Research Inventy: International Journal Of Engineering And Science
Vol.4, Issue 2 (February 2014), PP 01-05
Issn(e): 2278-4721, Issn(p):2319-6483, www.researchinventy.com

Performance of Pilot Tone Based OFDM: A Survey

[1]Rashmi N, [2]Chandan Hegde,[3]Ganeshkumar S Abli, [4]Kiran Kumar J B
[1]Asst.Prof BMSIT, ECE Dept. ,[234] Students BMSIT, ECE Dept.
([1]rashmiswamy84@gmail.com,[2]chandan5490@gmail.com,[3]abli.ganesh@gmail.com,[4]kirankumarjb.01@gmail.com)

ABSTRACT: *Orthogonal frequency division multiplexing is a multi-carrier technique with high spectral efficiency. But they experience a high 'peak to average power ratio' (PAPR) which increases the power consumption by the transmitter. A Pilot tone in OFDM significantly lowers the BER which shows the quality of the signal transmitted. The impact of the position of the pilot carrier is more on the mean square error (MSE) of the system and hence the performance of the system relies indirectly upon the pilots, and hence optimization of the pilots and their positions is a necessary step. The 'maximum distance distribution method' of pilot carriers which considers the ratio between the total number of subcarriers and total number of pilot subcarriers proves to be a non-significant method as it doesn't minimize the MSE of the channel estimation[2]. Therefore an optimal process is the need of the hour to approach this problem. In this paper we have given an overview of different pilot insertion schemes such as Branch and bound algorithm, Hill climbing algorithm, Differential evolution algorithm and Modified pilot carrier insertion schemes, as well as channel estimation methods for each of the above algorithms have been compared in this context.*

INDEX TERMS: *BER, Channel estimation method, minimize MSE, modified pilot carrier insertion schemes, optimization of the pilots*

I. INTRODUCTION

Data transmissions at a high data rate and the techniques to achieve them have been the top priority topics for research in the communication field and OFDM is one of the emerging field with many technologies using it as their core concept. These is because of its fascinating characteristics such as robustness in fading frequency selective channel and also ease of implementation. OFDM is used in applications like DAB, WLAN and ADSLs which require high data rates. However these systems depend upon the channel state information or CSI for the purpose of which pilot or training sequence [1] are used.

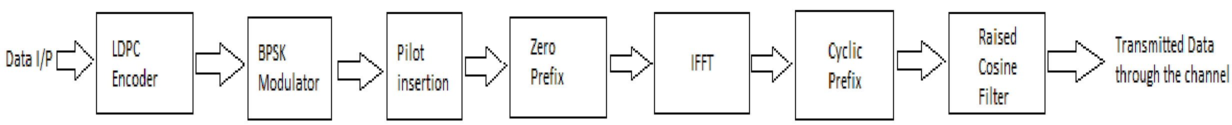

Fig1: Transmitter

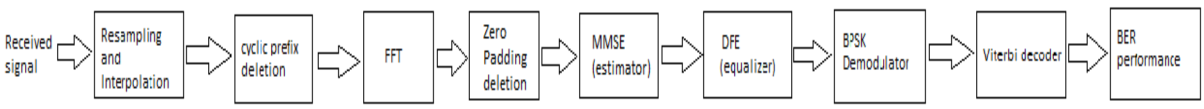

Fig2: Receiver

The above figure shows the transmitter and receiver part of the basic OFDM system. Estimation of channel using pilot tones was first proposed in [2]. There are many ways to establish CSI, in that 'none pilot tone' based OFDM system is also one which is used in optical fiber communication. It uses mDAPSK as its [3] modulation technique. Pilot estimation is effective on MMSE (minimum mean square error estimator) which has less complexity and computation which is achieved by taking LMMSE into consideration. MMSE also minimizes ICI [4] produced in channels like AWGN. The pilot position optimization is an integer optimization problem and thus belongs to the class of NP hard i.e. its solution can be found in polynomial time using heuristic algorithms on a non-deterministic Turing machine (a hypothetical device which can simulate any computer algorithm)[10] which has been discussed in this paper.

Channel estimation can be done through pilots either placing them in comb type or in block type. In comb type pilots are inserted after a specified number of bits. It can vary according to the requirement where as in block type insertion [5] pilots are inserted in blocks.

This paper makes a survey of some of the major techniques and algorithms involved in optimal pilot insertion for the channel estimation and a good pilot carrier placement technique with low MSE.

II. HILL CLIMBING (LOCAL SEARCH)

Hill climbing [6] is the technique used for local search optimization in which using an initial setting the process is started and then changes are made to the settings and the obtained result i.e. the mean square error (MSE) is compared with the result of previous iteration to see if there has been an improvement in the result i.e. if the result has low MSE. And this low MSE result can be used as the initial setting for next run. Here the changes are made in the initial settings by altering the pilot based system i.e. one of the M_d data carrier positions is swapped with that of a pilot carrier. Thus the algorithm is repeated only until the latest result has low MSE than previous one and hence optimization of the end result is achieved. Here the main problem is to find a good initialization in order to find a global minimum and also the algorithm has to be run many times in order to show improvements. To save efforts, maximum distance distribution method is used as initial setting in which pilots are equally distributed among a specific no. of data carriers.

The algorithm is given as below:

- select initial pilot carrier positions
  $n = \{n_\ell | \ell = 1 : M\}, n_\ell \in S_c$
  where Sc is the set of potential pilot carrier positions
- determine M_d data carrier positions
  $\tilde{n} = S_c \backslash n$
- compute MSE
- for $i = 1 : M$
- for $j = 1 : M_d$
- Swap the positions
  $n' = n$; $\tilde{n}' = \tilde{n}$
- $n'(i) = \tilde{n}(j)$; $\tilde{n}'(j) = n(i)$
- compute MSE′ for n′
  where MSE′ is the new result
- if MSE′ < MSE
- Use MSE′ for next iteration
  $n = n'$; $\tilde{n} = \tilde{n}'$; MSE = MSE′
- end
- end
- end

III. BRANCH AND BOUND

As previous method suffers from bad initialization, Branch and Bound can be used as the other alternative. Here a number of sets (upto K_M) of pilot positions are compiled and an extra position n_i based on branch metric [6] is added to each of the K_M sets $\{n_1,\ldots,n_{i-1}\}$. Then their corresponding results i.e. the MSE is compared and the set of positions which results in least branch metric is selected. Computational load which plays an important role in the convergence of this algorithm is decreased by selecting only few sets based on cumulative metric [6]. The convergence of the algorithm can also be improved by using a cost function $\tilde{g}(m) = sign(g(m)).|g(m)|^\alpha$, as given in [6]. The three parameters used here are K_g, K_m and α where K_g is used to limit the growth of the position sets and K_m affects the convergence of the algorithm.

The algorithm is as follows:

- compute the cost function $\tilde{g}(m)$, $m = 1,...,N$
- initialize tree = $[n_1, \Sigma_1 = 0]$, $n_1 \in S_c$
- for $i = 2 : M$
- treenew = empty; x=# rows in tree
- for $k = 1 : x$
- $\{n_1,...,n_{i-1}\}$ = tree(k ; 1 : i − 1)
- define $f_i(y) = \sum_{\ell=1}^{i-1} \tilde{g}(y - n_\ell)$, $y \in Sc$
- select the K_g values with smallest $f_i(n_i^j)$ with $n_i^j \notin \{n_1,...,n_{i-1}\}$, $j = 1,...,K_g$
- for $j = 1 : K_g$
- test if $\{n_1,..., n_{i-1},n_i^j\}$, $j = 1,...., K_g$
- if not : add pilot carrier position
- $\Sigma_i = \Sigma_{i-1} + f(n_i^j)$;
- treenew=[treenew ;$\{n_1,...,n_{i-1},n_i^j\},\Sigma_i$]
- end
- end
- end
- sort treenew on Σ_i and select K_M best ones to replace tree
- end
- compute MSE for all entries in tree and select the smallest

Though the computational complexity of this technique is high, it gives low MSE results and hence optimization of pilot positions is achieved.

IV. DIFFERENTIAL EVOLUTION ALGORITHM

Differential evolution (DE) algorithm is a method to optimize the power and placement of the MIMO-OFDM system which uses [7] Least Square (LS) algorithm for its estimation. The performance of the LS algorithm can be increased by the differential evaluation method instead of placing the pilots orthogonally. DE takes upper bound of the mean square error (MSE) into account as a fitness function [8] of the DE algorithm for optimization tasks. In this method the pilots are inserted in a comb type manner the subcarriers. The locations of the pilot tones in the system are optimized by the bounds on the objective function based on channel capacity and SER (symbol error rate). The steps involved in differential algorithm are as below:

- Initialization
- Evaluation
- REPEAT
  - Mutation
  - Recombination
  - Evaluation
  - Selection
- UNTIL (stop criteria are met)

Hence the power and locale of the pilot carrier is optimized.

V. MODIFIED DATA PILOT INSERTION SCHEMES

In pilot based OFDM, interference between pilots and data causes degradation in frequency offset and channel estimation leading to inter-carrier interference (ICI) and significant decrease in the error performance. Hence a modified scheme is required to counteract the data-pilot interference. The two approaches considered here are Correlated data insertion scheme (CD) (i.e. there is a correlation between the left and right adjacent data carriers of each pilot carrier) and Null data insertion scheme (ND) (i.e. no data carriers are transmitted on left and right adjacent tones of each pilot carrier).

(5.1) Correlated Data Insertion Scheme

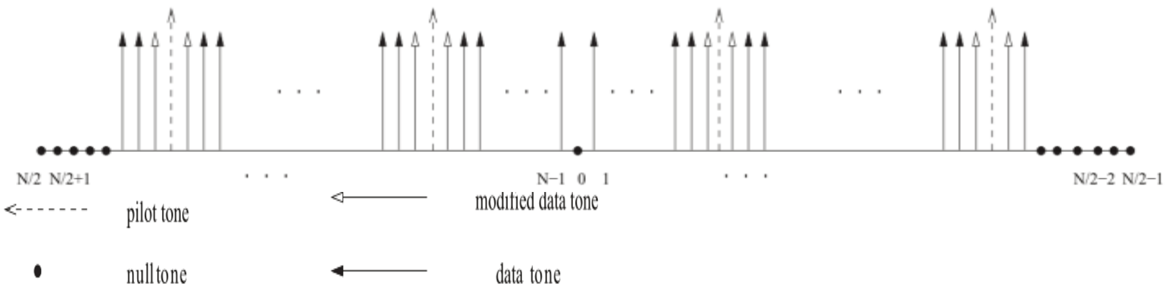

Fig3

Here interference between pilot and data carriers are prevented by performing some processing on the adjacent left and right data tones, as interference is larger between pilot and its adjacent data tones. Here by processing we mean correlating [9] the two adjacent data tones. Also the other way is to modulate the left and right adjacent tones of each pilot differently than that used for the other data tones. For example if QPSK is used to modulate the data tones then 16-QAM can be used to modulate the adjacent data tones of each pilot. The latter method experiences slight performance degradation but achieves the same data rate as that of the conventional data-pilot multiplexing scheme (CV) which uses maximum distance distribution.

(5.2) Null Data Insertion Scheme

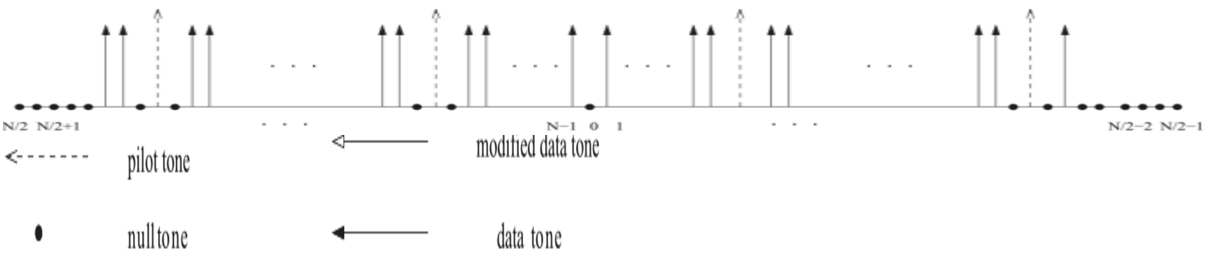

Fig4

Here in order to decrease the interference between pilots and data carriers, null tones are inserted as the adjacent data tones for each pilot.

VI. OBSERVATION

The survey of different techniques of OFDM pilot insertion has been completed. Among the heuristic algorithms discussed, Hill Climbing algorithm has lesser complexity than the Branch and Bound algorithm but Branch and Bound algorithm shows a slightly lower MSE than the hill climbing (HC) algorithm. Maximum distance distribution (MDD) has a good MSE compared to the above heuristic algorithms when the FFT size is more (>1024). For lower FFT size, the first two algorithms give better MSE than MDD. HC suffers from bad initialization setting problem, sometimes it takes MDD as an initial pilot position setting. The two algorithms found the optimal pilot carrier placement in the 97.4% and 87.2% of the cases. Also due to the construction of position sets, the computational complexity of Branch and Bound technique is high. However it results in lower MSE.Differential Evolution algorithm gives up to 30 db SNR, also optimizing the power and hence increasing the performance. The advantage of this algorithm is Robustness and reduced Doppler shift. Overall the bandwidth of the system is increased.For comparison between the modified pilot insertion schemes we consider the data throughput, which here, is defined as the ratio of no. of data bearing sub-carriers to the total no. of OFDM sub-carriers is $(N_d - N_p)/N$. Data throughput is greater for CD insertion scheme compared to Null data insertion scheme, but with a trade off in the case of complexity of computation.

VII. CONCLUSION

In this literature survey we conclude that for pilot position optimization Branch and Bound algorithm is simpler to implement than the Hill Climbing algorithm and gives satisfactory results. And when it comes to modified pilot insertion techniques Correlated Data insertion scheme gives better BER performance compared to Null Data insertion scheme along with better data throughput.

REFERENCES

[1] Imad Barhumi, Geert Leus, Member, and Marc Moonen , "Optimal Training Design for MIMO OFDM Systems in Mobile Wireless Channels" , *IEEE Trans. On Signal Processing*, VOL. 51, NO. 6, JUNE 2003.
[2] Rohit Negi and John Cioffi, "Pilot Tone Selection For Channel Estimation For Mobile OFDM System", *IEEE Transactions on Consumer Electronics*, Vol. 44, No. 3, AUGUST 1998.
[3] Bo Liu, Lijia Zhang, Xiangjun Xin,, Jianjun Yu, "None pilot-tones and Training Sequence Assisted OFDM Technology Based on Multiple-Differential Amplitude Phase Shift Keying" , 2012.
[4] Meng-Han Hsieh , Che-Ho Wei, "Channel Estimation For OFDM System Based On Comb Type Pilot Arrangement in Frequency Selective Fading Channel", *Optical society of America* , IEEE, 1998.
[5] Tejasvi Arora , Dr. Suresh Kumar ,"Pilot Symbol Estimation Technique in OFDM System*", International Journal of Computational Linguistics and Natural Language Processing* , Vol 1 Issue 4 November 2012.
[6] Heidi Steendam "How to Select the Pilot Carrier Positions in CP-OFDM" *Communications Theory*- IEEE ICC 2013.
[7] Muhammet Nuri SEYMAN, Necmi TAS¸ PINAR , "Optimization Of Pilot Tone Using Differential Evolution Algorithm In MIMO OFDM System*", Turk J Elec Eng & Comp Sci*, Vol.20, No.1, 2012.
[8] en.wikipedia.org/wiki/Fitness_function
[9] Xiaoyu Fu and Hlaing Minn, "Modified Data-Pilot-Multiplexed Schemes for OFDM Systems", *IEEE Transaction on Wireless Communication,* VOL. 6, NO. 2, FEBRUARY 2007
[10] W.Hamalanen , "Class NP, NP-Complete and NP-Hard Problems" , Nov. 6. 2006.