Synchronization and Preamble Concept for Frame Detection in OFDM

Rakhi Thakur and Kavita Khare

***Abstract*—With the rapid growth of digital communication in recent years, the need for high-speed data transmission has been increased. The communications industry faces the problem of providing the technology that be able to support a variety of services ranging from voice communication with a bit rate of a few kbps to wireless multimedia in which bit rate up to 2 Mbps. Many systems have been proposed and orthogonal frequency division multiplexing (OFDM) system has gained much attention for many reasons. One of the major problems, encountered in the OFDM systems is their synchronization. The synchronizations tasks sometimes require an extensive processing and highly effective systems and methods for synchronizing OFDM receiver parameters to an OFDM transmitter are provided. These parameters may include carrier frequency, burst timing, frame detection and cyclic prefix length. In this paper I am discussing synchronization through frame detection. According to this present invention synchronization may be maintained even at low cost with high speed.**

***Index Terms*—OFDM, PN sequence, LTS, sts etc.**

I. Introduction

A. *Symbol Timing Synchronization*

Different OFDM systems have different requirements for symbol timing; for example, WLANs cannot spend more time beyond the preambles whereas a broadcast system can spend several symbols to acquire accurate symbol timing estimate. We will concentrate on WLAN case. A WLAN standard such as IEEE 802.11a and HiperLAN/2 specifies a preamble signal at the beginning of the transmission. The preambles of 802.11a standard are presented in Fig.1 and characteristics are shown in Table I in both the standards; the preambles are designed such that the start of the symbols can be easily determined at the beginning of the transmission. The first 10 parts starting are all short training symbols (sts); all of them are 16 samples long. The last two parts are long training symbols (LTS) that span 64 samples as it is for a regular OFDM symbol. The middle part GI is 32 samples long and saves the long training symbols from multi-path interferences. The knowledge of the preamble is available to wireless local area network (WLAN) receiver, thus it can easily make use of a simple cross-correlation technique for symbol timing [4]. And with this preamble design, it should be possible to detect the packet, control the gain of the amplifier and choose the best signal in case of single input multiple outputs (SIMO) and multiple inputs and multiple outputs (MIMO), as well as estimate the symbol timing, the frequency offset and the channel.

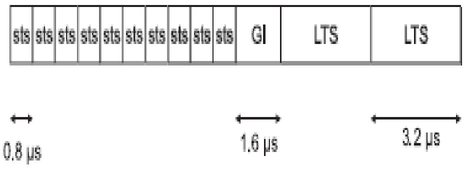

Fig. 1. Preamble structure of an IEEE802.11a data packet

TABLE I: CHARACTERISTICS OF THE 802.11A STANDARD

S.No.	Characteristics	Value
1.	Working Frequency	5MHz
2.	No. of Sub carriers	52(48 data +4 Pilot)
3.	Subcarrier Separation	312.5KHz
4.	Modulation Used	BPSK/QAM
5.	Bandwidth	20 MHz.

After the packet detection algorithm signals the start of a packet, the symbol-timing algorithm refines the estimation to sample level precision. Using the cross-correlation between the received signal and a known reference does this; for example the end of the short training symbols or the start of the long training symbols [2].

B. *Packet Detection*

1) Detect signals by using 10-short preambles with PN (Pseudo noise codes, identical codes)
2) Once the correlation is above a pre-defined threshold, receiver announces detection of packet

$$G\ (i) = S\ (m{=}0 \text{ to } L{-}1)\ S\ (n{=}0 \text{ to } N{-}1)\ (Zi)n+mN\ (Zi)\times n+(m+1)N \quad (1)$$

Zi = received signal samples.
N = number of samples in GI time (0.8 us)
L = number of symbols in short pre-amble period (10 each)
$G\ (i)$ = received signal level

Running index "n" from the above equation will sample the received signal during the designated preamble pulse (the 1st and the last, 10th pulse). Once the (conjugate pair) signals are acquired, the correlation takes place. The phase information of the two signals should yield zero: only the energy level of the correlation result is our concern. Next, the correlation of the 2nd preamble pulse and its counter part, conjugate of the 9th pulse is performed. As long as the correlation is below a pre-defined threshold, the iteration continues until the last pair of preamble pulses (5th and 6th) in the mid section of the short preamble time frame, completes its correlation. The iteration (recursive correlation) will terminate if any signal pair correlation energy level exceeds a predefined threshold. Only then, the receiver announces the detection of signal packet. An

Manuscript received October 9, 2012; revised December 20, 2012.

Rakhi Thakur is with Kalaniketan Polytechnic college Jabalpur Madhya Pradesh India(e-mail: rakhi082003@yahoo.co.in)
Kavita Khare is with Maulana Azad National institute of technology Bhopal India (e-mail: kavitakhare1@yahoo.co.in)

DOI: 10.7763/IJMO.2013.V3.237

efficient 802.11a can perform the packet detection routine in the first 2/3rd of the short preamble time-slots as shown in Fig. 1.

C. Coarse Carrier Frequency Acquisition

1) Correlate 1st preamble pulse and the conjugated of the last, 10th pulse on the 1st iteration
2) Correlate 2nd preamble pulse and the conjugated of the 9th pulse on the 2nd iteration, and so on …
3) Take the average of above mentioned phase correlations which gives the received signal phase error [3]

Coarse carrier frequency acquisition is done during the short preamble period, similar to the packet detection as described above. Now, the focus will be on the phase information of the PN codes. Due to the receiver LO (Local Oscillator) frequency not initially synchronized to transmit LO frequency, the packet of received data (signal constellation) will be rotating with an angular velocity of $\omega=2\pi f$. The receiver is to estimate the frequency error by extracting implicit information from the PN code phase error between its conjugate pair of signals, received at different time-slot during the short preamble time, allocated at the beginning of the data packet. After performing a string of phase correlations, the receiver is to compute the average phase error from time-slot to time-slot. An efficient 802.11a can perform the coarse carrier frequency offset estimation in the last 1/3rd of the short preamble time-slots [5].

The synchronization tasks that we would like to focus on now are frame and frequency synchronization based on preambles. There are many techniques for OFDM based wireless communications. A small range of all the options can be found in [1]. Fig. 1 depicts the preamble structure of an IEEE802.11a data packet. It consists of ten short training symbols (sts) and two long training symbols (LTS) separated by a guard interval (GI). The first seven sts are used for signal detection, automatic gain control and carrier sensing [3].

The remaining three short training symbols serve as training symbols for a coarse estimation of the frequency and clock offsets. Using repeated short symbols of one forth of the original length yields a spectrum after the fast Fourier transform (FFT) where only every forth element differs from zero due to the periodicity of the signal in the time domain. This circumstance enables an estimation of the frequency offset that is larger than one carrier spacing. A detailed description of an OFDM receiver exploiting this shortened periodicity can be found in [1]. Fig. 2 shows a simplified structure of the frequency offset estimator and frame detector. The receiver correlates the received signal with a delayed version of the received signal. Using this autocorrelation method the beginning of the frame can be estimated, as the autocorrelation will be significantly higher when the received preamble samples are pushed through the correlator. Ordinary data symbols cannot have this periodic structure and lead to a lower correlation value. Hence, finding the beginning of the frame means finding the peak value at the output of the correlator. The samples of the received signal $y(k)$ are modulated by a frequency offset with respect to the transmitted signal $x(k)$. This is introduced by differing oscillator frequencies in the transmitter and the receiver. The phase of the samples grows continuously in consequence of this frequency-offset Δfc: where Ts is the sampling period.

$$Y(k) = x(k).e^{j2\pi\Delta fcTsk} \quad (2)$$

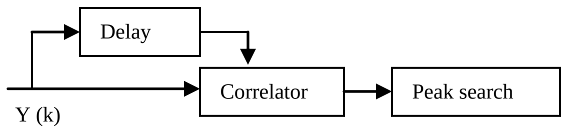

Fig. 2. Structure of the frequency offset estimator and Frame Detector

II. Barker Code PN Generator

Barker codes, which are subsets of pseudo noise (PN) sequences, are commonly used for frame synchronization in digital communication systems. Barker sequence is used to encode all data sent over the air. Each 13-chip sequence represents a single data bit (1 or 0), and is converted to a waveform, called a symbol, that can be sent over the air. These symbols are transmitted at a 1 MSps (1 million symbols per second) symbol rate using a technique called Binary Phase Shift Keying (BPSK). In the case of 2 Mbps, a more sophisticated implementation called Quadrature Phase Shift Keying (QPSK) is used; it doubles the data rate available in BPSK, via improved efficiency in the use of the radio bandwidth [6]. Barker codes have low correlation side-lobes. A correlation side-lobe is the correlation of a codeword with a time-shifted version of itself. The correlation side-lobe, C_k, for a k-symbol shift of an N bit code sequence $X\{j\}$ is given by [1]: -

$$C_k = \sum_{j=1}^{N-k} X_j X_{j+k} \quad (3)$$

where X_j is an individual code symbol taking values +1 or -1, for $1 \le j \le N$, and the adjacent symbols are assumed to be zero.

III. FPGA Implementation of Frame Detection in OFDM

Random data is taken by Barker Code Generator and transmitted; from the screenshots we can see that the transmitted data (original data) matches the received data. The number of slices utilized by the correlator design on Spartan-3E are 16 out of 14752 which is considerably very economical and area saving. The number of bonded IOB's is 5 out of 250 available resources, which also is very convenient. The design works at a frequency of 127MHz. If a pipelined architecture were adopted, then the operating frequency can be increased. This can be recommended for future advancements. Delay is 6.957ns, which is considerable. Total memory usage is 170 MB.

TABLE II: FPGA Resource Utilization

Resource	*Used*	*Available*	*Utilization*
IOs	5	250	2%
Function Gen.	27	384	7.03%
CLB Slices	16	14752	0.11%
Dffs or Latches	15	29504	0.05%
Macro cells	27	36	75%
Pins	5	34	15%
Function Block	39	107	36%

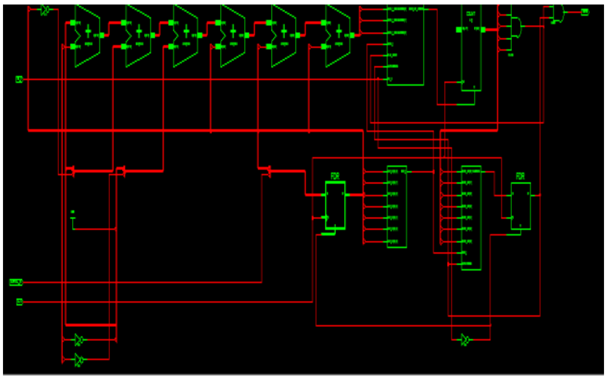

Fig. 3. RTL view of Frame Detection by using Barker Code

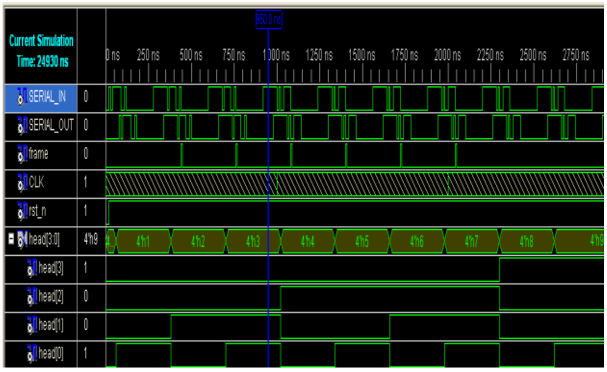

Fig. 4. Simulation waveform by using Barker Code

IV. Conclusion

Frame detection and timing acquisition are challenging tasks in orthogonal frequency-division multiplexing systems plagued by narrowband interference (NBI) in WLAN. Most existing solutions operate in the time domain by exploiting the repetitive structure of a training symbol and suffer from considerable performance loss in the presence of NBI. In this work, a novel solution in which frame detection is accomplished in the frequency domain on the basis of Barker code PN sequence generator is presented after frame detection, the test statistic is employed as timing metric to accurately locate the position of the training symbol within the received data stream. Computer simulation and Table II indicates that the solutions are remarkably robust to NBI and also it gives low area, which reduces the cost of the system.

References

[1] A. A. Eyadeh, "Frame Synchronization Symbols for an OFDM System," *International Journal of Communications*, Issue 1, vol. 2, 2008.

[2] M. I. Rahman, S. Sekhar Das, and F. H. P. Fitzek, "OFDM Based WLAN Systems," Center for TeleInFrastruktur (CTIF), Aalborg University, Tech. Rep., 2005.

[3] K. Pham Clive, *O'Connor OFDM Block Structure and Synchronization*, 2003.

[4] T. Weiss, A. Krohn, F. Capar, I. Martoyo, and F. K. Jondral, *Synchronization Algorithms and Preamble Concepts for Spectrum Pooling Systems*.

[5] L. Sanguinetti, M. Morelli, and H. Vincent Poor, "Frame Detection and Timing Acquisition for OFDM Transmissions with Unknown Interference," *Wireless Communications, IEEE Transactions*, vol. 9, Issue: 3, pp. 1226 – 1236, 1998.

[6] *IEEE 802.11b Wireless LANs Wireless Freedom at Ethernet Speeds*.

Rakhi Thakur completed her graduation in Electronics and Tele-communication in 2002, and post graduation in Microwave Engineering in 2005 from R.G.P.V. University. She is a research scholar in MANIT, Bhopal. Her research interests are VLSI and Embedded System for Mixed applications. Earlier she was HOD of EC department in SRIST, Jabalpur but since April 2010 she in Govt. Polytechnic College Jabalpur.