Effects of Fixed Point FFT on the Performance of OFDM in Wireless LAN

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ABSTRACT
This paper analyzes the effects of fixed point Fast Fourier Transform (FFT) computation in Orthogonal Frequency Division Multiplexing (OFDM) for Wireless Local Area Network (WLAN) application. The performance of WLAN has been investigated using Matlab simulations under Additive White Gaussian Noise (AWGN) channel for different modulation schemes. The simulations carried out here, show the effects of fixed point FFT on the performance of OFDM used in wireless LAN. Extensive computer simulations show that fixed point computation provides very near result as floating point if the delay parameter is suitably selected.

Categories and Subject Descriptors
C.2.1 **[Network Architecture and Design]:** *Wireless communication*

General Terms
Performance, Reliability, Experimentation.

Keywords
Wireless LAN, OFDM, fixed-point FFT, floating-point FFT.

1. INTRODUCTION
With the rapid growth of digital wireless communication in recent years, the need for high speed mobile data transmission has increased. Many wireless communication systems being developed use OFDM to achieve high data rates. OFDM is a strong candidate and has been suggested or standardized in high speed communication Systems like WLAN [1]. OFDM technique has taken a long time to be of prominence practically. The hardware solution, which makes use of multiple modulators and demodulators, was somewhat impractical for use in the civil systems. The ability to define the signal in the frequency domain, in software on VLSI (very large scale integration) processors, and to generate the signal using the inverse Fourier transform is the key to its current popularity.

OFDM systems are better than single-carrier systems in multi-path fading channel environment [2]. OFDM is used in many high data rate transmission systems, for example, digital video broadcasting (DVB), IEEE 802.11, IEEE 802.16, HIPERLAN Type II, many derivatives of digital subscriber line (DSL) and Home networking etc [3, 4]. It is projected that OFDM systems are the strongest candidate for 4G systems.

This paper investigates the effects of finite word length in FFT implementation for WLAN application. More particularly the investigation shows that performance of WLAN using floating point computation can be achieved by using fixed point implementation, if number of bits used for fraction part is selected suitably.

The paper is organized as follows. Following the introduction, the fundamental concepts of OFDM and principles behind OFDM is outlined in Section 2. Section 3 discusses on WLAN standards. Section 4 and 5 discusses the Floating-point and the Fixed-point representation respectively. Section 6 is dedicated for discussion on experimental results. Finally, section 7 provides the concluding remarks.

2. OFDM
OFDM is the most popular scheme now for higher bit rate applications. This has built in orthogonality and works on basis of simple frequency analysis. Spectrum utilization in OFDM is much higher [5]. Guard band protects interferences. OFDM is implemented using fast computation of FFT. The incoming serial data is first converted form serial to parallel and grouped into 'x' bits each to form a complex number. The number 'x' determines the signal constellation of the corresponding sub carrier, such as BPSK, QPSK, 16 QAM, 64QAM, and 256 QAM. The complex numbers are modulated in the base band by the inverse FFT (IFFT) and converted back to serial data for transmission. The receiver performs the inverse process of the transmitter [6].

3. WIRELESS LAN STANDARDS
The Institute of Electrical and Electronics Engineers (IEEE) has established a committee to setup standards for Local Area and Metropolitan Area Networking named the "802 LMSC" (LAN MAN Standards Committee). Within this committee the 802.11 workgroup has task of developing the standards for wireless networking [7]. Within this 802.11 workgroup, there are task

groups with even more specific tasks, and these groups are designated with an alphabetic character such as “a”, or “b”, or “g”. Salient features of the existing WLAN standards are shown in the Table 1.

Table 1. 802.11 standards

IEEE Standard	Release Date	Frequency	Maximum Data Rate
802.11	1997	2.4 GHz	2Mbps
802.11a	1999	5GHz	54 Mbps
802.11b	1999	2.4GHz	11 Mbps
802.11g	2003	2.4GHz	54 Mbps
802.11n	2007 (projected)	2.4 / 5GHz	540 Mbps

4. FLOATING-POINT REPRESENTATION

The IEEE standardizes floating-point representation in IEEE 754. Floating-point representation is similar to scientific notation in that there is a number multiplied by a base number raised to some power. For example, 118.625 is represented in scientific notation as 1.18625 x 10^2. The main benefit of this representation is that it provides varying degrees of precision based on the scale of the numbers. For example, it is beneficial to talk in terms of angstroms (10-10 m) when working with the distance between atoms. However, dealing with the distance between cities, this level of precision is no longer practical or necessary. IEEE 754 defines binary representations for 32-bit single-precision and 64-bit double-precision (64-bit) numbers as well as extended single-precision and extended double-precision numbers. Examine the specification for single-precision, floating-point numbers, also called floats. A float consists of three parts: the sign bit, the exponent, and the mantissa. The sign bit is 0 if the number is positive and 1 if the number is negative. The exponent is an 8-bit number that ranges in value from -126 to 127. The exponent is actually not the typical two's complement representation because this makes comparisons more difficult. Instead, the value is biased by adding 127 to the desired exponent and representation, which makes it possible to represent negative numbers.

5. FIXED-POINT REPRESENTATION

The In fixed-point representation, a specific radix point - called a decimal point in English and written "." is chosen so there are fixed number of bits to the right and fixed number of bits to the left of the radix point. The bits to the left of the radix point are called the integer bits [8]. The bits to the right of the radix point are called the fractional bits. In this example, assume a 16-bit fractional number with 8 magnitude bits and 8 radix bits, which is typically represented as 8.8 representations. Like most signed integers, fixed-point numbers are represented in two's complement binary. Using a positive number keeps this example simple. To encode 188.625, first find the value of the integer bits. The binary representation of 118 is 01110110, so this is the upper 8 bits of the 16-bit number. The fractional part of the number is represented as 0.625 x 2n where n is the number of fractional bits. Because 0.625 x 256 = 160, binary representation of 160, which is 10100000, is used to determine the fractional bits. Thus, the binary representation for 118.625 is 0111 0110 1010 0000. The value is typically referred to using the hexadecimal equivalent, which is 76A0. Fixed point can be represented either by signed number or unsigned number.

6. RESULTS

Simulation tests were conducted for effect of fixed point FFT computation in WLAN applications. The system was modeled using Matlab. The aim of doing the simulations was to measure the performance of base band OFDM under AWGN channel conditions, for different modulation schemes like BPSK, QPSK, 16-QAM, and 64-QAM. In all simulations WLAN IEEE 802.11a standard are adapted. OFDM simulation Parameters are shown in the Table 2.

Table 2: OFDM simulation Parameters

Parameter	Value
Modulations used	BPSK,QPSK,16QAM, 64 QAM
FFT size	64
Number of carriers used	64
Guard time	16 samples
Guard period type	Cyclic extension of the symbol

Figure 1 presents the bit error rate performance of OFDM against signal to noise ratio (SNR) for different modulation schemes The results shows that using QPSK, the transmission can tolerate a SNR of >10dB. The bit error rate (BER) drops as the SNR drops below 6dB. However, using BPSK allows the BER to be improved in a noisy channel, at the expense of transmission data capacity. Using BPSK the OFDM transmission can tolerate a SNR of >6-8dB. In a low noise link the capacity can be increased by using 16-QAM and 64-QAM. In this experiment floating point FFT was used and the result can be considered as best possible for reference.

Next performance of OFDM using fixed point computation incorporated in IFFT and FFT was compared with the performance of floating point FFT implementations. Fixed point FFT was simulated for word lengths of 8 bit and 16 bit, assuming use of 8 bit and 16 bit DSP processors.

Simulation studies were undertaken first for 8 bit. The performance of BPSK and QPSK based WLAN systems are presented at Figure 2 and 3 respectively. The BER performance against SNR was evaluated for different combinations of integer part lengths and fractional lengths of 2, 4, 6, and 0.From the results it is seen that the performance of 8 bit fixed point WLAN is far from floating point implementation.

Following this 16 point implementation was tested. The performance of BPSK, QPSK, 16-QAM, and 64-QAM based WLAN systems are presented at Figure 4 to 7 respectively. In these figures, the BER performance against SNR was evaluated for different combinations of integer part lengths and fractional lengths of 6, 8, 10, and 12,14,0. From these it is seen that the performance of each modulation system reaches its peak value when the fractional part is 8-12 bits. Moreover the performance similar to floating point implementation when the fractional part is closest to half the bit length used to represent variables in FFT/IFFT.

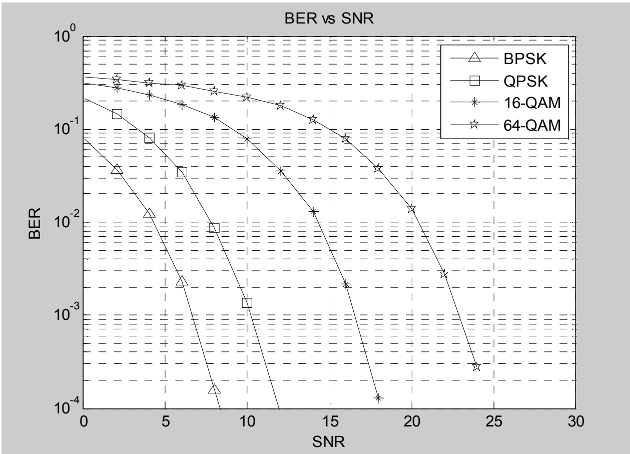

Figure 1. BER vs. SNR plot for OFDM using BPSK, QPSK, 16-QAM, 64-QAM

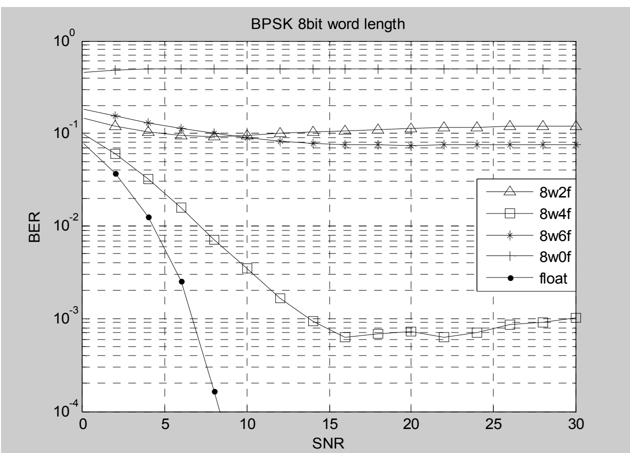

Figure 2. BER vs. SNR of OFDM using BPSK modulation and fixed point FFT of word length 8 bits

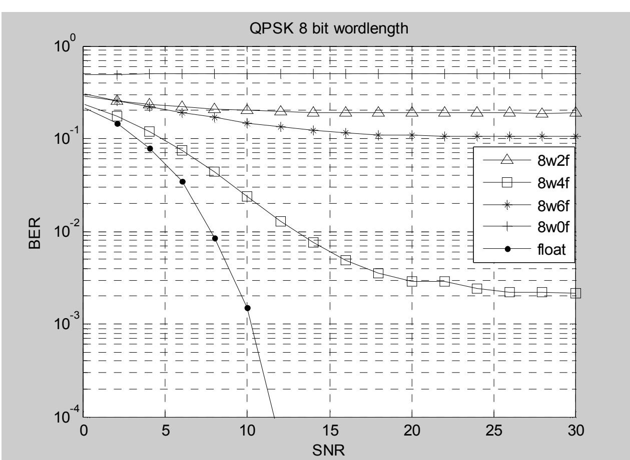

Figure 3. BER vs. SNR of OFDM using QPSK modulation and fixed point FFT of word length 8 bits

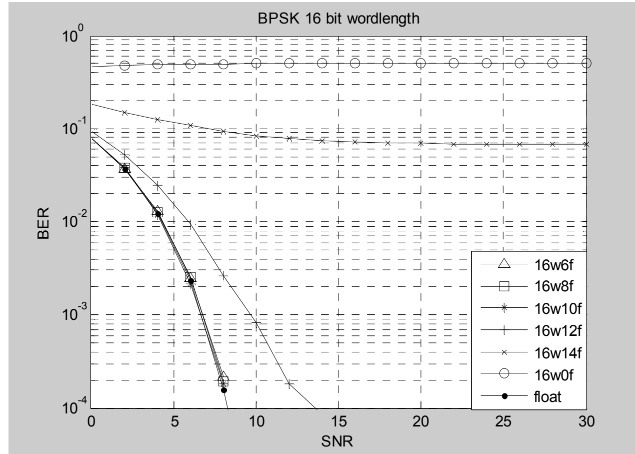

Figure 4. BER vs. SNR for OFDM using BPSK modulation and fixed point FFT of word length 16 bits

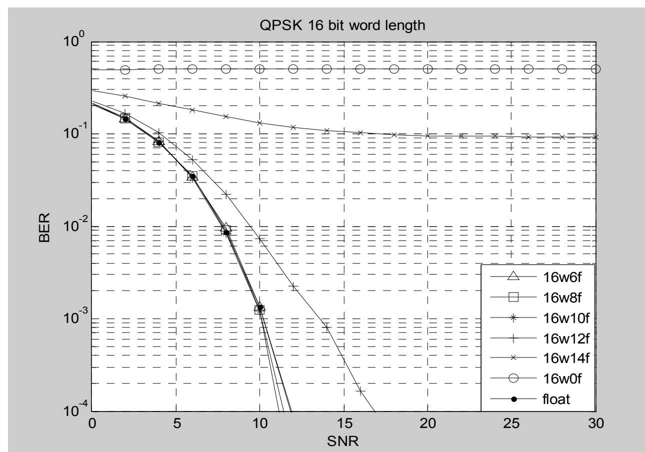

Figure 5. BER vs. SNR for OFDM using QPSK modulation and fixed point FFT of word length 16 bits

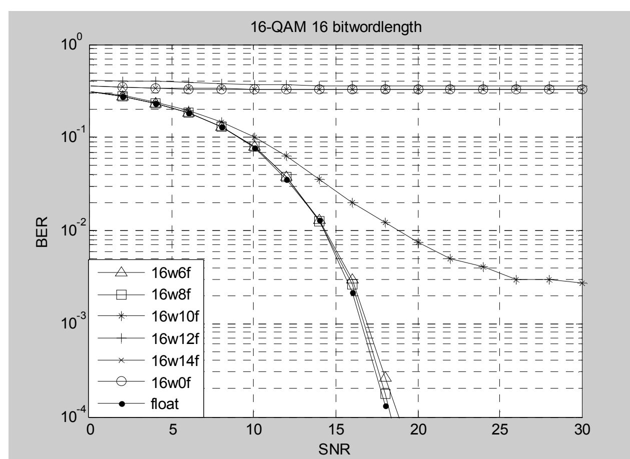

Figure 6. BER vs. SNR for OFDM using 16-QAM modulation and fixed point FFT of word length 16 bits

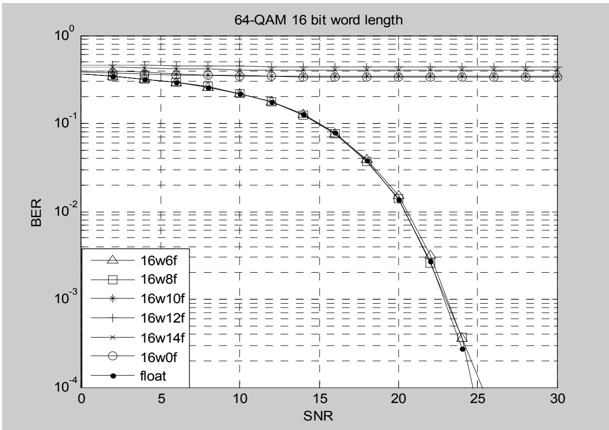

Figure 7. BER vs. SNR for OFDM using 64-QAM modulation and fixed point FFT of word length 16 bits

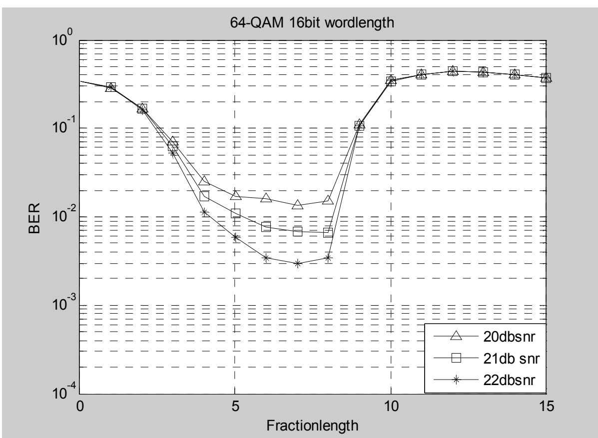

Figure 8. BER vs. fraction length of OFDM using 64 -QAM modulation and fixed point FFT of word length 16 bits.

Figure 8 presents the performance of WLAN system for 20 dB, 21 dB, and 22 dB SNR. The BER Performances are plotted against number of fractional bits used out of 16 bit representation. From this it is seen that fractional part should be 6-8 bits out of 16 bits representation.

7. CONCLUSION

From the simulation studies conducted, it is seen that word length of 8 bits is not sufficient to achieve desired BER performance with respect to floating point performance for any combination of integer part lengths and fractional part lengths. In case of input word length of 16 bits, it is seen that fixed-point FFT provides nearly similar performance to floating point FFT if the fraction size parameter is suitably selected. Again it also seen that the fraction part is of half the size of word length, the system provides best performance.

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