

# Trend Analysis Pilot Aided Channel Estimation in OFDM Systems

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**Abstract**— Orthogonal frequency division multiplexing (OFDM) technique has a major problem due to the impact of the flat fading channel. Many channel estimation techniques addressed this problem. This paper presents a technique named trend analysis pilot aided (TAPA) channel estimation, which is dynamic technique minimizes the required training data. Simulation results show that the proposed technique exhibits almost the same BER performance with other training techniques.

**Index Terms** — TAPA, channel estimation, flat fading, OFDM.

## I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is currently wide spread technique in many wireless standard technologies such as, IEEE 802.11a/g/n, IEEE 802.15.3a, IEEE 802.16, IEEE 802.20, DAB, DVB, 3GPP Long Term Evolution (LTE) in Europe [1], [2].

The major power of the OFDM technique is that it transforms the frequency selective fading channel into parallel flat fading sub-channels, that makes the technique robust to frequency selective fading channels. But also, this gives the disadvantage that the OFDM needs to flat fading channel estimation techniques.

Many researches are going in this are and directed mainly in three dimensions, namely; training based techniques [3], [4], [5], blind estimation techniques [6], [7], [8] and semi-blind estimation techniques using pilots [9], [10].

Training based estimation techniques give the best results from the point of view of the BER performance but they are also putting overhead on both the channel bandwidth and the computational power of the receiver.

This paper presents a proposed technique to reduce the required training data for the receiver and so, minimize the channel bandwidth requirements and reduce the computational power of the receiver.

## II. THE OFDM TRANSCEIVER ARCHITECTURE

An OFDM carrier signal is the sum of a number of orthogonal sub-carriers, with baseband data on each sub-

carrier being independently modulated. Commonly, using some type of quadrature amplitude modulation (QAM) or phase-shift keying (PSK). This composite baseband signal is typically used to modulate a main RF carrier.

The OFDM transmitter is presented in figure 1. and the receiver is presented in figure 2.

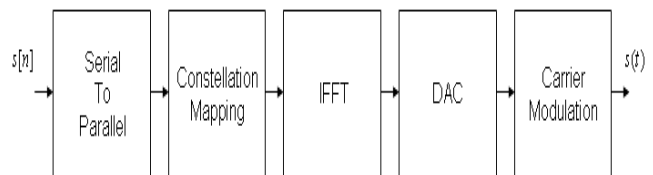


Figure 1: The OFDM transmitter.

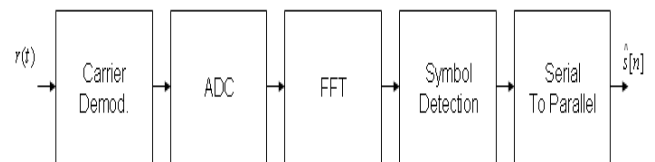


Figure 2: The OFDM receiver.

Where,  $s[n]$  is a serial stream of binary digits,  $N$  is the number of sub-carriers, DAC is a digital-to-analog converter,  $f_c$  is the carrier frequency and  $s(t)$  is the transmission signal, an inverse FFT is computed on each set of symbols, giving a set of complex time-domain samples. These samples are then quadrature-mixed to bandpass in the standard way,  $r(t)$  is the received signal, ADC is analog-to-digital converter,  $\hat{s}[n]$  is an estimate of the original binary stream send by the transmitter and a forward FFT is used to convert back to the frequency domain.

If  $N$  sub-carriers are used, and each sub-carrier is modulated using  $M$  alternative symbols, the OFDM symbol alphabet

will consist of  $M^N$  combined symbols. To avoid ISI in multipath fading channels, a guard interval of length  $T_g$  is inserted prior to the OFDM block. During this interval, a cyclic prefix is transmitted such that the signal in the interval  $-T_g \leq t < 0$  equals the signal in the interval  $T - T_g \leq t < T$ . The OFDM signal with cyclic prefix is:

$$v(t) = \sum_{k=0}^{N-1} X_k e^{j2\pi kt/T} \quad -T_g \leq t < T \quad (1)$$

Where  $\{X_k\}$  are the data symbols and  $T$  is the OFDM symbol time.

The sub-carrier spacing of  $\frac{1}{T}$  makes them orthogonal over each symbol period. In general, the transmitted signal can be represented as, [1], [2]:

$$s(t) = R \{v(t) e^{j2\pi f_c t}\} \quad (2)$$

### III. THE TAPA CHANNEL ESTIMATION TECHNIQUE

Trend Analysis Pilot Aided (TAPA) technique is depending upon sending initial pilots from the transmitter to the receiver then making curve fitting for the send and the receive data and check the slope to determine the change in the parameter and the second derivative to determine the sign of the change. If the percentage relative change (PRCH) in the overall performance, proposed by this paper, is some percent defined by the simulation results and controlled by the equation:

$$PRCH = \alpha_1 \% \Delta BER - \alpha_2 \% \Delta CC - \alpha_3 \% \Delta BW. \quad (3)$$

Where,  $\% \Delta BER$  is the percentage enhancement in BER,  $\% \Delta CC$  is percentage increase in the computational complexity and  $\% \Delta BW$  is the percentage increase in the required bandwidth.

Then, the parameter value can be considered constant, otherwise the parameter value is changed.

According to the error detection technique, if the detected error rate (DER) in the receiver, proposed by this paper, is changed by some percentage defined by the simulation results and controlled by the equation:

$$DER = \alpha_1 \% \Delta BER - \alpha_2 \% \Delta CC - \alpha_3 \% \Delta BW. \quad (4)$$

then, the receiver sends to the transmitter on a control channel to send pilots again and the whole process is repeated. If the receiver didn't ask, the transmitter to send pilots for 100 frames, then the transmitter send automatically pilots to the receiver and the process is repeated.

It is suggested to take  $\alpha_1 = \alpha_2 = \alpha_3 = 1$  in equations (3) and (4) and of course, it is needed to choose the PRCH and DER that maximize the equations (3) and (4).

### IV. SIMULATION SCHEMES AND RESULTS

Simulation is performed to compare the BER performance of the proposed TAPA channel estimation and equalization and other present techniques. Comparison is performed with ideal channel parameters case and no channel parameters case beside the Added Pilot Semi-Blind Channel Estimation (APSB) [10] and the Backpropagation neural networks [11]. Simulation is performed is typical channel models and standard parameters of DVB-H. Simulation is performed using parameter set 3 and channel profiles as specified in [12], [13].

The multipath channel profile is used for fixed reception using indoor antenna and the typical urban (TU6) channel profile is used for mobile reception with indoor/outdoor antenna. The simulation is performed using MATLAB R13.

The main parameters are indicated in table 1.

Table 1: The simulation configuration

| Parameter             | Value          |
|-----------------------|----------------|
| Modulation Scheme     | 4-PSK<br>8-PSK |
| Subcarriers           | 64             |
| PRCH                  | 10%            |
| DER                   | 2%             |
| Average SNR           | 0:20 dB        |
| Average SNR increment | 5 dB           |

The simulation is performed under the assumptions that, the channel fading is constant over the frame and independently distributed from one frame to the other and no carriers frequencies offsets (CFO's). In all simulations, all results are averaged over 250 random channel realizations and the processing time is used as a complexity measure.

The simulation is performed to decide the parameters PRCH and DER by allowing the PRCH and the DER to take the values [2-16] by increment 2. The simulation results for the case of Rician channel profile and 4-PSK modulation are presented in figure 3.

Repeating the same simulation analysis for other considered channel models and other considered modulation schemes and applying equations (3) and (4), then averaging the results across all simulation results. This gives PRCH=10% (on the average) and DER=2% (on the average). So, these values are used to continue the rest of the simulation.

The simulation results, in the presence of Rician fading channel, are presented in figure 4 and 5, in the presence of Rayleigh fading channel in figure 6 and 7 and in the presence of TU6 channel model in figure 8 and 9.

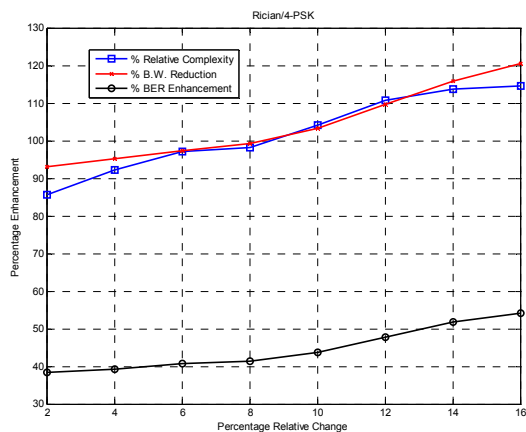


Figure 3: The percentage performance parameters of the OFDM (4-PSK) in Rician channel.

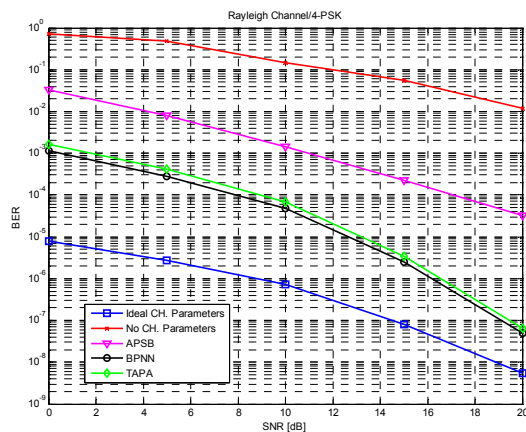


Figure 6: The BER vs SNR performance of the OFDM (4-PSK) in Rayleigh channel.

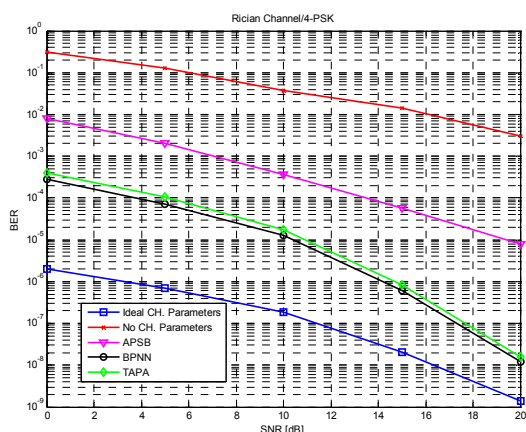


Figure 4: The BER vs SNR performance of the OFDM (4-PSK) in Rician channel.

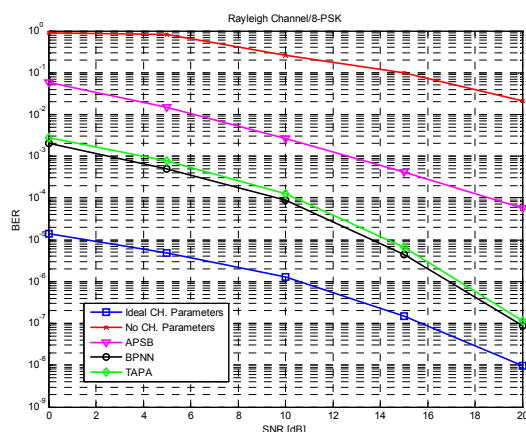


Figure 7: The BER vs SNR performance of the OFDM (8-PSK) in Rayleigh channel.

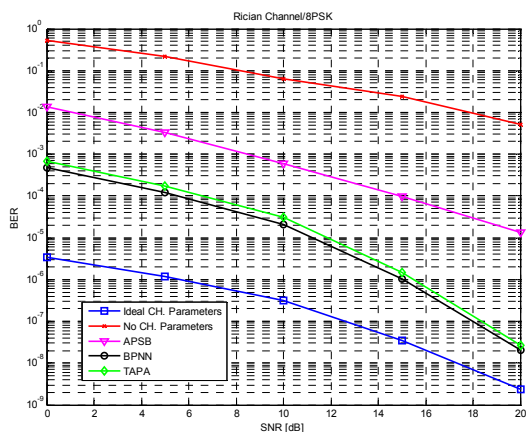


Figure 5: The BER vs SNR performance of the OFDM (8-PSK) in Rician channel.

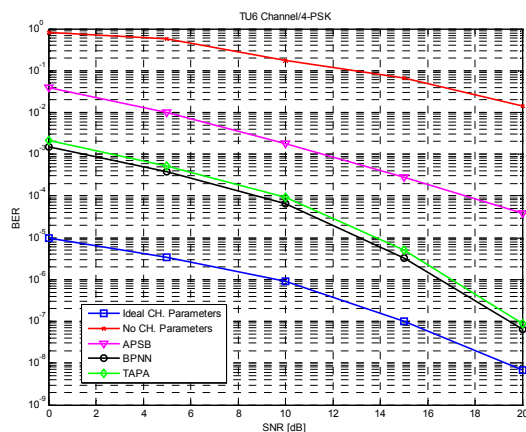


Figure 8: The BER vs SNR performance of the OFDM (4-PSK) in TU6 channel.

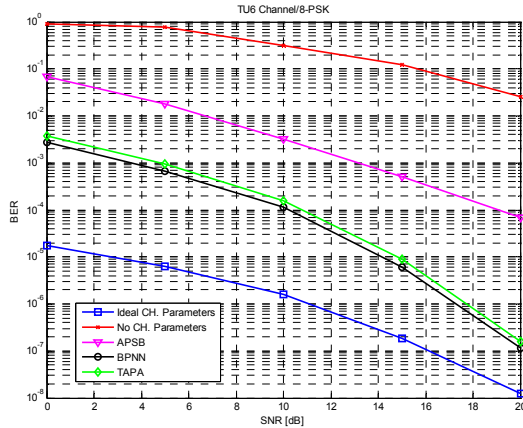


Figure 9: The BER vs SNR performance of the OFDM (8-PSK) in TU6 channel.

The computational complexity enhancement, the required bandwidth reduction and the BER reduction of the TAPA over the backpropagation neural networks is presented in table 2.

Table 2: Computational complexity enhancement, bandwidth requirement reduction and BER reduction of TAPA over backpropagation.

| Channel Model/Mod. | % Computational Complexity | % Bandwidth Reduction | % BER Reduction |
|--------------------|----------------------------|-----------------------|-----------------|
| Rician/4PSK        | 104%                       | 103%                  | 44%             |
| Rician/8PSK        | 103%                       | 104%                  | 42%             |
| Rayleigh/4PSK      | 104%                       | 103%                  | 43%             |
| Rayleigh/8PSK      | 101%                       | 101%                  | 41%             |
| TU6/4PSK           | 98%                        | 100%                  | 40%             |
| TU6/8PSK           | 102%                       | 102%                  | 39%             |

The simulation results show, in the three considered channel models and the two considered modulation techniques, that as the SNR increases, the BER of the proposed TAPA technique decreases and also, the BER decrease rate increases, with increasing SNR as expected.

The simulation results show that the proposed TAPA technique has, on the average, 102% better computational complexity than the backpropagation and it has also, on the average, 102% bandwidth reduction but on the other side, it has, on the average, 42% lower BER performance.

## V. CONCLUSIONS

The paper proposes a TAPA dynamic channel estimation technique. The proposed technique minimizes the required transmitted training data and hence minimizes the required channel bandwidth and it also minimizes the computational complexity of the receiver. But, it has a disadvantage that, it can't adapt fast to sudden changes in the environment.

The simulation results show that the proposed TAPA technique us a compromise among the channel bandwidth

minimization, the computational complexity and the BER performance.

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