IEEE 802.11ac WLAN Simulation in MATLAB

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Abstract

Simulation is very easy and important way to analyse any engineering concept or prototype model before converting it into operational mode. Especially, simulation is very vital in the designing of electronic circuits because it gives cost effective result in making of printed circuit board. There are many simulation software available in the market and each one has its own merits and demerits. Researchers normally prefer to use appropriate simulation software for implementing their research topic and analysing in all aspects and thus better conclusion can be made very easy and quickly. MATLAB software is most popular simulation software in educational institutions and even for research laboratories. One of such research topics simulation in MATLAB software has been explained in this paper. IEEE Wireless Local Area Network (WLAN) 802.11ac based on Orthogonal Frequency Division Multiplexing (OFDM) technology has been simulated and tested for the purpose of studying synchronization issue in OFDM receiver. Paper focuses on basic principle of OFDM technology and its use in IEEE 802.11ac WLAN standard. It also describes IEEE 802.11ac WLAN simulation results in MATLAB software.

Keywords: MATLAB, IEEE, OFDM, WLAN, ISI, Simulation

I. INTRODUCTION

In the present era, the definition of electronic communication has been changed. Electronic communication does not simply mean to transmit information from one end and to receive information at other end. Time of transmission and quality of reception are the main parameters for any electronic communication needs to fulfill as per requirements of application for becoming commercially viable. This has opened many areas of research in the field of electronic communication especially in wireless communication. One of the important technologies to facilitate high speed communication is OFDM. OFDM is basically a special version of parallel communication which solves the problem of multipath delay restriction on speed of transmission in serial communication. The bandwidth efficiency of OFDM based parallel communication is higher than the conventional parallel communication. OFDM technology has many issues such as synchronization among sub carriers, high peak-to-average power ratio (PAPR) etc. along with benefit of spectral efficiency and simplicity in equalization. Because of multi path delay phenomena, the speed of serial communication cannot be exceeded beyond Shannon limit otherwise symbols will be distorted due to inter symbol interference (ISI). This issue is resolved in OFDM technology based parallel communication by dividing a high speed data link into several low speed data links. Thus user sends data on multiple orthogonal carriers instead on single carrier.

OFDM technology is based on old Frequency Division Multiplexing (FDM) technology. In FDM, different users send their data on allocated frequency but in OFDM, single user sends data on many closed spaced frequencies. This concept first introduced by chang in the year 1966. But it did not become commercial and popular till 1990 because of hardware complexity, issues due to large number of subcarriers and cost. Later, use of Inverse Fast Fourier Transform (IFFT) and Fast Fourier Transform (FFT) opened a way of easy implementation of OFDM technology in digital communication. Then, OFDM had been accepted for most of the high speed communication systems such as HDSL, ADSL, VHDSL, HDTV, DVB and DAB [1]. It is also taken up in the IEEE standards 802.11a/g/n/ac of wireless local area networks, HIPERLAN/2 [2] and wireless metropolitan area networks (WMAN/WiMax, IEEE 802.16) [3]. The third generation (3G) systems for mobile communication also use OFDM technology. The fourth generation (4G- LTE) systems [4] are supporting even more challenging physical layer requirements, such as video calling and streaming.

Due to tremendous benefits and wide adaptability of OFDM technology in digital communication, it has found that many researchers are involved in solving existing problems and improving quality of communication with required speed. Out of many OFDM based applications, WLAN is most suitable application and untouched research area in India. It is very important to replace complex wired LAN by WLAN based on OFDM technology. It is advisable and preferable to simulate OFDM based communication link for any research work. MATLAB is widely accepted software for simulating engineering concepts. MATLAB is user friendly software which supports model simulation too.

The paper is aimed to describe the simulation of IEEE 802.11ac WLAN standard using MATLAB software. The paper also shows results of simulation with detailed description.

II. IEEE 802.11ac link simulation

Wired Local Area Networks is now going to be outdated and it is being replaced by Wireless LAN which is OFDM based speedy and trendy technology. Because of advancement in the WLANs periodically, it becomes popular at homes, offices and even public places. Since beginning of IEEE 802.11 standard for WLAN, it has got significant response and adaptability. It is long journey of WLANs started from internet browsing, email services and moderate speed applications to high speed services include video streaming & calling and transfer of large amounts of data. It is fact that no smart mobile device or tablet is available without built in WLAN card. It is high demand to provide high speed internet connectivity to the laptop and mobile phone which force research groups to throw updated standards like 802.11ac and 802.11ad operating on the 5 GHz band and the 60 GHz band respectively. The 802.11ac is the extension of the successful standard 802.11n standard. It is also known as Very High Throughput (VHT). The 802.11ac is expanded in modulations up to 256 – QAM, bandwidth to 160 MHz and up to 8 spatial streams for making it able to deliver data at the rate of 1 Gbps theoretically.

Many standards and amendments for WLANs have been released around basic standard 802.11a since 1999 and most of them in use today. First standard 802.11a was released in 1999 operating in the 5 GHz with capability to reach a total throughput of 54 Mbps. Just after one year, in early 2000, IEEE launched 802.11b operating in the 2.4 GHz band with data rate of 11Mbps. Subsequently, in 2001, 802.11b was extended to new standard 802.11g for increasing data rate up to 54 Mbps. Later in 2009, data rate was drastically uplifted to 600 Mbps by amending standard 802.11n which is based on Multiple Input Multiple Output (MIMO) techniques.

Next part of paper describes history and simulation of IEEE 802.11ac standard [5] and point to point results. The 802.11ac is the extension of 802.11a and 802.11n standards [6] so that it reuses most of the part of these standards. 802.11ac is designed for the bandwidth of 20, 40, 80 MHz and optional 160 MHz to support data rate at least 1 Gbps theoretically. The subcarriers split from available bandwidth are separated by 312.4 KHz spacing in 802.11ac standard. Synchronization errors are solved by pilot or training sequences which are carried by few subcarriers [7]. These special designed training sequences are used as reference to estimate timing and frequency offset. Majority subcarriers are carrying data symbols. OFDM data symbol are suffixed or prefixed by sufficient guard interval (GI) to provide resistance to ISI which finally helpful to solve the problem of timing offset. This is called cyclic prefix. But it increases payload to the data frame. The GI is normally 20 % of the OFDM symbol. Considering the symbol duration of 4µs and cyclic prefix 800 ns (20 % of symbol duration) in IEEE 802.11 standards, total duration would be of 4.8 µs. It would allow receiver to handle small symbol timing inaccuracy due to delay spread of 600 ns.

802.11ac data frame is also called Very High Throughput (VHT) frame. As seen in figure 1, it can be divided in three parts; legacy preamble, VHT preamble and DATA. It is good to understand these three parts separately for simulating it. The first part of the frame, legacy preamble is used to support old versions of 802.11 standards. It is completed with three fields; Legacy Short Training Field (L-STF), a Legacy Long Training Field (L-LTF), and a Legacy Signal (L-SIG) field, same as used in 802.11a and 802.11n standards. These fields are followed by VHT preamble. This part is main part of 802.11ac which supports very high throughput. There are four fields in the second part VHT preamble which are VHT Signal-A (VHT-SIG-A), VHT Short Training (VHT-STF), VHT Long Training (VHT-LTF) and VHT Signal-B (VHT-SIG-B). Last part of frame is DATA symbols.

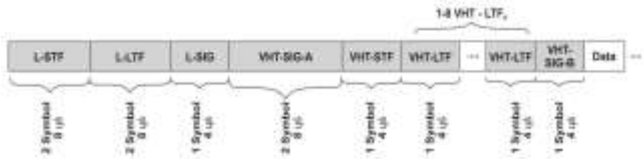

Fig. 1 802.11ac data frame

Legacy preamble is very important in 802.11ac frame to support previous standards. For 20 MHz bandwidth, 12 subcarriers are being used for carrying a Legacy Short Training Field L-STF. It looks for time and frequency synchronizations as well as automatic gain control (AGC). As per IEEE standard 802.11ac, the legacy short training sequence is represented by 10 short symbols and each symbol has 16 samples. Figure 2 shows result of the same.

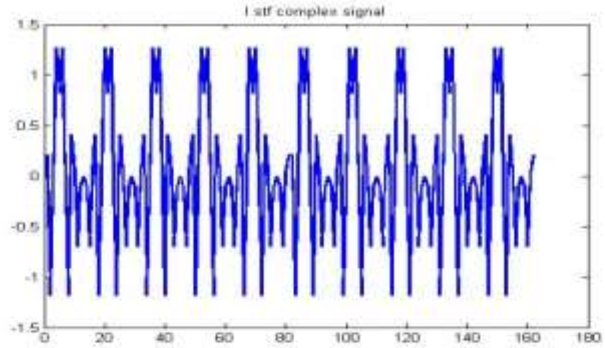

Fig. 2 Legacy Short Training Samples

Legacy Long Training Field is being carried by 52 subcarriers in 20 MHz bandwidth which is especially important for channel estimation. It is also used for fine estimation of frequency offset and thus it provides fine tuning of frequency synchronization. As per IEEE standard 802.11ac, the legacy long training sequence is represented by 2 long symbols of each 64 samples with long guard interval of 32 samples. Figure 3 shows waveform of L-LTF.

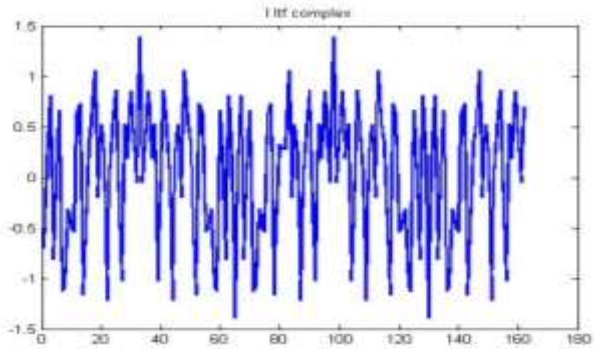

Fig. 3 Legacy Long Training Samples

L –SIG is the last field in legacy preamble which specifies data rate and length of packet as shown in figure 4.

Fig. 4 L-SIG Field

As per IEEE standard 802.11ac, the legacy signal field is represented by 1 symbol of 81 samples. Figure 5 shows waveform of L-SIG.

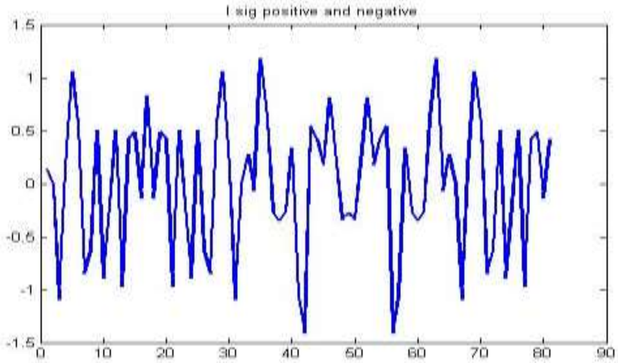

Fig. 5 L-SIG Waveform

VHT preamble is the second and main part of 802.11ac frame. The fields of this part are used by only 802.11ac standard and the devices based on previous standards 802.11a and 802.11n ignore them. The VHT-SIG-A field consists of two symbols each having 24 bits. The first symbol VHT-SIG-A1 is Binary Phase Shift Keying (BPSK) modulated with binary convolution coding of rate ½ and VHT-SIG-A2 is Quadrature BPSK modulated. They depict channel bandwidth, coding and whether frame is for single user or multi users. It also contains field to indicate whether a short GI is used or not, type of encoding, beam forming as shown in figure 6.

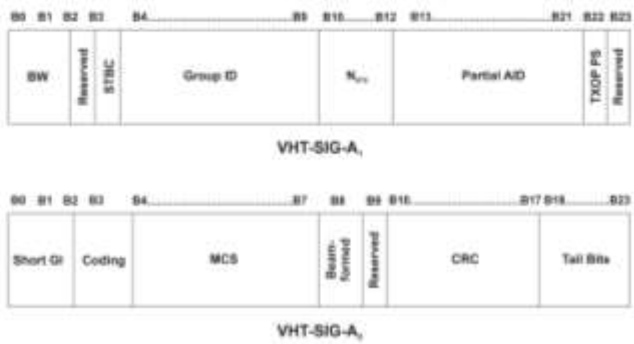

Fig. 6 VHT-SIG-A Field

VHT-SIG-A filed consists of 2 symbols of each has 81 samples. Figure 7 shows waveform of VHT-SIG-A field.

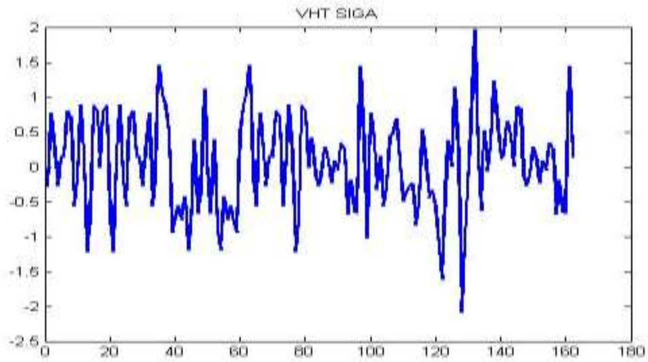

Fig. 7 VHT-SIG-A Waveform

After coarse timing estimation, fine estimation is performed using field VHT-STF. This field also provides information for controlling gain automatically in MIMO OFDM transmission. This field is similar to L-STF and carries a small portion of the subcarriers, while remaining subcarriers are all set to zero. As per IEEE standard 802.11ac, the VHT STF field is represented by 1 symbol of 81 samples. Figure 8 shows its simulated waveform.

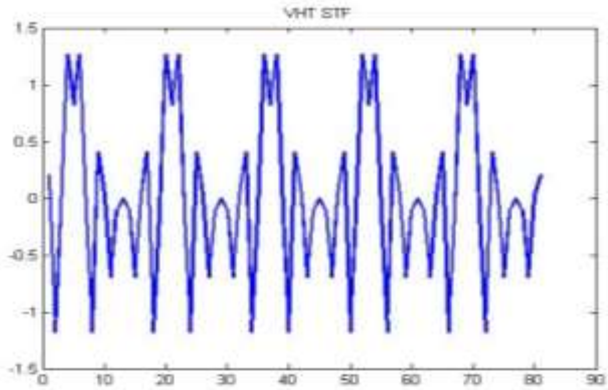

Fig. 8 VHT-STF Waveform

Channel estimation and equalization is being done in MIMO receiver with the help of VHT-LTF. Its simulating waveform is shown in figure 9. It is also one symbol of 81 samples.

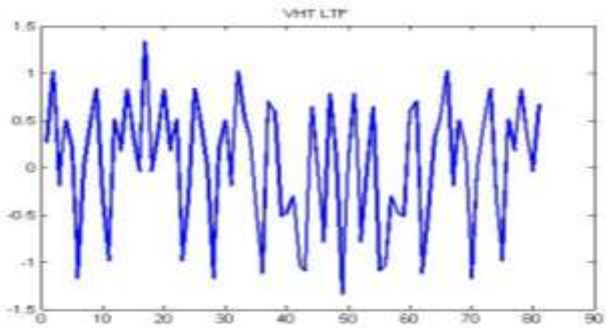

Fig. 9 VHT-LTF Waveform

One symbol of VHT-SIG-B field with Bipolar Phase Shift Keying modulation indicates the length of the transmitted data. Figure 10 shows fields of VHT-SIG-B for single user and VHT-SIG-B for different bandwidths.

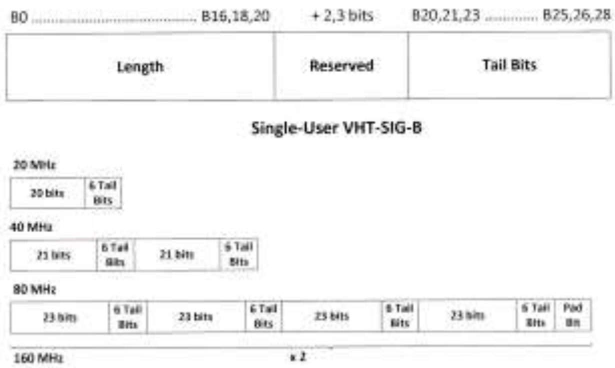

Fig. 10 VHT-SIG-B Field

As per IEEE standard 802.11ac, the VHT SIG-B field is represented by 1 symbol of 81 samples. Figure 11 shows its simulated waveform.

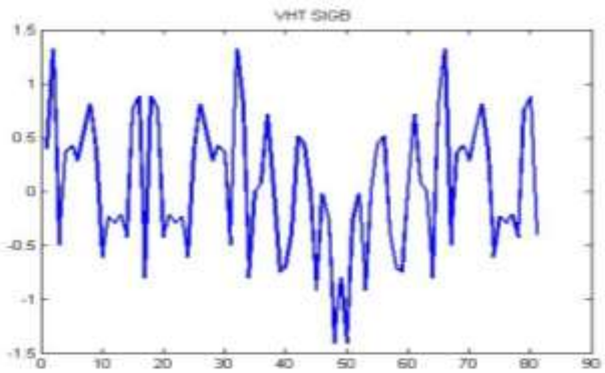

Fig. 11 VHT-SIG-B Waveform

The last part of the 802.11ac frame is DATA field. It consists SERVICE field and Physical layer Service Data Unit (PSDU) followed by optional padding and tail bits. Number of OFDM symbols in PSDU to be transmitted is variable which is set in L-SIG field. Service field also carries information about scrambler initialization. Thus, Out of 165 symbols of 802.11ac frame, 10 symbols are preamble symbols as mentioned in legacy preamble and VHT preamble part. Remaining 155 symbols are data symbols. Figure 12 and 13 are simulating waveform of 802.11ac data field and 802.11ac complete filed including preamble field.

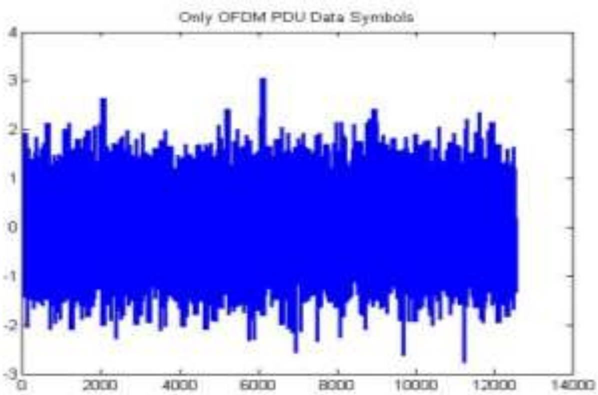

Fig. 12 DATA Field Waveform

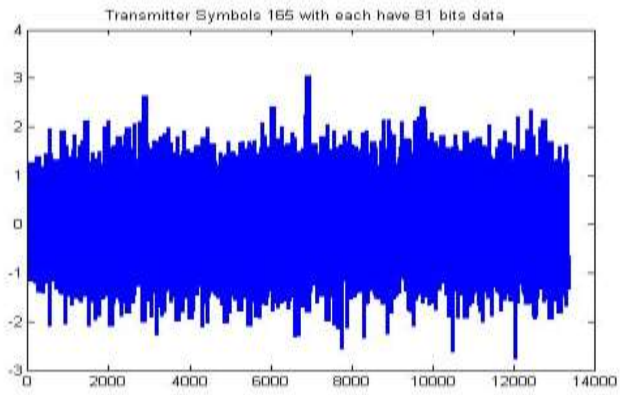

Fig. 13 802.11ac Transmitted Frame Waveform

III. Testing and Validation

Any software does not show error if program coding is done as per syntax of programming language. Program only shows syntax error. It does not show logical error. So there is always needed to test and validate program as per theoretical knowledge and algorithm. In this case, understanding of 802.11ac frame and right way of designing its mathematical model is very important for accurate simulation of IEEE 802.11ac link. As this standard is based on wireless communication, Bit Error Rate V/s Signal to Noise Ratio graph study is one of the measures of quality. Proper selection of channel in reference to application is also very important to study BER V/s. SNR. IEEE 802.11ac signal was then passed through channel and observed errors. Objective of simulation was to apply algorithm to minimize synchronization error. This simulation was used for implementation of various synchronization algorithms [8]. One of the results is shown in figure 14.

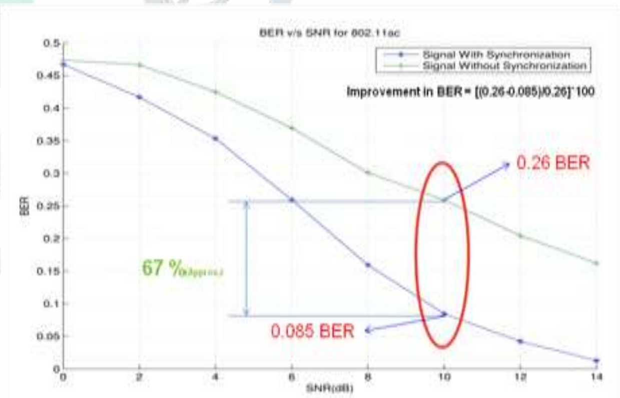

Fig. 14 BER V/s. SNR for IEEE 802.11ac link

IV. CONCLUSION

We have studied IEEE 802.11ac standard which was released in December, 2013. This is amendment to previous 802.11a standard which was released in March 2012. We have also tested and verified simulation results at each stage of transmitter link. Complete link was also tested without channel and with channel. It is found that it is accurate simulation of 802.11ac for studying and implementing any research issue of IEEE 802.11ac WLAN.

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