A Novel Approach of Frequency offset Estimation for OFDM System

Minal Saxena, Kavita Khare

Abstract:- ***Orthogonal frequency division multiplexing(OFDM)has recently attracted vast research attention from both academia and industry and has become a part of new emerging standards for broadband wireless access. Synchronization at receiver end represents one of the most challenging issues and plays a major role in physical layer design.This paper presents design and implementation of a Channel estimation algorithm which successfully achieves minimization of Timing and Frequency offsets at receiver end. Also it has been synthesized and simulated on Virtex 6 device.***

Key words:-Cyclic prefix, timing offset, Intersymbol Interference(ISI),Channel estimator.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is the basis of some WLAN and WiMax air interfaces. It also has been proposed for use in next generation cellular systems such as Super-3G and HSOPA (High Speed OFDM Packet Access) in the 3GPP standards group. OFDM has a number of advantageous features, such as good tolerance to multi-path fading and inter-symbol interference (ISI). By using a number of sub-carriers, the symbol length can be kept long and a guard period in the form of the cyclic prefix used to mitigate ISI(2).

II. II.RELATED WORK-

An initial approach for the frequency offset estimation was usage of a null symbol [7] ,where nothing is transmitted for one symbol period so that the drop in received power can be detected to find the beginning of the frame. The carrier frequency offset is found in the frequency domain after applying a hanning window and taking the FFT.This drop in received power suffered from related errors and hence this approach was not feasible. Moreover there was an overhead of the null symbol.[6] In [6]an approach with a rapid synchronization method is presented for OFDM system using either a continuous transmission or a burst operation over a frequency selective channel. This method gave very accurate estimates of symbol timing and carrier frequency offset and provided a very wide acquisition range for carrier frequency offset[6].It gave a future approach for wireless LAN where such a fast and a low overhead synchronization process was necessary. Working ahead with model of[5] and a new approach of circular convolution , a mathematical model has been proposed in [10].It was designed for a continuous stream of OFDM symbols under transmission.Up linking and down linking parameters were specified. A correlator suggested in [8] was implemented to find the start of the frame by repeating a part of the symbol as cyclic prefix.This model was proposed for wireless fading channels. Also its basic design structure was compared with the modification of the estimation technique proposed in[6].

A much advance estimator design is proposed in this paper, as compared to the above correlator model approach[5].This research presents a novel proposed design of an estimator which works excellently for wireless systems , tracks the start of the frame well and minimizes the frequency offset.

The use of 'ARGMAX' function in the program makes the appearance of peak in the output more sharp and hence calculations are specific for offset estimations.

III. OFDM System

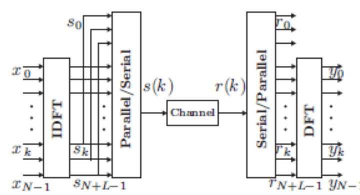

Fig.1 OFDM System

The complex data symbols *xk* are modulated on *N* subcarriers by an inverse discrete Fourier transform (IDFT) and the last *L* samples are copied and put as a preamble (cyclic prefix) to form the OFDM symbol [s_0……. s_{N+L-1}](4). This data vector is serially transmitted over a discrete-time channel, whose impulse response is shorter than *L* samples. At the receiver, the cyclic prefix is removed and the signal r(k) is demodulated with a discrete Fourier transform (DFT).

The insertion of a cyclic prefix avoids ISI and preserves the orthogonality between the tones, resulting in the simple input-output relation.

$y_k = h_k x_k + n_k$ k= 0…………. N -1;\

The uncertainty in the arrival time of the OFDM symbol is modelled as a delay in the channel impulse response, *i.e.*, ±(*k* ¡ μ), where μ is the integer-valued unknown arrival time of a symbol.

The uncertainty in carrier frequency due to a difference in the local oscillators in the transmitter and receiver gives

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rise to a shift in the frequency domain. Such behaviour is modelled as a complex multiplicative distortion of the received data, with a factor,where $e^{j2\pi k\epsilon/N}$ " denotes the difference in the frequency of the transmitter and receiver oscillators as a fraction of the inter-carrier spacing. Hence, the received signal is

$$r(k) = s(k-\theta)e^{j2\pi k\epsilon/N}$$

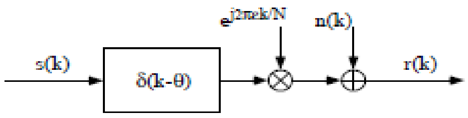

Fig 2.OFDM System Model.

This channel model is shown in Figure 2. This system model is also a special case of the signal model shown in Figure 1. The goal is to estimate θ and ε from the observation signal $r(k)$(8).Where θ and ε are the phase and frequency error respectively.

IV. CYCLIC PREFIX

Transmitting a cyclic prefix of the data during guard interval transforms the linearly convolutive channel into circularly convolutive channel. Hence, the channel equalizations problem is simplified. Specially, channel equalizations in the frequency domain can be done using one tap filters. This is because cyclic prefixing makes the channel matrix circulant, which is diagnosed by IDFT and DFT operations(11). The added guard interval and its effect reducing the ISI as shown in the figure The OFDM demodulation must be synchronized with the start and end of the transmitted symbol period. If it is not then ISI will occur (since information will be decoded and combined for two adjacent symbol period) and ICI will also occur because Orthogonality will be lost. The guard interval helps to solve this problem.With a cyclic extension the symbol period is prolonged but it represents slightly extended frequency spectrum. As long as the correct no of samples are to be taken for decoding, they may be taken from anywhere within the extended symbol. Since a complete period is integrated, Orthogonality is maintained. Therefore both ISI and ICI are eliminated. Although the cyclic prefix introduces a loss in SNR. This may be considered as a small price to pay to mitigate interference. Note that some bandwidth efficiency is lost with addition of the guard period, but the advantages that we get are many and hence compromising solution is required

V. PROPOSED ALGORITHM

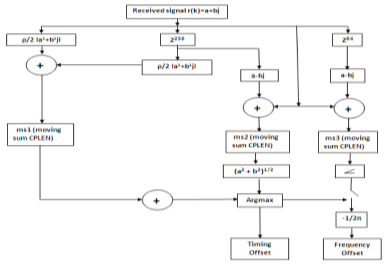

Fig. 3. Block diagram of the algorithm

The WiMAX OFDM preamble is defined differently for the uplink and the downlink. The specification also defines variants for doing initial ranging on the downlink. In this case, the time domain signal has a repeated pattern. The long preamble, used for downlink ranging, consists of a 4x64 pattern symbol, where a 64-sample pattern is repeated 4 times. The uplink uses a short preamble with just a 2x128 pattern symbol(3). These preamble symbols all have the usual cyclic prefix attached.The pattern of the preamble is like this

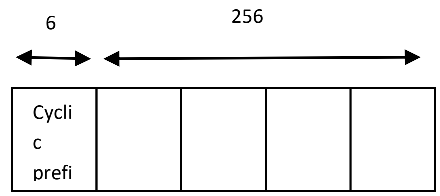

Fig.4 .Preamble

V. VI.DATA FLOW

The received signal is r(k) =a+bj

This algorithm data flow consists of three parts-

$$ms1=\frac{\rho}{2}\sum_{k=m}^{m+L-1}|r(k+N|^2+|r(k)|^2 \qquad (1)$$

(N =256)

$$ms2=\frac{\rho}{2}\sum_{k=m}^{m+L-1}r^*(k)r(k+n) \qquad (2)$$

ms1 and ms2 are compared to get the maximum value ie; argmax.Here even the start of the frame is detected when the cyclic prefix is correlated with the data sequences from which it was extracted(3).

$$ms3=\frac{\rho}{2}\sum_{k=m}^{m+L-1}r^*(k)r(k+n) \qquad (3)$$

Here (N=64) and ρ (SNR) is set to 1.

VI. SYSTEM SPECIFICATIONS

In IEEE802.16-2004 the cyclic prefix can be 64, 32, 16 or 8 samples long(4). The correlation with delay 64 is used to calculate an angle that is used only when the magnitude of the difference between ms1 and ms2 reaches a maximum (argmax). This operation ensures that the frequency offset calculation is done at the best time, i.e., when the correlation over the actual received symbol cyclic prefix is complete(5). Synthesis and simulating the algorithm in VHDL.

The system specifications for the designed algorithm are as follows-

Table 1. system specifications

No of carriers	256
Cyclic prefix length	64
Sampling frequency	75 Mhz
Modulation type	QPSK

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Here the number of carriers is 256 with FFT size being 1024. The cyclic prefix length is 64 bits and is recovered in the output stage by the peak observed.

VIII. RESULTS

The algorithm is simulated in VHDL (VLSI Hardware Description Language).The RTL design structure has been obtained and is as follows

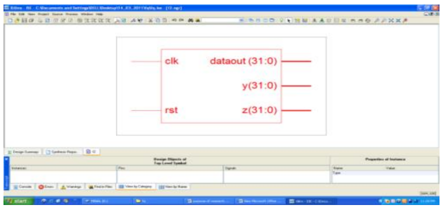

Fig 5. RTL outputs

The following outputs for the estimation of frequency offsets are obtained after simulating and synthesis of the algorithm.The output obtained are as follows-

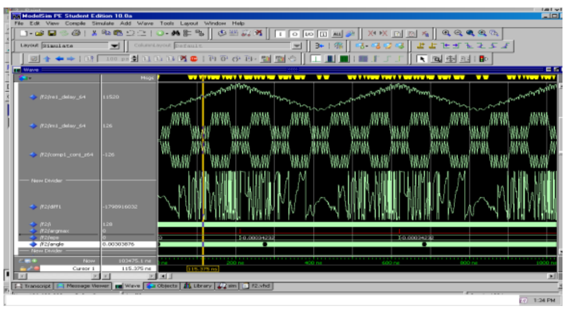

Fig 5. Output for frequency offset after simulations

The value of ε is.00034232 for delay of 256 bits.

A. Implementing the ARGMAX function-

An implementation of this is described here. The receiver does not know when the transmitted signal will arrive, and it is assumed that the input to the circuit will be noise before the preamble is seen. The correlation between data at a distance of the symbol length averaged over CPlen (Length of cyclic prefix) points will tend to be zero for noise, but the energy will be non-zero. This means that the output of the subtractor will be negative until the start of the preamble (or any symbol). Taking advantage of this, the “argmax” circuit can defer searching for a maximum until its input crosses zero and goes positive. This point is about one half of the CPlen or less distance away from the peak. The search window can start at the zero crossing point and continue for CPlen/2 plus an error margin to account for noise-induced error in the zero-crossing point. In the absolute worst case, the search window size would equal CPlen, which is 64. The consequence is that memory is needed to store 64 results from the arctan(y/x) calculation. This will take 64 locations in an memory, which is small compared to the other storage.The peak is denoted by red mark in fig 5. As argmax.

B. Device Utilization

Device utilization summary at OFDM receiver unit.

Resource	Utilization	%
Number of Slice Registers	6420 out of 93120	6%
Number used as Logic	10864 out of 46560	23%
Number used as Memory	480 out of 16720	2%
Number with an unused Flip Flop	9906 out of 16326	60%
Number with aunused LUT:	4982 out of 16326	30%
Number of fully used LUT-FF pairs:	1438 out of 16326	8%
Number of bonded IOBs:	162 out of 360 45%	45%

The above outputs for the estimation of frequency offsets are obtained after simulating and synthesis of the algorithm for N= 256.The values for frequency offset has been obtained after simulations as .00034232 and timing offset has been observed as1.864ns.The design is achieved on Fmax of 75.5 Mhz and uses 2% of the total memory of the Virtex-6 Device. Hence the design of the estimation algorithm is successfully simulated in VHDL .the design when implemented was found to be 95% better in performance than a simple frequency estimator. All in all a hardware implementation of the designed algorithm is ready for next generation wireless communication

CONCLUSION

An efficient Algorithm has been designed in hardware.The design is achieved on Fmax of 75.5 Mhz and uses 2% of the total memory of the Virtex-6 Device. Hence the design of the estimation algorithm is successfully simulated in VHDL .the design when implemented was found to be 95% better in performance than a simple frequency estimator[1]. All in all a hardware implementation of the designed algorithm for minimized frequency offset is ready for next generation wireless communication

REFERENCES

[1]Channel Estimation for OFDM Systems -Anza Rani James, Revathy S Benjamin, Shilpa John, Treesa Mary Joseph, Vineetha Mathai, and Dr. Sakuntala S. Pillai ,Proceedings -ICSCCN 2011

[2] Superimposed training aided Carrier Frequency Offset Estimation in OFDM systems by Malihe Ahmadi Aryan Saadat Mehr -IEEE EIT 2007 Proceedings

[3]OFDM Baseband Modulation Technology based on VHDL Lin Lin ,Yan-feng Qiao, Wan-xin Su 2010- Proceedings of the IEEE.

[4] Moose P., "A Technique for Orthogonal Frequency Division Multiplexing Frequency Offset Correction", *IEEE Transactions on Communications*, Vol. 42, No. 10, pages 2908-2914, October 1994

[5] Jan-Jaap van de Beek, Magnus Sandell, Per Ola Börjesson, "ML Estimation of Time and Fr[3]

and Frequency Offset in OFDM Systems", IEEE Transactions on Signal Processing, July 1997.

[6] T. M. Schmidl and D. C. Cox, "*Robust frequency and timing synchronization for OFDM*," IEEE Trans. Commun., vol. 45, pp. 1613--1621, Dec. 1997.

[7] H. Nogami and T. Nagashima “A frequency and timing period acquisition technique for OFDM system”PIRMC pp1010-1015,Sept 27-29,1995

[8] J J van de beek ,M Sandell,M.Isaksson and P. Borjesson,”Low complex frame synchronization in OFDM systems” ICUPC Nov6-10,1997

[9] “OFDM Transceiver Reference Design”, Lattice Semiconductor OFDM Transceiver design package, 2005.

[10] “Implementation of an OFDM Wireless Transceiver using IP Cores on an FPGA”, Lattice Semiconductor white paper, 2005. Frequency Offset in OFDM Systems",

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