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FADING MINIMIZATION WITH OFDM TECHNIQUES AND MAXIMUM LIKELIHOOD FUNCTION

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Wireless communications [1]-[4] is a rapidly growing piece of the communications manufacturing, which provides high-speed high-quality information exchange between the portable devices located anywhere in the world. The estimation of the Carrier Frequency Offset (CFO) is a classical problem, and it can be estimated via data added or non-blind algorithms, semi blind algorithms, and non-data added or blind algorithms. This research paper mainly concentrates on Maximum Likelihood Carrier Frequency Offset (ML CFO) blind estimation algorithms based on data symbol repetition for OFDM systems.

Keywords *- CFO, CP, De-Modulation, IFI, ISI, Modulation, OFDM*

INTRODUCTION

As technology and system requirements in field of computer science and telecommunications are changing very fast. Over the previous years, since the transition from analog to digital communications, and from wired to wireless, different standards and solutions have been adopted, developed, implemented and modified, often to deal with new and different business requirements. OFDM (Orthogonal Frequency Division Multiplexing) has been shown to be an effective technique to combat multipath fading in wireless communications. OFDM is a modulation scheme that allows digital data to be efficiently and reliably transmitted over a radio channel, even in multipath medium. It transmits data by using a large number of narrow bandwidth carriers with regularly spaced in frequency, forming a block of spectrum. The separation of the subcarriers is such that there is a very compact spectral utilization. Using OFDM, it is possible to have overlapping sub channels in the frequency domain, therefore increasing the transmission rate. OFDM makes possible to use Maximum Likelihood (ML) decoding with reasonable complexity. OFDM is computationally efficient with FFT techniques.

ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

As wireless communication evolves towards broadband systems to support high data rate applications, therefore a technology is needed that can efficiently handle frequency selective fading. The widely used solution to this context is OFDM system. The key idea of OFDM is to divide the whole transmission band into a number of parallel subchannels (also called subcarriers) so that each subchannel is a flat fading channel [11]-[13]. In this case, channel equalization can be performed in all subchannels in parallel using simple one-tap equalizers.

OFDM Merits/Demerits

The OFDM is a promising transmission scheme, which has been considered extensively, as it has the following key advantages [5]-[13]:

- OFDM makes efficient use of the spectrum.
- OFDM becomes more resistant to frequency selective fading than single carrier systems by converting the frequency selective fading channel into narrowband flat fading sub-channels.
- OFDM eliminates Inter Symbol Interference (ISI) and Inter Frame Interference (IFI) through use of a Cyclic Prefix (CP).
- OFDM recovers the symbols lost due to the frequency selectivity of the channel by using adequate channel coding and interleaving.
- OFDM makes channel equalization simpler than single carrier systems by using adaptive equalization techniques.
- OFDM seems to be less sensitive to sample timing offsets in comparison with single carrier systems.
- OFDM provides good protection against co-channel interference and impulsive parasitic noise.
- OFDM makes it possible to use Maximum Likelihood (ML) decoding with reasonable complexity. OFDM is computationally efficient with FFT techniques.
- The several advantages of the OFDM systems could only appear if the main three drawbacks were treated carefully. OFDM has the following negative aspect:
- OFDM signal has a noise like amplitude with a very large dynamic range; so, it requires RF power amplifiers with a high peak to average power ratio, which may require a large amplifier power back off and a large number of bits in the Analog to Digital (A/D) and Digital to Analog (D/A) designs.
- OFDM is very sensitive to Carrier Frequency Offset (CFO) caused by Doppler Effect. Hence, CFO should be estimated and cancelled completely.
- It is difficult to make an estimate the starting time of the FFT symbol in OFDM receiver.

LITERATURE SURVEY

OFDM is a great technique to handle impairments of wireless communication channels such as multipath propagation. Hence, OFDM is a practical candidate for future 4G wireless communications techniques [1]-[4]. On the other hand, one of the major drawbacks of the OFDM communication system is the drift in reference carrier. The offset present in received carrier will lose orthogonality among the carriers. Hence, the CFO causes a reduction of desired signal amplitude in the output decision variable and introduces ICI. Then it brings up an increase of BER. The effect caused by CFO for OFDM system was analyzed in [7]-[9]. In [7] BER upper bound of OFDM system is analyzed without ICI self-cancellation and BER of OFDM system is analyzed using self-cancellation, but this method is less accurate. In [9], it is indicated that CFO should be less than 2% of the bandwidth of the sub-channel to guarantee the signal to interference ratio to be higher than 30 dB. A critically sampled OFDM system/OQAM system is also not robust to CFO [9], even when optimal pulses are used as shaping filters. Thus, carrier frequency offset greatly degrades system performance. Therefore, practical OFDM systems need the CFO to be compensated with sufficient accuracy, and this has led to a whole lot of literature on CFO estimation algorithms. Most of the existing CFO estimators for OFDM are based on periodically transmitted pilot symbols. Yet, the pilot symbols transmission loses a significant bandwidth, especially in the case of continuous transmissions. Therefore, pilot-based schemes are mainly suited for packet oriented applications.

Semi blind approaches proposed in the literature are the first step to improve the bandwidth efficiency [20] based on various assumptions e.g. usage of a single pilot symbol, 2 identical consecutive OFDM data blocks, or some specific structure within the OFDM symbol.

Recently, blind, or non-data aided have received extensive attention, as the bandwidth will be kept for real data. Among different classes of blind methods, subspace based methods [18]-[20] are the famous category which were lately shown to be equivalent to ML estimator [19]. Those methods depends on the low rank signal model induced by either some unmodulated carriers or virtual carriers (VC) at the edges of OFDM block, which aim at minimizing the interference caused to adjacent OFDM systems. While OFDM systems are suited by design to multipath transmission, many existing CFO estimators deal only with frequency flat channels. Extension of ML methods to multipath Rayleigh fading channels may be found in [21]. More recently, non-circularity introduced by real-valued modulations was exploited in [22]. In [23] a blind CFO estimation algorithm has been derived by exploiting the conjugate second-order cyclostationarity of the received OFDM signal in the case of non-circular transmission. In [24] this method, designed for standard OFDM systems, has been extended and analyzed in the context of OFDM/OQAM transmissions. On the other hand, the derived estimator assures adequate performance only when a large number of OFDM symbols are considered. In [25] a blind joint CFO and symbol timing estimator based on the unconjugated cyclostationarity property of the OFDM/OQAM signal has been derived. Constant modulus (CM) constellations allow highly accurate CFO estimation [26].

In the blind CFO Estimator the used subchannels will be totally used to transmit real data and the CP will not be extended by any extra guard intervals. The blind estimators are considered as a bandwidth efficient ones. The blind estimators of the CFO in the OFDM system can be built basically based on the structure of the OFDM frame or its components: Blind CFO estimators based on the used carriers, VC based blind CFO estimators, and the CP based blind CFO estimators. In the following subsections different blind estimators based on used carries are introduced.

PROPOSED ALGORITHM

Transmitter Side:

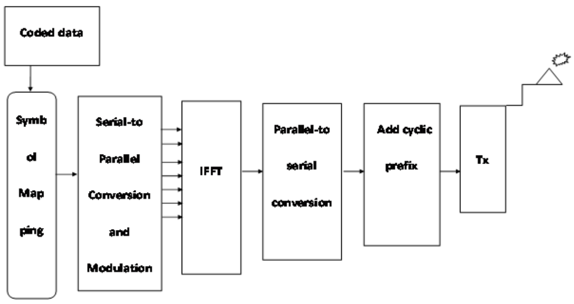

Figure 1: Flowchart of Proposed Method at Transmitter Side

Step 1: Coded Data Generator

The input signal which we used is the **Coded** data generated.

Step 2: Symbol Mapping

The symbol mapping is Serial to parallel Conversion and mapping into frequency domain components after modulation.

Step 2: Serial to Parallel Conversion

The input serial data stream is applied to a serial to parallel converter and shifted into a parallel format. By assigning each data word to one carrier in the transmission, the data is then transmitted in parallel

Step 3: Modulation of Data

The data to be transmitted on each carrier is modulated into a PSK format. The data on each symbol is thus mapped. In the simulations we used BPSK and QPSK type digital modulation.

Step 4: Inverse Fast Fourier Transform

After the required spectrum is worked out, an inverse Fourier transform is used to find the corresponding time domain waveform.

Step 5: Add cyclic prefix

The guard period is then added to the start of each symbol .The length of the guard interval should be at least more than the multipath delay spread of the fading channel.

Step 6: Transmitter

The transmitter basically performs sending operation to the receiver. The serial to parallel converter serially transmitted data is converted to parallel form and add some prefix original data. The IFFT of each symbol is then coded the original transmitted spectrum. The OFDM symbols are then subjected to modulation by using a bank of sub-carriers as those used in the transmitter.

Receiver Side:

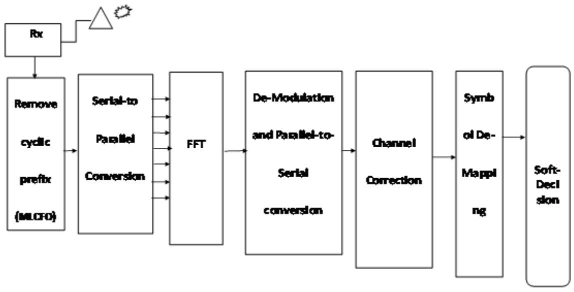

Figure 2: Flowchart of Proposed Method at Receiver Side

Step1: Receiver: The receiver basically does the reverse operation to the transmitter. The serially received data is converted to parallel form and then guard period is removed. The FFT of each symbol is then taken to find the original transmitted spectrum. The OFDM symbols are then subjected to demodulation by using a bank of sub-carriers as those used in the transmitter. The words are combined back to produce the original data stream.

Step 2: Remove cyclic prefix : The guard period is then added to the start of each symbol .The length of the guard interval should be at least more than the multipath delay spread of the fading channel.

Step3: Channel Model Used: The channels are some improvement in the performance of OFDM systems using MLCFO improves the bandwidth of system, reduce time complexity.

Step 4: Serial to Parallel Conversion

The input serial data stream is applied to a serial to parallel converter and shifted into a parallel format. The data is then transmitted in parallel by assigning each data word to one carrier in the transmission.

Step 5: Fast Fourier Transform: After the required spectrum is worked out, an inverse Fourier transform is used to find the corresponding time domain waveform. Or The FFT of each OFDM symbol is performed to find the original transmitted spectrum.

Step 6: De-Modulation of Data: The data to be transmitted on each carrier is modulated into a PSK format. The data on each symbol is thus mapped. In the simulations we used BPSK and QPSK type digital modulation.

Step7: Parallel to Serial Converter: The parallel data is converted to the serial form to be passed through the channel.

Step 8: Symbol De-Mapping: For each transmission carrier, the phase angle is then evaluated and converted back to the word by demodulating the received phase (demapping).

Step 8: Soft Data: The output signal which we used is the soft data.

SIMULATION RESULTS AND COMPARISON

Extensive computer simulations are done to validate our proposed Modified ML method. Monte Carlo simulations are conducted to evaluate the performance of the modified estimator. The performance of modified method is compared with three methods; first one is cyclic prefix based CFO estimation [19] which will be denoted by CPB estimation, second technique we used to compare is also a cyclic prefix based CFO estimation [32] but this is much the better than the technique given in [19]. Notation used for this technique is Mod-CPB, which is based on modified cyclic prefix. Third technique used for comparison is CFO estimation based on symbol repetition [18] and notation used for this technique is SR (Symbol Repetition) method. Our modified technique is also based on symbol repetition ML estimation technique but different from the technique given in [18]. Notation used for Modified ML technique is Prop-SR. The estimator performance is evaluated by using normalized mean square error (MSE) and is given by

$$MSE = \frac{1}{P}\sum_{P=1}^{P}\frac{|\hat{\in} - \in|^2}{(2\pi / N)^2}$$

Where $\hat{\in}$ the estimated CFO and P are is the number of Monte Carlo runs.

Performance of Modified Method is Compared Cyclic Prefix Based CFO Estimation

Fig.3 and *fig 4* Plots the normalized CFO MSE of the modified method as a function of SNR in dB over the dispersive channel. Channel is assumed to be constant over entire observation window i.e. for 20 OFDM symbols.

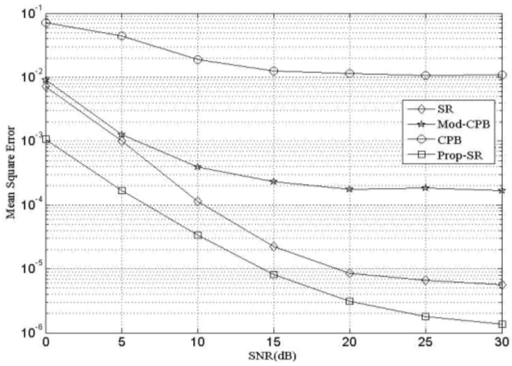

Figure 3: MSEs of the CFO of the proposed estimator, under M=20 as a function of SNR over dispersive channel 1

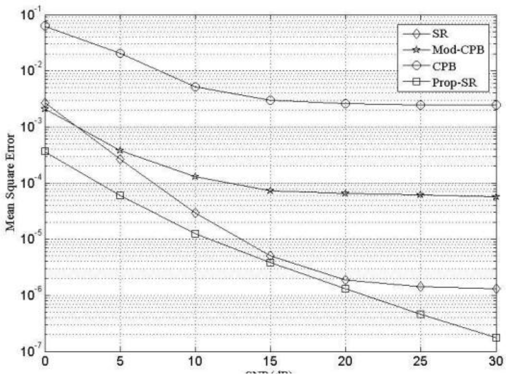

Figure 4: MSEs of the CFO of the proposed estimator, under M=20 as a function of SNR over dispersive channel 2

Following are the parameters used in simulation:

- Total No. of subcarriers = 64
- Normalized Freq. offset = 0.01
- Number of symbols used for estimation = 20
- Number of Monte Carlo runs = 1000

- Dispersive channel 1 with channel-tap powers = [0.0849 0.0011 0.1670 0.0402 0.0070 0.0112 0.2333 0.0000 0.1079 0.0005 0.1294 0.0004 0.0399 0.1484 0.0027 0.0001 0.0261]
- Dispersive channel 2 with channel-tap powers = [0.1462 0.0045 0.1815 0.15530 0.0125 0.4142 0.0789 0.0000 0.0070];

Fig.3 and *fig.4* shows that modified SR technique Prop-SR is optimum.

Performance of Modified Method is Prop-SR Technique for CFO Estimation

The performance of Mod-CPB diverges from that of SR at SNR = 5dB. When the channel is dispersive, the performance of the CPB becomes much worse than the Prop-SR method. As channel length decreases performance of Prop-SR method becomes better. Prop-SR technique gives around 4dB better performance than SR technique. This is because modified SR technique performs estimation in time-domain whereas SR technique performs estimation in frequency domain i.e. after DFT operation. And also as angle operation is done after averaging in proposed technique, the disturbances caused by variation in correlation can be averaged out.

CFO estimation range of SR technique is limited to 25% of the subcarriers spacing, whereas Prop-SR technique is able to estimate the CFO of around 50% of subcarriers spacing. The performance of SR and Prop-SR technique for CFO 25% and 45% of the subcarrier spacing. Figure shows that at 0.45 CFO the performance of SR method becomes worse, while the performance of Prop-SR method is approximately same for 0.25 and 0.45 CFO. Number of subcarriers used are 64 and channel is taken as dispersive channel.

In *fig.3*, *fig.4*, and *fig.5* we have assumed that Carrier Frequency Offset is constant over all OFDM symbols.

The performance of methods considering CFO as a uniformly distributed random variable lies in the range [-0.4, 0.4], i.e. lies within 40% of the subcarrier spacing.

Prop-SR technique performs best in this condition, whereas SR technique shows much more variations in its performance. This is because SR technique performs well only when CFO lies within 30% of subcarrier spacing, whereas Prop-SR method gives good performance up to 50 % of subcarrier spacing. This is due to the averaging which we have applied in Prop-SR technique which nullifies the effects of variations in correlation.

Fig. 6 also shows that Prop-SR technique also outperforms the other two CPB and Mod-CPB techniques.

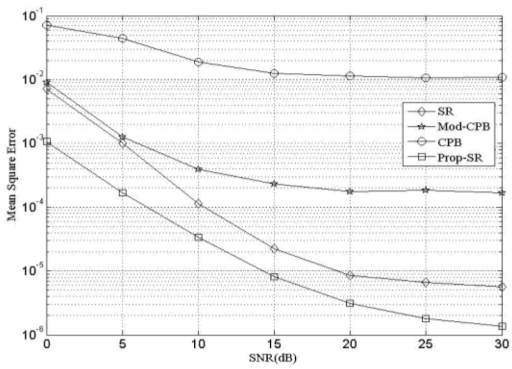

Figure 3: MSEs of the CFO of the proposed estimator, under M=20 as a function of SNR over dispersive channel 1

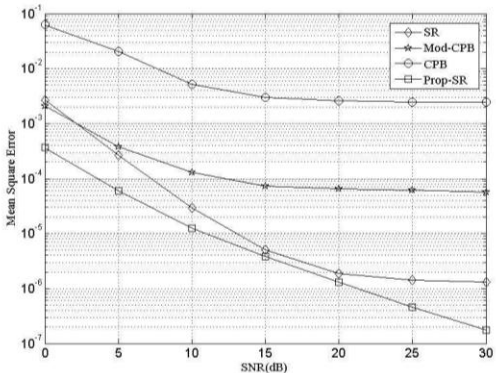

Figure 4: MSEs of the CFO of the proposed estimator, under M=20 as a function of SNR over dispersive channel 2

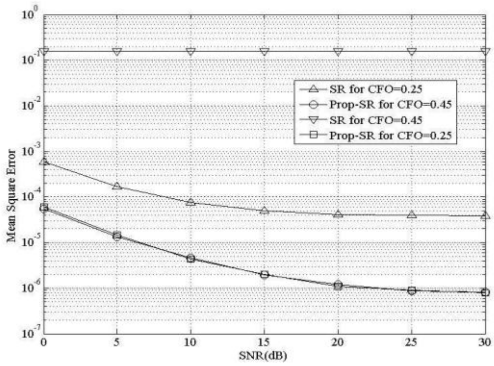

Figure 5: MSEs of the CFO of the modified estimator, for CFO=0.25 and 0.45.

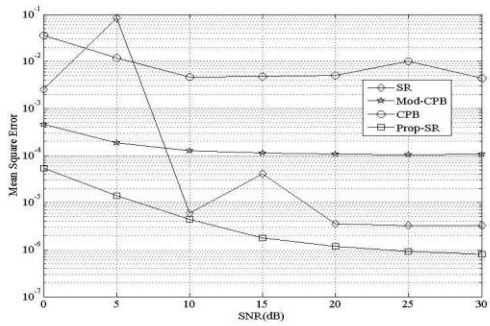

Figure 6: MSEs of the CFO of the modified estimator, for uniformly distributed CFO under M=20 over dispersive fading channel.

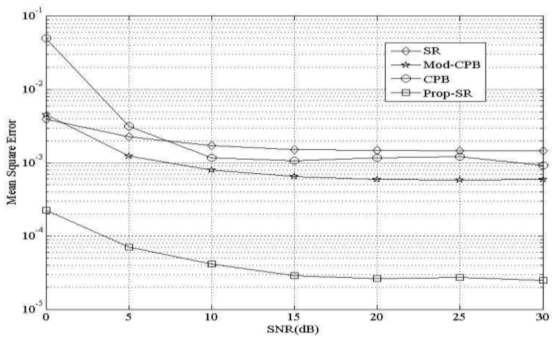

Figure 7 MSEs of the CFO of the modified estimator, under M=20 as a function of SNR over low Doppler shift channel

Fig.7 shows the performance of Prop-SR technique in dispersive fading channel with low Doppler shift, i.e. channel changes for every OFDM symbol. Notice that the performance of SR method over slow-fading channel becomes poor than CPB and Mod-CPB after 10 dB, whereas Prop-SR technique outperforms all the techniques.

CONCLUSION

OFDM is a great technique to handle impairments of the frequency selective channel. Hence, OFDM is a practical candidate for future 4G wireless communications techniques. On the other hand, one of the major drawbacks of the OFDM communication system is the drift in reference carrier. The offset present in received carrier will lose orthogonality among the carriers, and hence, the CFO causes a reduction of desired signal amplitude in the output decision variable and introduces ICI, then brings up an increase of BER. This leads to the necessity to estimate the CFO in order to cancel it in next stage. This thesis presents a modified ML Blind CFO estimator based on symbol repetition known as Prop-SR. The main advantage with the Prop-SR algorithm is that it gives much better performance in dispersive fading channel. However there is a cost to pay, which is reduced bandwidth efficiency due to data symbol repetition. But, symbol repetition is done only in the synchronization phase of symbol transmission (i.e. when CFO is estimated) so the performance of estimator can overcome the cost of reduced bandwidth efficiency. The Prop-SR algorithm is equipped with lower complexity and is computationally efficient with respect to its peer ones.

Prop-SR technique outperforms its similar SR technique in many conditions and it has been shown by simulation results that Prop-SR provides significant improvement in SNR over SR technique.

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