

Preamble Signal Shortening Employing Least Squares Search Methods in MIMO-OFDM Base Wireless LAN Systems

Joseph MUGURO, Shuji KUBOTA

Graduate School of Science and Engineering, Shibaura Institute of Technology, 3-7-5 Toyosu, Koto, Tokyo, 135-8548, Japan

E-mail: ma15084@shibaura-it.ac.jp, kubota@sic.shibaura-it.ac.jp

Abstract - MIMO-OFDM is the generally accepted standard in all WLAN systems. However, this method increases training signals required to estimate the propagation matrix of multi-antenna system. In this study, we investigate methods of shortening VHT-LTF training signal in WLAN systems. Simulation results have shown that 1/2 and 3/4 reduction in VHT-LTF training signal is possible while maintaining a considerable network performance.

Index Terms — MIMO- OFDM, IEEE 802.11ac, Channel Estimation, Training signal

1. Introduction

The IEEE 802.11a/b/g/n/ac WLANs have been deployed successfully. The most recent release 802.11ac uses 8 antennas from the previous 802.11n which used four antennas [1]. Multiple Input Multiple Output-Orthogonal Frequency Division Multiplexing (MIMO-OFDM) based WLANs require a training field/preamble be added for each antenna in the system [2]. Higher number of antennas improves data speeds but increases the training field overhead [1]. This leads to consequent reduction of effective throughput. Previous research has focused on improving the channel estimation methods and analysis [3], [4]. A preceding research was conducted by [5] and reported significant results upon which this research is building on. This paper proposes shortening methods for the IEEE802.11ac Very High Throughput Long Training Field (VHT-LTF) preamble signal.

2. Proposed system

The relationship that exists between data streams and the training field of 802.11ac WLAN releases is described by Fig. 1 below [1]. From this, we note the increase of VHT-LTF symbols with the spatial streams.



Fig. 1. IEEE 802.11ac frame structure.

The proposed system was designed as shown in Fig. 2 to reduce the training matrix in the transmitter side. On the receiver side, various data fitting techniques are employed to recover the omitted data. For the transmission of half VHT-LTF preamble, Simple averaging method and Least Square (L.S) estimation was employed to recover the omitted data. For quarter (1/4) of the VHT-LTF preamble, we used L.S optimization algorithm employing the following functions.

(1) Fourier series fitting model

From the above L.S algorithm, Fourier series equation below was modelled to fit the reconstructed data points and make inference to the missing data points.

$$f(x) = a_0 + \sum_n (a_n \cos(n\pi x) + b_n \sin(n\pi x)) \quad (1)$$

(2) Polynomial data fitting

The modelled equation returns the coefficients for a polynomial $p(x)$ of degree n that is a best fit (in a L.S sense) for the received data.

$$P(x) = p_1 x^n + p_2 x^{n-1} + \dots + p_n x + p_{n+1} \quad (2)$$

(3) Effective throughput calculation

The Physical layer throughput for the WLAN system was calculated by the equation below [6].

$$Tphy = NSym \times \log_2 M \times Rc \times NSS \times (1-PER) \text{ [Mbps]} \quad (3)$$

Where M is the Modulation index number, Rc is the FEC coding rate, NSS is the number of spatial stream, PER is the Packet error rate and $NSym$ is the total number of modulation symbols/sec and $Mbps$ is Megabits/sec.

To evaluate the real transmission capability of traffic, effective PHY layer throughput $Treal$ is calculated as shown below.

$$Treal = Tphy \times Tdata_time / Tframe_time \text{ [Mbps]} \quad (4)$$

From (3) and (4), reducing the preamble field increases the number of symbols transmitted as well as improves the ratio of data/frame.

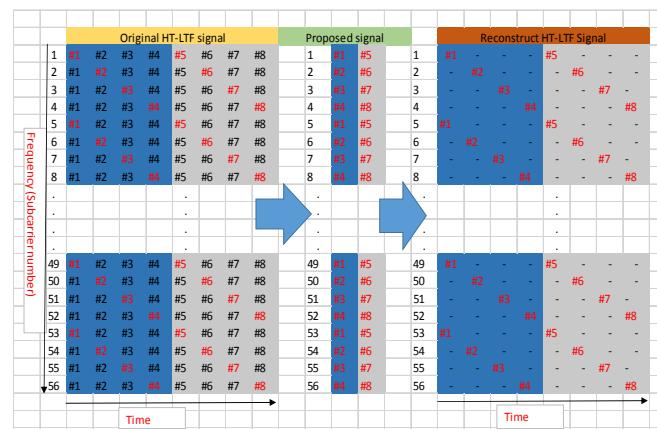


Fig. 2. Proposed system with 1/4 of VHT-LTF preamble.

3. Simulation parameters

We modelled WLAN system in Matlab and perform simulations to verify the results of the research. The

parameters used for the simulation are listed in the table below.

Table 1. Simulation parameters

IEEE802.11ac Parameters	Values
Modulation order (M)	OFDM (QPSK, 16QAM, 64QAM, 256QAM)
Coding rate (Rc)	1/2, 2/3 3/4, 5/6
No of Spatial Streams (Nss)	8
Sub-Carrier number	56 (Pilot:4×1, Data:52×1)
FFT size	64
OFDM symbol size	4.0u sec (Guard Interval: 0.8 u sec)
Bandwidth	20 MHz
Channel Model	TGn B (Home environment)
Doppler frequency size	3 Hz
Payload size	1500 [Byte]

4. Simulation results

The following results were obtained using different data fitting methods of IEEE 802.11ac with and without preamble reduction.

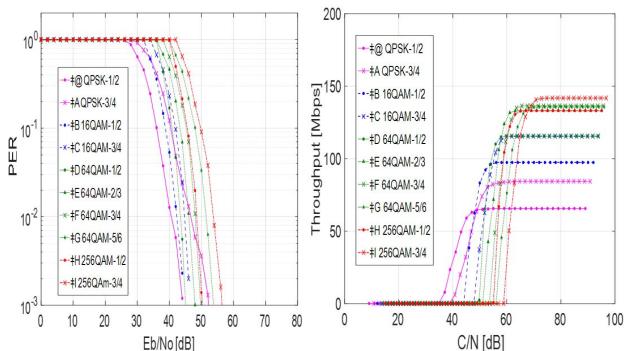


Fig. 3. IEEE 802.11ac PER and Effective throughput performance with no preamble reduction.

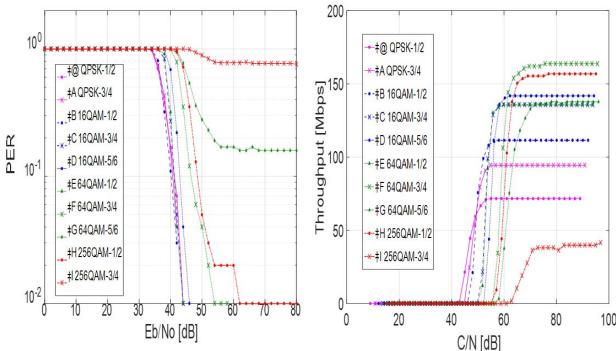


Fig. 4. PER and Effective throughput performance of 1/2 VHT-LTF preamble using simple averaging method.

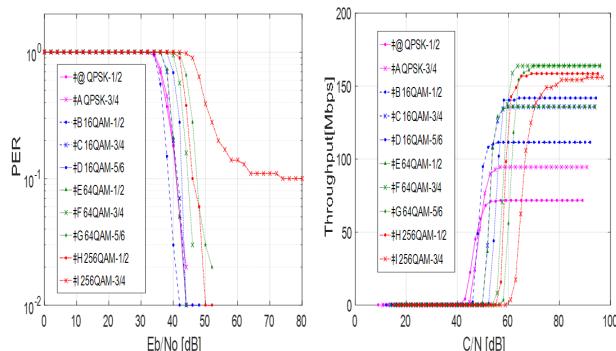


Fig. 5. PER and Throughput performance of 1/4 VHT-LTF preamble using L.S method.

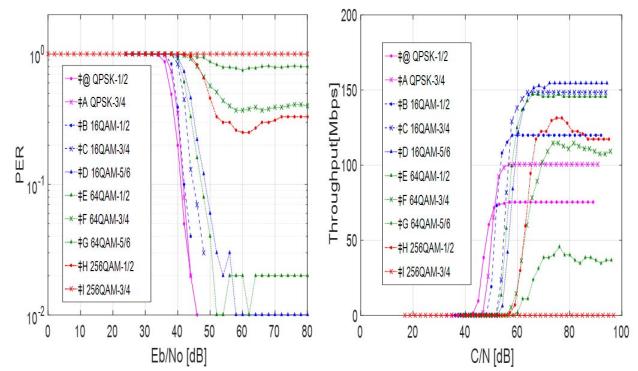


Fig. 6. PER and Throughput performance of 1/4 VHT-LTF preamble using L.S method.

5. Conclusion

The results confirm the applicability of different preamble shortening methods. The L.S search method with $\frac{1}{2}$ preamble reported the best improvement in throughput performance. Using $\frac{1}{2}$ VHT-LTF gives rise to throughput improvement ranging from 10% to 20% of the original 802.11ac performance. Simple averaging has the advantage of simplicity but low performance in higher modulation schemes (64 QAM rate 5/6 and 256 QAM rate 3/4). On the other hand, L.S method employing polynomial or Fourier fitting has a good performance with increased computational load.

For $\frac{1}{4}$ of VHT-LTF, application of simple averaging is limited and hence L.S is the only reported method. L.S search gave considerably good performance for lower modulation schemes (QPSK and 16QAM) as seen in Fig. 6. The results shows an average of 6% improvement in throughput from that of $\frac{1}{2}$ VHT-LTF results in Fig. 4 and 5. This can be attributed to the fractional difference in (4).

Higher order modulations (64 and 256 QAM with higher FEC rates) performance was highly degraded and hence reduction would seem non-applicable with the current recovery methods.

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