Multiband Orthogonal Frequency Division Multiplexing Based Ultra Wideband System

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ABSTRACT

Multiband OFDM based Ultra Wideband (UWB) system combines OFDM modulation technique with a multi banding approach, which divides the spectrum into several sub-bands, whose bandwidth is approximately 500MHz. Three band multi band OFDM systems have been designed using a time frequency code of length 3. The important blocks in the transmitter side are QPSK modulator, IFFT, DAC, up converter and time frequency code generator to provide multiple access and frequency diversity. We model channel as a simple delay element. A basic receiver just follows the inverse of the transmission process so important blocks in the receiver side are down converter, ADC and FFT.

OFDM based system is very sensitive to timing and frequency offsets, the received constellation is slightly different from transmitted constellation due to processing delay and additional delay introduced from the channel. This paper provides the analysis of impact of delay on OFDM based UWB system.

Keywords- Multibanding, OFDM, UWB.

I. INTRODUCTION

Shannon-Hartley theorem shows that higher data rate can be achieved at a faster rate by increasing the bandwidth rather than the received SNR according to equation-1

$$C = B\log_2(1+SNR) \qquad (1)$$

Channel capacity of UWB system operating at 7.5GHz BW is 7.5GB/S for SNR of 0dB. So, UWB falls in the power limited regime. FCC has restricted the maximum power limit for UWB system to -41.3dBm/MHz close to noise floor [1]. The traditional way of emitting UWB signal is by radiating the pulses of very short duration and hence also given the name of Impulse Radio (IR) which is not much popular in present day scenario. The problems of single band impulse radio technology are summarized as [2]:

- Inherent implementation difficulties of truly wideband circuit design as design of active circuits that perform well over large bandwidth is challenging and usually gives rise to increased cost and power consumption.
- High sample rates in digital to analog converters (DACs) and analog to digital converters (ADCs).
- Single band UWB signals are not so well suited to low-cost RF-CMOS implementations.

Multiband UWB (MB-UWB) signaling is simply the division in the frequency domain of a single UWB signal into multiple sub-bands. These sub-bands may be transmitted in parallel or sequentially and may be received by separate receive paths or one single frequency-agile receiver [3].

This paper is organized as follows. Section I give the introduction to UWB and need for MB-UWB. Section II describes the Orthogonal Frequency Division Multiplexing (OFDM) and MB-OFDM UWB. In Section III we give the system model and simulation parameters used in the study. Section IV gives the simulation results. Finally section V concludes the paper.

II. MULTI-BAND ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

OFDM is a type of multi channel modulation that divides a given channel into many parallel sub-channels or sub-carriers, so that multiple symbols are sent in parallel so that each sub-carrier experience a flat channel. An OFDM signal consists of *N* orthogonal sub-carriers modulated by *N* parallel data streams. Each baseband sub-carrier is of the form given by equation-2

$$\phi_k(t) = e^{j2\pi f_k t} \qquad (2)$$

where, f_k is the frequency of k_{th} sub-carrier. $\phi_k(t)$ forms an orthonormal basis function. One baseband OFDM symbol multiplexes *N* modulated subcarriers as given by equation-3.

$$s(t) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} x_k\phi_k(t) \qquad 0 < t < T_S \qquad (3)$$

where, x_k is the k_{th} complex data symbol taken usually from a QPSK constellation and T_S is the length of the OFDM symbol, $T_S = NT$ where *N* is the number of sub-carriers and *T* is the base band elementary period. The subcarrier frequencies f_k

are equally spaced as $f_k = k / T_S$ which makes the subcarriers $\phi_k(t)$ on $0 < t < T_S$ orthogonal.

2.1 OFDM System Implementation

For continuous time implementation as in equation-3 it needs *N* oscillators and DACs, which is of very high complexity. So, discrete time implementation of equation-3 is commonly used in practice, which is achieved by *T* spaced sampling as given by equation-4

$$s(nT) = IDFT(x_k) \quad (4)$$

IDFT is implemented by using IFFT and the frequencies are orthogonal because the basis function of Fourier transform is orthonormal. The modulation and demodulation of OFDM using FFT's is shown in Fig. 1.

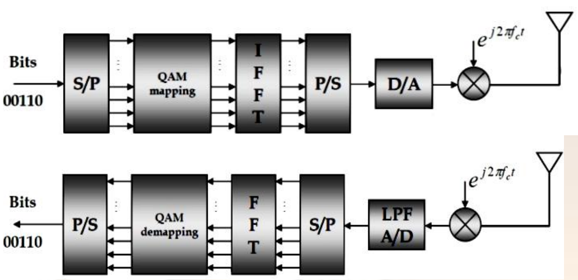

Fig 1: OFDM Modulator and Demodulator using FFT

2.2 Multi Band OFDM

In MB approach the transmission of data for a given user occurs on different sub-bands (each of at least 500MHz) in subsequent periods of time. Different types of modulation schemes can be adopted for data modulation within each sub-band. The most popular is OFDM so the name MB-OFDM UWB.

In each sub-band, OFDM is applied. Frequency hopping between different bands is supported, so for every symbol duration the transmitted signal hops between sub-bands [4].

In MB approach, the spectrum is divided into 14 bands (each with a bandwidth equal to 528 MHz), and devices are allowed to statically or dynamically select which bands to use for transmission. The entire spectrum is divided into 4 distinct groups. Only Group A is intended for first generation devices because of current technology limitations. Other groups have been reserved for future use. Fig 2 shows time-frequency coding for the MB-OFDM system, where the first OFDM symbol is transmitted on sub-band 1, the second OFDM symbol is transmitted on sub-band 3, the third OFDM symbol is transmitted on sub-band 2, the fourth OFDM symbol is transmitted on sub-band 1, and so on [5].

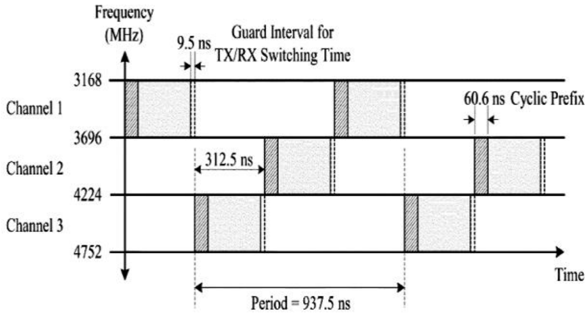

Fig 2: T-F coding for MB OFDM

III. System Model

The system model in Fig. 1 can be used to implement OFDM based UWB system by suitably choosing the pass-band carrier frequency. For MB-OFDM UWB simulation we need time frequency kernel to switch the center frequencies between three bands as shown in Fig. 2. The complete system level block diagram is shown in Fig. 3.

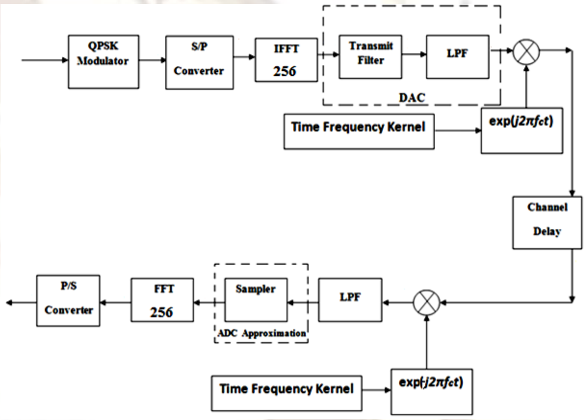

Fig 3: System level block diagram of MB-OFDM UWB

The simulation parameters are shown in Table 1.

Table 1: MB-OFDM based UWB system parameters used in the simulation

Simulation Parameter	Value
Center frequency (f_c)	3432MHz, 3960MHz, 4488MHz
Number of Subcarriers (N)	128
Constellation	QPSK
FFT Size	256
OFDM Symbol Duration (Ts)	$242.4e{-}9S$
Baseband Period (T)	$242.4e^{-9}/128S = 1.89nS$
Subcarrier Separation (f)	$528/128 = 4.1250MHz$
System Bandwidth	$528MHz$
TFC Number	3
Transmit Filter Duration	$T/2 = 0.9469nS$
Transmit LPF cut-off frequency	$1/T = 528MHz$
Transmit spectrum power	Always less then $-41.25dBm/MHz$

IV. RESULTS

The time domain and frequency domain plot of the transmitted OFDM signal is shown in Fig. 4, which is below the FCC mask.

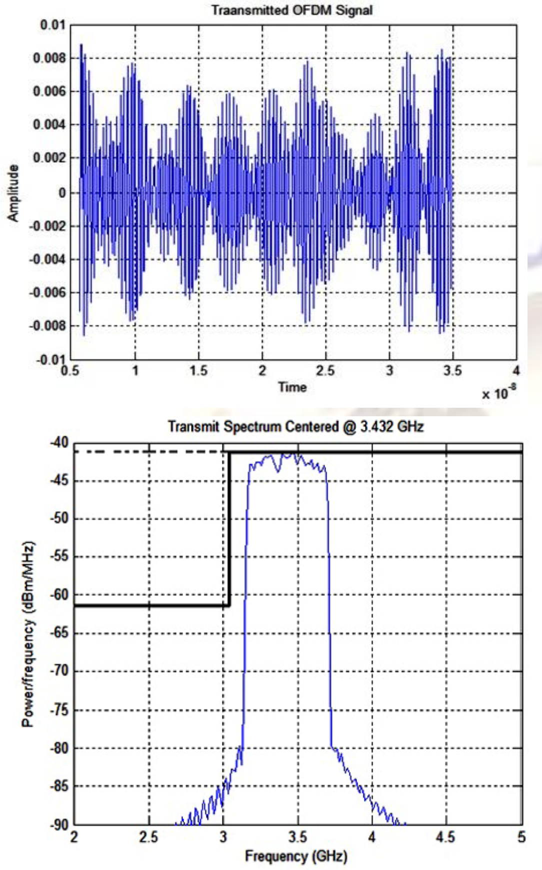

Fig 4: Time response and Frequency response of transmitted OFDM signal.

The transmitted constellation and received constellation after passing through ideal delay channel is shown in Fig. 5 and Fig. 6.

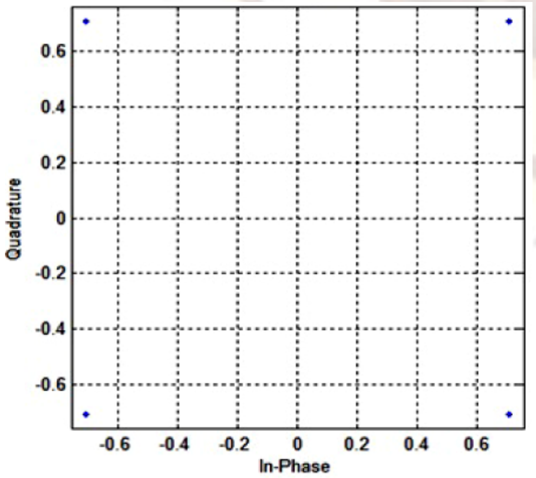

Fig 5: Transmit QPSK Baseband Constellation

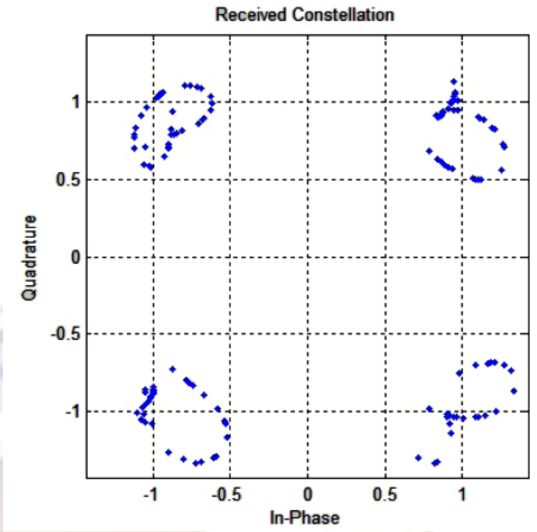

Fig 6: Recovered QPSK Constellation

V. CONCLUSION

The UWB provides opportunities for new applications as well as enhancements to the existing products in the communication industry due to its large bandwidth, high data rate and low power consumption. MB based OFDM in UWB provides additional advantage in multipath environment. For a sub channel, channel can be considered as approximately flat which comes from the OFDM implementation.

This paper provides the analysis of impact of channel delay and processing delay on OFDM based UWB system.

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