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RESEARCH ARTICLE

802.11a Synchronizer Performance Analysis (Simulation)

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Abstract— In this paper performance of 802.11a Synchronizer is analyzed in terms of packet detection and time synchronization using MAT LAB. We have done rigorous research into OFDM WLAN synchronization algorithms and implemented a synchronizer which performs packet detection and time synchronization. The result of the research has practical reference value for further study.

Keywords— IEEE, MAT LAB, OFDM, WLAN, ALGORITHMS

I. INTRODUCTION

The IEEE 802.11a specification provides higher data rates (up to 54Mbps) in the 5GHz frequency band. It also employs a spreading technique known as Orthogonal Frequency Division Multiplexing (OFDM).
Interest in OFDM has increased over the past few years. OFDM modulation schemes are now used in both wired wireless systems and have been standardized for systems such as DAB, DVB and ADSL. OFDM has also been suggested for future generations of wireless systems, such as WLAN and third generations of wireless systems, such as WLAN and third generation systems.[1]
Besides many nice features such as no ISI/ICI, high data and robust dispersion, MCM/OFDM systems do have weaknesses. The two most important ones are: **Sensitive to time and frequency errors**: Both time and frequency dispersion during modulations, transmission and demodulation would potentially destroy and orthogonal ties between sub-carriers. Possible reasons include inadequate cyclic prefix and inter-carrier spacing and /or uncorrected timing and frequency offsets. **High Peak-to Average Power Ratios**: (PAPR) that require high-cost linear amplifies. Current low-cost devices bring nonlinearly and downgrade systems' performance substantially.
OFDM has already been accepted for the new wireless local area network standards IEEE 802.11a [1], High Performance LAN type 2 (HIPERLAN/2) and Mobile Multimedia Access Communication (MMAC) Systems. Also, it is expected to use for wireless broadband multimedia communications.

The new standards for broadband specify bit rates of up to 54 Mbps. Such high rate imposes large bandwidth, thus pushing carriers for values higher than UHF band. For instance, IEEE 802.11a has frequencies allocated in the 5- and 17- GHz bands [1] [3]. OFDM can be seen as either a modulation technique or a multiplexing technique. It is a special type of multi-carrier transmission, where several data streams modulate different sub-carriers.

TABLE I
IEEE 802.11 CLASSIFICATIONS

Standard	**IEEE 802.11a**	**IEEE 802.11b**	**IEEE802.11g**
Release	Sept 1999	Sept 1999	Jun 2003
Bandwidth(MHz)	20	20	20
Frequency(GHz)	0.5	2.4	2.4
Data Rate(Mbit/s)	6,9,12,18,24,36,48,54	5.5,11	6,9,12,18,24,36,48,54
Modulation	OFDM	DSSS	OFDM,DSSS

II. SYNCHRONIZATION CHALLENGES

Synchronization is a common problem exists in communication systems. A symbol is transformed in the process of moving from a transmitter to a receiver by modulation, RF components, channel, noise, etc. At the receiver idea, some key parameters, i.e., carrier frequencies, symbol timing, etc. have to be "guessed" by the receiver by certain means. Apparently a good understanding of the rationale behind synchronization problems is a key to mitigate them. The main factors responsible for the channel impairments are:

Linear Distortion: Possible techniques include guard interval insertion, pass band channel equalization, baseband equalization, and vector coding/structured channel signaling and combination of these methods.

Phase Jitter: Phase jitter could be treated as random distortion to the constellation if transmitted data in different data in different sub-carriers are uncorrelated. So, phase jitter is not that fatal for OFDM systems. For single carrier system, however phase jitter will cause the rotation of constellation and further high BER. Recent research reveals that severely affect BER in wireless system, and tracking phase jitter is difficult. **Non-linear distortion:** Mostly caused by power parts because of the high peak-to-average ratio of OFDM. **Impulse Noise :** Very good impulse noise rejection **Single frequency interference:** Sensitive to frequency domain impulse noise. The interesting part is its duality, single carrier modulation, is sensitivity to time domain impulse noise. The good news is the occurrence of single frequency noise that lies exactly in the transmission band is rare.

The IEEE 802.11a receiver is coherent, which means that the phase has to be estimated before the decoding takes place. There is no way to know the phase of the transmitter except using the received data to calculate an estimate.[5]

The pilots are normally used to estimate the phase. In the table below are some of the timing related parameters:

TABLE II
TIMING RELATED PARAMETERS FOR IEEE 802.11A

Parameter	**Value**
N_{SD} : Number of sub carriers	48
N_{SP} : Number of pilot sub carriers	4
N_{ST} : Number of sub carriers, total	52
$\int_s$: sampling frequency	20 M Sample / s

Sub carrier frequency spacing	0.3125 MHz (=20 MHz/64)
T_{FFT} : IFFT / FFT time	3.2 μs
T_{GI} : GI duration	0.8 μs(T_{FFT}/4)
T_{G12}: Training symbol GI duration	1.6μs (T_{FFT} / 2)

Synchronization has to perform at least two synchronization tasks. The first one is to find out where the symbol boundaries are and what the optimal timing instants are to minimize the effects of inter-carrier interference (ICI) and inter-symbol interference (ISI). The second task is to estimate and correct the carrier frequency offset of the received signal to avoid the ICI.

III. **OFDM PHY SERVICE PARAMETER LISTs**

The architecture of the IEEE 802.11 MAC is intended to be PHY independent. Some PHY implementations require medium management state machines running in the MAC sub layer in order to meet certain PMD requirements. The PHY-dependent MAC state machines reside in sub layer defined as he MAC sub layer management entity (MLME). In certain PMD implementations, the MLME may need to interact with the PLME as part of the normal PHY SAP primitives.[4] These interactions are defined by the PLME parameter list currently defined in the PHY service primitives as TXVECTOR and RXVECTOR. The list of these parameters, and the values they may represent, are defined in the specific PHY specifications for each PMD.

TABLE III
TXVECTOR PARAMETERS FOR 802.11A

Parameter	**Associate primitive**	**Value**
LENGTH	PHY TXSTART. Request (TXVECTOR)	1 4095
DATATRATE	PHY.TXSTART. request (TXVECTOR)	6,9,12,24.36,48 and 54 (support of 6, 12,and 42 data rates is mandatory)
SERVICE	PHY TXSTART. request (TXVECTOTR)	Scrambler initialization 7 null bits+9 reserved null bits
TXPWR LEVEL	PHY TXSTART. REQUEST (TXVECTOR)	1 8

TABLE IV
RXVECTOR PARAMETERS FOR 80211.A

Parameter	**Associate primitive**	**VALUE**
Length	PHY.RXSTART.INDICATE	1 4095
RSSI	PHY.RXSTART.INDICATE (RXVECTOR)	0 RSSI maximum
DATARATE	PHY.RXSTART.request (RXVECTOR)	6, 9. 18, 24, 36, 48, and 54
service	PHYRXSTART.request(RXVECTOR)	Null

IV. **PERFORMANCE METRICS**

A. Packet (Frame) Detection

The information exploit here is the structure of short training symbols in preambles. Decision statistic m is:

$$M_n = \left| \sum_{K=0}^{L-1} r_{n+k}\, r^*_{n+k+Ds} \right|^2 / \left| \sum_{k=0}^{L-1} r_{n+k+Ds}\, r_{n+k+Ds} \right|^2$$

Where Ds is the period of short training symbol, which is 16 in the standard. L is a window that averaging over several samples to reject noise. The equation provides a coherence value to quantify the similarity between the repeating short training symbols while trying to eliminate the effect of different received power levels. Ideally m_n will approach 1 when repeat patterns appear. 0.75 works well as a threshold in our simulation.

B. Symbol Timing Estimation (Fine Time Synchronization):

Symbol fine time synchronization could use time domain CP or frequency domain pilot Sub-carriers.

$$M_n = \left| \sum_{K=0}^{L-1} r_{n+k}\, r^*_{n+k+64} \right|^2 / \left| \sum_{k=0}^{L-1} r_{n+k+64}\, r^*_{n+k+64} \right|^2$$

Here we are look for the position where Mn begin to fall, that is, the position where CP was inserted. Because late timing will create ISI, we made a conservative estimation by adjusting the estimated m_n by 1 or 2 samples. Note that we estimated symbol timing for long training symbols too.

V. **STEPS SIMULATED**

A. Packet Detection

The structure of the WLAN preamble enables the receiver to use a very simple and efficient algorithm to detect the packet. This method takes the advantage of the periodicity of the short OFDM training symbols at the start of the preamble. This approach is called the delay and correlate algorithm. Generally packet detection can be described as a binary hypothesis test:

Ho: packet not present
H1: packet present

The actual test is usually of the form that tests whether a decision variable *Mn* exceeds a predefined threshold Th. The packet detection case is shown below:

$M_n<T_h$: packet not present
$M_n>T_h$: packet presents

$$c_n = \sum_{k=0}^{L-1} r_{n+k} r^*_{n+k+D}$$

$$p_n = \sum_{k=0}^{L-1} r_{n+k+D} r^*_{n+k+D} = \sum_{k=0}^{L-1} \left| r_{n+k+D} \right|^2$$

So, packet detection has been performed as per following diagram

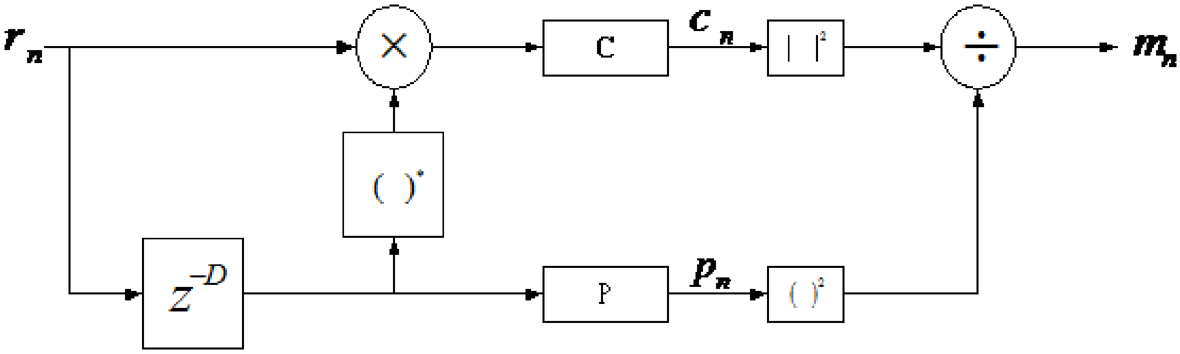

Fig. 1 Block Diagram for packet detection

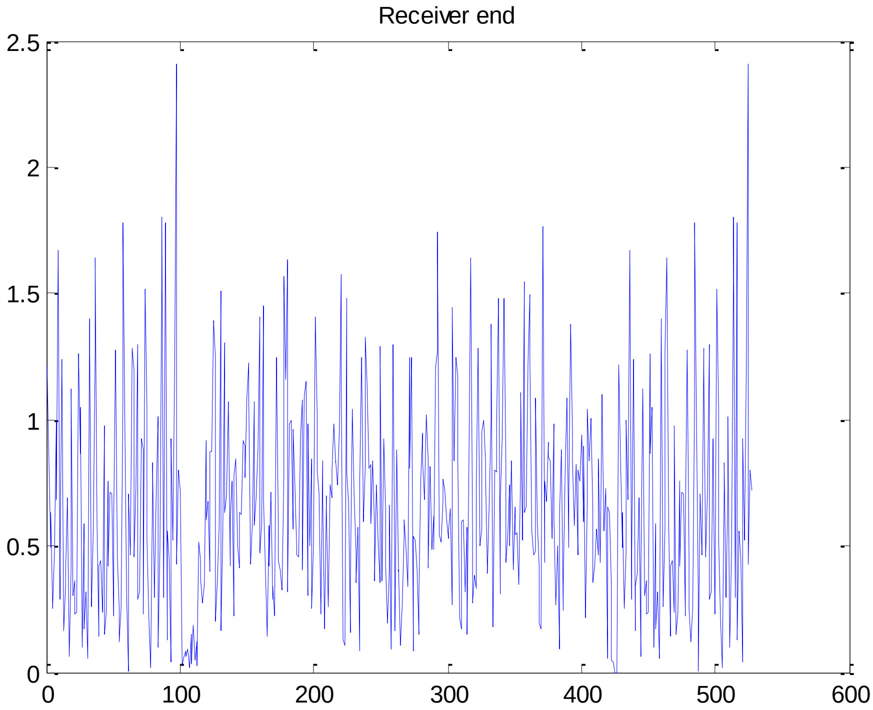

Fig. 2 Received Signal (training sequence)

The C window is a cross-correlation between the received signal and delayed version of the received signal IEE802.11a has D=16, the period of the short training symbols. The P window calculates the received energy during the cross correlation window. The value of P window is used to normalize the decision statistic, so that it is not dependent on absolute received power level.

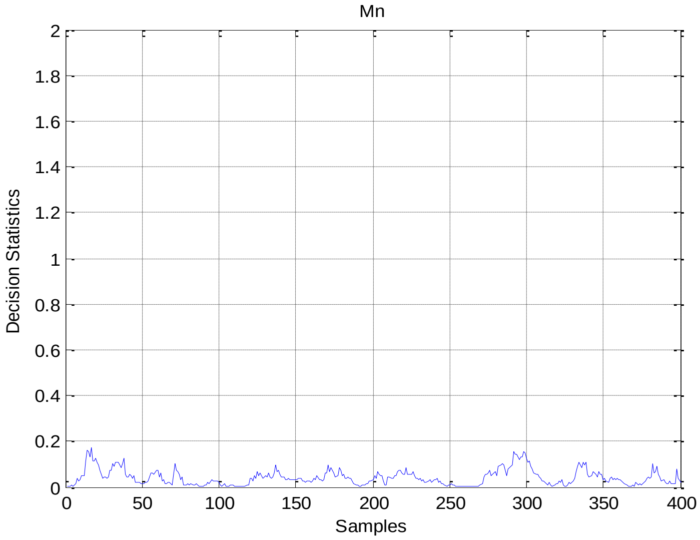

Fig. 3 Decision Statistic (for packet detection)

B. Symbol Timing estimation for WLAN Receiver

Symbol timing refers to the task of finding the precise moment of when individual OFDM start and end. The symbol timing result defines the DFT window, i.e. the set of the samples used to calculate DFT of each received OFDM symbol.

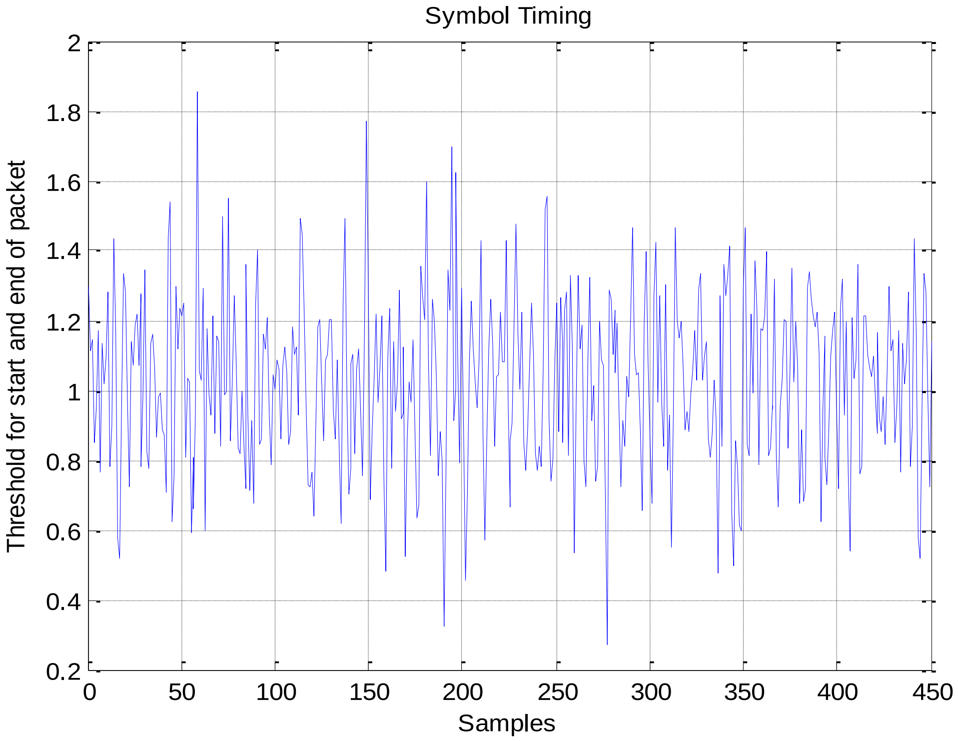

Fig. 4 Coarse Symbol Timing Estimation (using short training symbols)

After the packet detector has provided an estimate of start edge of the packet, the symbol timing algorithm refines the estimate to sample level precision. WLAN receiver has knowledge of the preamble available to them, which enables the receiver to use simple cross correlation based symbol timing algorithm.

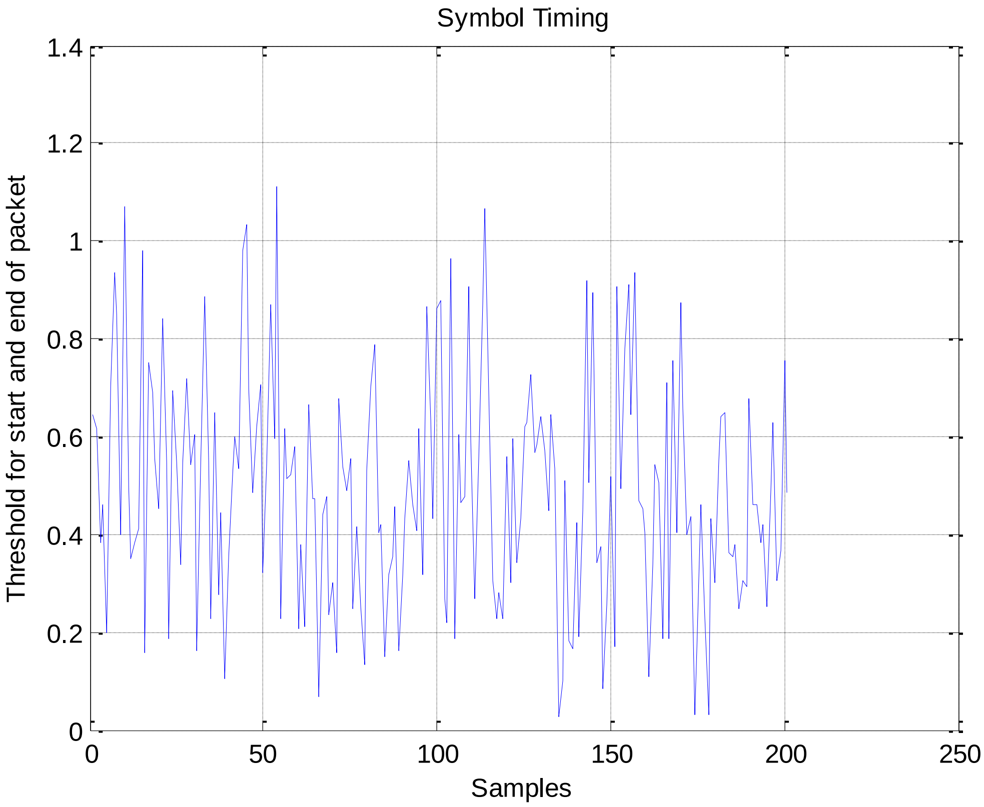

Fig. 5 Fine Timing Estimation (using long training symbol)

VI. **CONCLUSION**

The digital baseband design has been created and verified for back-to-back R_X and T_X blocks with the specified propagation delays. Certain algorithms have been implemented for frame detection, symbol timing estimation. These simulations have been tested and verified for different channel conditions. Moreover, channel modelling has been carried out for WLAN environment. Channel estimation based on comb type pilot arrangement is presented by giving the channel estimation methods at the pilot frequencies and the interpolation of the channel at data frequencies. The simulation results show that comb type pilot based channel estimation with low pass interpolation performs the best among all channel estimation algorithms. A new method for estimating the input sequence from the available distorted output based on third order cumulates has been discussed. The proposed algorithm estimates the input signal from the available distorted output only. Further research can be carried out to explore new synchronization techniques along with novel channel estimation algorithms.

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