (different frequency components of the signal experience different fading), which implies ISI in the time domain. Therefore, a high bit rate SC digital signal experiences frequency selective fading and ISI occurs, which may result in significant distortion since the symbols interfere with each other, highly distorting the received signal and affecting the reliable detection of the symbols.

V. Comparative Analysis between OFDM and SC-FDE

OFDM was initially proposed by R. Chang, in the year of 1966, His work presented an approach for multiple transmission of signals over a band-limited channel, free of ISI. By dividing the frequency selective channel in several frequency narrowband channels, the smaller individual channels would be subjected to flat fading. One drawback of the OFDM modulation is the high envelope fluctuations of transmitted signal. Consequently, these signals are more susceptible to nonlinear distortion effects namely those associated to a nonlinear amplification at the transmitter, resulting in a low power efficiency. This major constraint is even worse in the uplink since more expensive amplifiers and higher power back-off are required at the mobile. Instead, when a SC modulation is employed with the same constellation symbols, the envelope fluctuations of the transmitted signal will be much lower [11-13]. Thus, SC modulations are especially adequate for the uplink transmission (i.e., transmission from the mobile terminal to the base station), allowing cheaper user terminals with more efficient high-power amplifiers. Nevertheless, if conventional SC modulations are employed in digital communications systems requiring transmission bit rates of Mbits/s, over severely time-dispersive channels, high signal distortion levels can arise. Therefore, the transmission bandwidth becomes much higher than the channel's coherence bandwidth. As consequence, high complexity receivers will be required to overcome this problem. In order to compare OFDM and SC-FDE, refer to the transmission chains of both modulation systems, depicted in Fig.4. Clearly, the transmission chains for OFDM and SC-FDE are essentially the same, except in the place where is performed the IFFT operation. In the OFDM, the IFFT is placed at the transmitter side to divide the data in different parallel subcarriers. For the SC-FDE, the IFFT is placed in the receiver to convert into the time-domain the symbols at the FDE output. Although the lower complexity of the SC-FDE transmitter (it does not need the IDFT block), it requires a more complex receiver than OFDM. Consequently, from the point of view of overall processing complexity (evaluated in terms of the number of DFT/IDFT blocks), both schemes are equivalent [18]. Moreover, for the same equalization effort, SC-FDE schemes have better un-coded performance and lower envelope fluctuations than OFDM. Without channel coding, the performance of the OFDM is very close to SC-FDE with ZF equalization.

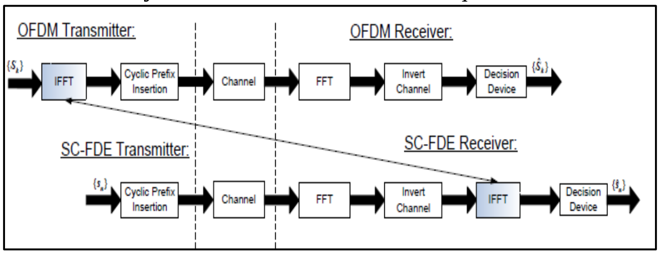
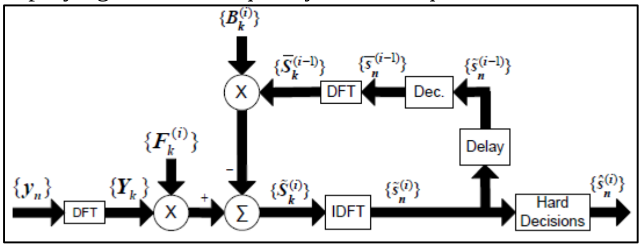


Fig. 4: Block diagram representation of OFDM and SC-FDE

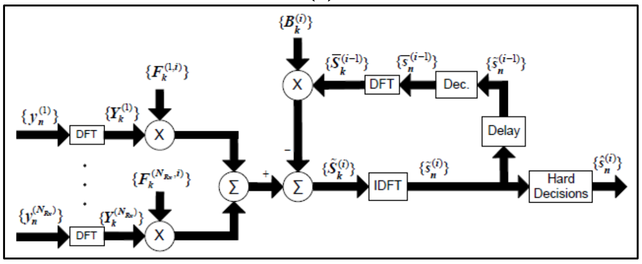
Moreover, SC-FDE has better un-coded performance under the same conditions of average power and complexity demands [19]. It should be noted that these results cannot be interpreted as if OFDM has poor performance, since the OFDM is severely affected by deep-faded subcarriers. Therefore, when combined with error correction codes, OFDM has a higher gain code when compared with SC-FDE [19]. Moreover OFDM symbols are affected by strong envelope fluctuations and excessive PMEPR (Peak to-Mean Envelope Power Ratio) which causes difficulties related to power amplification and requires the use of linear amplification at the transmitter. On the other hand, the lower envelope fluctuation of SC signals allows a more efficient amplification. This is a very important aspect for the uplink transmission, where it is desirable to have low-cost and low-consumption power amplifiers [16]. For downlink transmission, since that the implementation complexity is gathered at the base stations where the costs and high power consumption are not major constraints, the OFDM schemes are a good option. Considering that both schemes are compatible, it is possible to have a dual-mode system where the user terminal employs an SC-FDE transmitter and a OFDM receiver, while the base station employs an OFDM transmitter and an SC-FDE receiver. Obviously, from Fig. It becomes clear that this approach allows very low complexity mobile terminals the simpler SC transmissions and MC reception schemes.

A. *Decision Based Equalizer Iterative Receiver Structure*

Typically, the receiver for SC-FDE schemes is a linear FDE, however, it is well-known that nonlinear equalizers outperform linear ones. Among nonlinear equalizers the Decision Feedback Equalizer (DFE), is a popular choice since it provides a good tradeoff between complexity and performance [17]. Clearly, the previously described SC-FDE receiver is a linear FDE. Therefore, it would be desirable to design nonlinear FDEs, namely a DFE FDE. An efficient way of doing this is by replacing the linear FDE by an Iterative Block-Decision Feedback Equalizer (IB-DFE). IB-DFE is a promising iterative FDE technique, for SC-FDE. The IB-DFE receiver can be envisaged as an iterative FDE receiver where the feedforward and the feedback operations are implemented in the frequency domain. Due to the iteration process it tends to offer higher performance than non-iterative receiver. These receivers can be regarded as low complexity turbo FDE schemes where the channel decoder is not involved in the feedback[20]. True turbo FDE schemes can also be designed based on the IB-DFE concept. In this section, we present a detailed study on schemes employing iterative frequency domain equalization.



(a)



(b)

Fig. 5: IB-DFE Receiver structures (a) Without diversity (b) with spatial diversity

After the first iteration, the feedback coefficients can be applied to reduce a major part of the residual interference. After several iterations and for a moderate – to –high SNR, the correlation coefficient will be unity and the residual ISI will almost zero.

VI. CARRIER OFFSET MINIMIZATION

Frequency errors in OFDM schemes lead to ICI [8], and in order to mitigate this problem, two estimation techniques were proposed in [8] and [9]. An efficient equalization technique was also proposed in [10].The impact of CFO errors is serious in SFN broadcasting systems because there can be a different CFO between the local oscillator at each transmitter and the local oscillator at the receiver, which means that even in static channels we can have variations on the equivalent channel frequency response that are not simple phase rotations (which can be easily estimated and canceled at the receiver), and for this reason conventional CFO estimation techniques such as the ones of [11]–[13] are not appropriate for estimating the different CFOs inherent to SFN scenarios. Efficient channel estimation techniques are crucial to achieve reliable communication in wireless communication systems, and several techniques for ensuring accurate channel estimates have already been proposed ([12], [14], [15]). The efficiency of the conventional estimation techniques can eventually be enhanced with resort to the method proposed in [13], offering a good trade-off between the estimation performance and the computational complexity. It is important to note that the SFN transmission creates severe artificial multipath propagation conditions. In order to mitigate its effects SFN systems employ a large number of OFDM subcarriers, to ensure that the guard interval is large enough to cope with the maximum delay spread that can be handled by receivers. Albeit the system is defined to accommodate the worst case scenario (which is given by the maximum delay spread), it also may represent a waste of bandwidth and excess of redundant information, in most cases. In [16], the channel length estimation problem is studied and the authors propose an autocorrelation-based algorithm to estimate the channel length without the need of pilots or training sequences. In order to improve spectral efficiency in the channel estimation, various methods that take advantage of the sparse nature of the equivalent CIR are presented. In [17] [18] are employed blind receivers, which although does not need training sequences, it may lead to performance degradation.

A. Frame Structure

The different CIRs and CFOs can be obtained by employing the frame structure of Fig 6. (this structure allows to track the evolution of the equivalent CIR along the frame, and it employs training sequences with the objective of knowing the CIR for each transmitter, as well as the corresponding CFO). We start by admitting that the transmission of the training sequences is based on a scheduling scheme: each transmitter sends its training sequence TS, and then remains idle during the rest of the time slots reserved for training sequences transmission [20]. Each training sequence includes a cyclic prefix whose duration TCP is longer than the duration of the overall channel impulse response (including the channel effects and the transmit and receive filters). The cyclic prefix is followed by M (sub) blocks of size NT and duration TT, which are appropriate for channel estimation purposes (e.g., based on Chu sequences or similar. The overall training sequence duration is TTS = TCP +MTT.

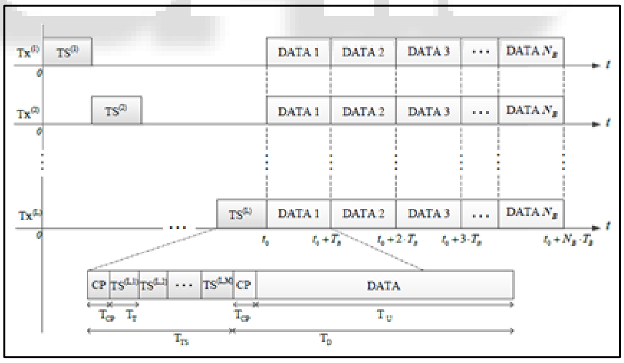


Fig. 6: OFDM Frame structure

One may think that a weakness of the proposed frame structure lies on a very long size when there are many transmitters, which causes inefficiency since large portion of the training sequences remains idle. However, it is important to point out that although the length of the training increases with the number of transmitters (and a portion of the training remains idle for each transmitter), the inefficiency is not significant for the following reasons:

1) The number of relevant transmitters covering a given area is in general small (typically L = 2 or L = 3).
2) The frame associated to a given training interval can be very long, provided that there are accurate CFO estimates and the oscillators are reasonably stable. It is possible to have frames with several tens of data blocks.

3) The training block associated to each transmitter can have duration much lower than data blocks. Therefore, the efficiency can be very high.

VII. RECEIVER STRUCTURES

In the following section, three frequency domain receivers are proposed for a non-synchronized SFN broadcasting system. For the sake of simplicity, a SFN transmission with two synchronous transmitters will be considered, in which each transmitter is affected by a different CFO and the number of relevant transmitters covering a given area is generally small, typically L = 2 or L = 3. This, however, can be easily extended to a larger network, with more unsynchronized transmitters.

A. Method 1

This receiver is entirely based on the IB-DFE. However it uses the initial CIR and CFO estimates provided by training sequences to estimate the equivalent channel, and updates the phase rotation for each data block of the frame. Nevertheless, this method does not performs CFO compensation, and it also assumes a constant equivalent channel within each block.

B. Method 2

In this method the receiver structure and requires a small modification to the IB-DFE. It is developed from method I, where after the phase update is performed the compensation of the average phase rotation, associated to the average CFO over the different transmitters. Instead of using the average phase rotation, a simple method based on the phase rotation associated to the strongest channel could be employed. However, since a different phase rotation is associated to each channel, an average phase compensation is more appropriate.

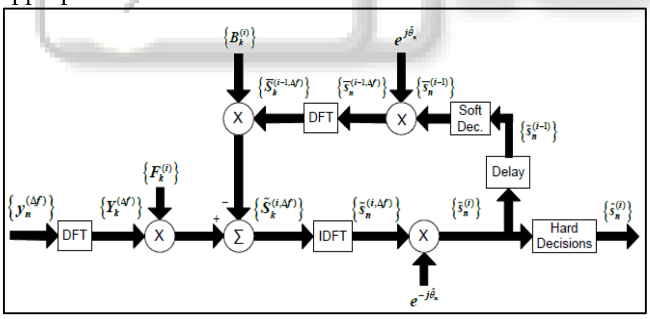


Fig. 7(a): Receiver structure with small modification of method-2

The CFO compensation technique is based on a weighted average, in order to combine average values from samples corresponding to the CFOs associated to the different transmitters.

C. Method 3

It is important to note that Method II works well when the dispersion on the CFOs is not high. However, it is not efficient in the presence of substantially different CFOs. In Method III, a receiver that tries to jointly compensate the frequency offset associated to each transmitter and equalize the received signal, is proposed. The objective is to use the data estimates from the previous iteration to obtain an estimate of the signal components associated to each transmitter, and posteriorly compensate the corresponding CFO. It is worth mentioning that for the first iteration the process is very straightforward, since there are no data estimates, and therefore, for the first iteration this receiver is reduced to a simpler version close to the one of Method II.

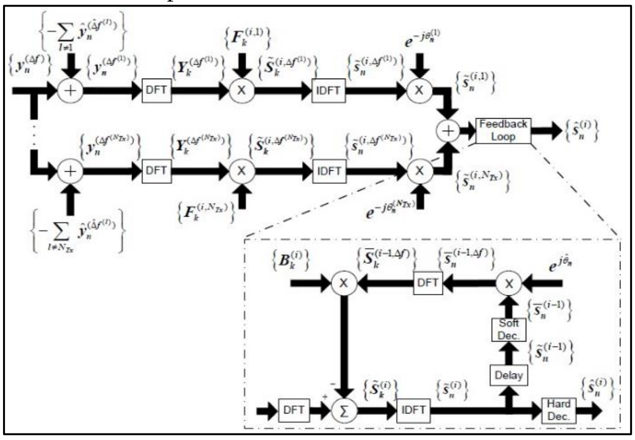


Fig. 7(b): Receiver structure for method-III with feedback network.

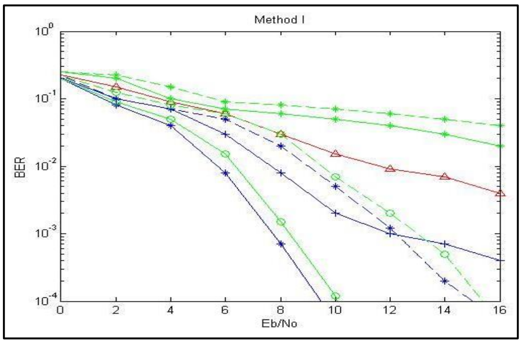
Feedback network shown here for further information this is only apply to the subsequent iterations. The set of operations described next are performed for all NTx signals within each iteration. In terms of complexity, Method I and Method II have almost the same complexity as conventional receivers. However, Method III is slightly more complex since in each iteration it requires an additional FFT/IFFT pair for each branch (i.e., the number of FFT/IFFT pairs is proportional to L).

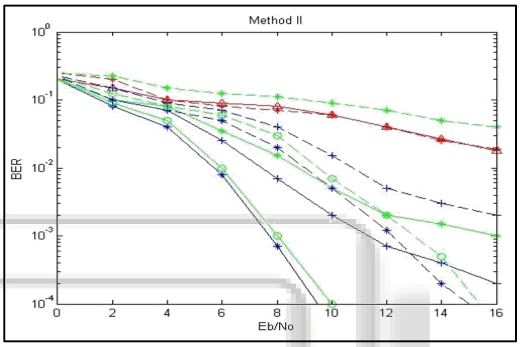
VIII. PERFORMANCE EVALUATION

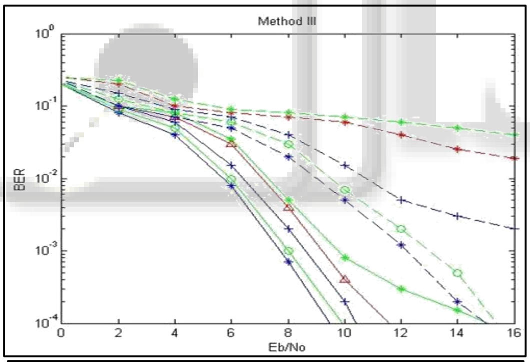
A set of performance results concerning the proposed frequency offset compensation methods for single frequency broadcast systems are presented next. It is assumed that identical signals emitted from different transmitters will arrive at the receiver with different delays, and will have different CIRs. Moreover, different CFOs between the local oscillator at each transmitter and the local oscillator at the receiver, are considered. At the receiver's antenna, the signals are added being the result similar to a transmission over a single strong time-dispersive channel.

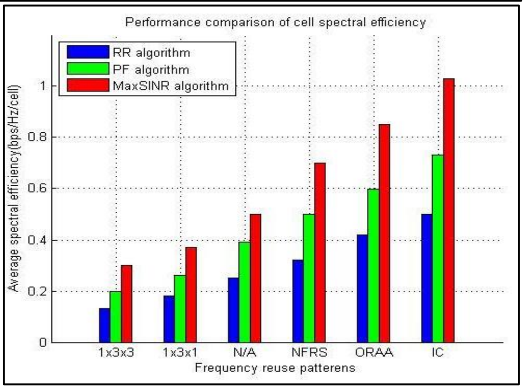
The chosen modulation relies on a SC-FDE scheme with blocks of N = 4096 subcarriers and a cyclic prefix of 512 symbols acquired from each block, although similar results were observed for other values of N, provided that N >> 1. The modulation symbols belong to a QPSK constellation and are selected from the transmitted data according to a Gray mapping rule. For the sake of simplicity, it was assumed linear power amplification at the transmitter. In general the performance is Different for different blocks, since the residual phase rotation on the signal associated to each transmitter increases as we move away from the training sequence or pilots (as the number of (sub) blocks increases).

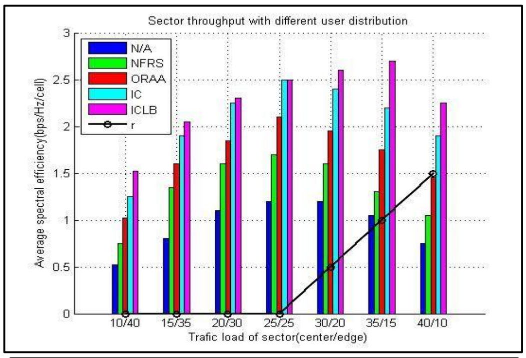
Below figure present the BER performance results for different values of Δf(1)-Δf(2), namely from 0:05 to 0:175, for BER=10□3. These results consider a difference of 10 dBs between the powers of the received signals from both transmitters. For comparison purposes, were also included the results regarding the scenario in which the transmitters are not affected by CFO (i.e., Δf(1) = 0 and Δf(2) = 0). From the above performance results, it is clear that the transmission with non-synchronized transmitters can lead to significant performance degradation, particularly for Method I, were can be observed a very high deterioration of the BER performance with increasing values of Δf(1) - Δf(2). The reason for this, is that this method does not performs a CFO compensation, it only updates the phase rotation for the channel associated to each transmitter, for each block.











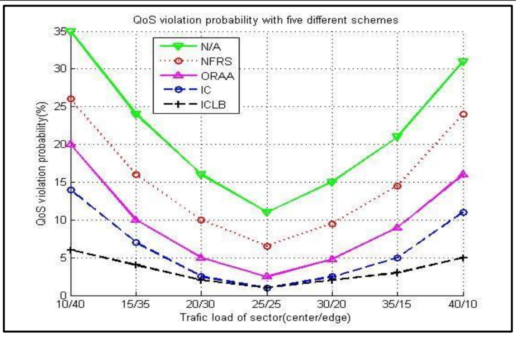


Fig. 8: (a, b, c) simulation results BER vs Energy to noise ratio for Methd-1, Method-2 and Method-3. (d, e, f) Comparisons of spectral efficiency vs traffic load of different algorithms.

The curves obtained with resort to Method II show very reasonable results, since together with the IB-DFE iterations, this method performs the compensation of the average phase rotation (associated to the average CFO over the different transmitters). However, for high values of Δf(1) -Δf(2) (typically = 0:15), it also indicates a significant degradation.

IX. CONCLUSION AND FUTURE SCOPE

The performance results are expressed as function of Eb=N0, where N0 is the one-sided power spectral density of the noise and Eb is the energy of the transmitted bits. Without loss of generality, it is considered a SFN transmission with two transmitters with different CFOs, where Δf(1) and Δf(2) denotes the CFOs associated to the first and second transmitter, respectively. Another important parameter to be considered is the number M of (sub) blocks following the cyclic prefix.

REFERENCES

[1] Fábio José Pinto da Silva, “Frequency-Domain Receiver Design for Doubly-Selective Channels”,

[2] F´abio Silva, Rui Dinis, and Paulo Montezuma, “Channel Estimation and Equalization for Asynchronous Single Frequency Networks”, IEEE Transactions in Broad Casting, Vol. 60, No. 1, March 2014

[3] R. Dinis, C.-T. Lam, and D. Falconer, “Joint frequency-domain equalization and channel estimation using superimposed pilots”, in Wireless Communications and Networking Conference, 2008. WCNC 2008. IEEE, 2008, pp. 447–452.

[4] A. Mattsson, “Single frequency networks in DTV”, Transactions on Broadcasting, vol.51, no. 4, pp. 413–422, 2005.

[5] U. Reimers, "The DVB project-digital television for Europe", IEE Colloquium on DVB (Digital Video Broadcasting): The Future for Television Broadcasting, vol. 33, pp. 1–7, 1995.
[6] F. Silva, R. Dinis, and P. Montezuma, "Joint detection and channel estimation for block transmission schemes", Military Communications Conference (MILCOM), pp. 1765–1770, 2010.
[7] Hyung G. Myung "Introduction to single carrier FDMA" 15th European Signal Processing Conference (EUSIPCO 2007), Poznan, Poland, September 3-7, 2007.PP 2144-2148.
[8] N. Benvenuto, R. Dinis, D. Falconer, and S. Tomasin, "Single carrier modulation with Nonlinear frequency domain equalization: an idea whose time has come—again," Proceedings ofIEEE, vol. 98, no. 1, pp. 69–96, 2010.
[9] Fabio Silva, Rui Dinis, and Paulo Montezuma "Channel Estimation and Equalization for Asynchronous Single Frequency Networks" IEEE TRANSACTIONS ON BROADCASTING, VOL. 60, NO. 1, MARCH 2014.PP 110- 119.
[10] A. Mattsson, "Single frequency networks in DTV," IEEE Trans. Broadcast.,vol. 51, no. 4, pp. 413–422, Dec. 2005.
[11] R. Dinis, T. Ara´ujo, P. Pedrosa, and F. Nunes, "Joint turbo equalization and carrier synchronisation for SC-FDE schemes," *Eur. Trans. Telecom.*, vol. 21, no. 2, pp. 131–141, Feb. 2010.
[12] V. Dalakas, P. Mathiopoulos, F. Cecca, and G. Gallinaro, "A comparative study between SC-FDMA and OFDMA schemes for satellite uplinks,"*IEEE Trans. Broadcast.*, vol. 58, no. 3, pp. 370–378, Sep. 2012.
[13] X. Wang, Y. Wu, G. Gagnon, B. Tian, K. Yi, and J. Chouinard, "A hybrid domain block equalizer for single-carrier modulated systems," IEEE Trans. Broadcast., vol. 54, no. 1, pp. 91–99, Mar. 2008.
[14] N. Benvenuto and S. Tomasin, "On the comparison between OFDM and single carrier with DFE using a frequency domain feedforward filter,"*IEEE Trans. Commun.*, vol. 50, no. 6, pp. 947–955, Jun. 2002.
[15] N. Benvenuto, R. Dinis, D. Falconer, and S. Tomasin, "Single carrier modulation with non linear frequency domain equalization: An idea Whose time has come again," *Proc. IEEE*, vol. 98, no. 1, pp. 69–96, Jan. 2010.
[16] T. Jiang, H.-H. Chen, H.-C. Wu, and Y. Yi, "Channel Modeling and Inter-Carrier Interference Analysis for Vehicle-to-Vehicle Communication Systems in Frequency-Dispersive Channels", Mobile Networks and Applications, vol. 15, no. 1, pp. 4–12, 2010.
[17] M. Sabbaghian and D. Falconer, "Joint Turbo Frequency Domain Equalization and Carrier Synchronization", IEEE Transactions on Communications, vol. 7, no. 11, pp. 204–212, 2008.
[18] T. Araújo and R. Dinis, "Iterative Equalization and Carrier Synchronization for Single-Carrier Transmission over Severe Time-Dispersive Channels", IEEE GLOBECOM' 04, pp. 204–212, 2004.
[19] R. Dinis, T. Araújo, P. Pedrosa, and F. Nunes, "Joint turbo equalisation and carrier synchronisation for SC-FDE schemes", European Trans. on Telecom. vol. 21, no. 2,pp. 131–141, 2010.
[20] B. Ng and D. Falconer, "A Novel Frequency Domain Equalization Method for Single-Carrier Wireless Transmissions over Doubly-Selective Fading Channels", IEEE GLOBECOM'04, 2004.

