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Integration of UWB Services with High Speed Transmission Coherent OFDM Network

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Abstract- The target of this paper is to offer a feasibility study of integration UWB services with implemented coherent orthogonal frequency division multiplexing (CO_OFDM) network. The simulation results are adduced of transmission 1.25 Gb/s Gaussian monocycle with single or multi-channel CO-OFDM signals using on-off keying (OOK) and bi-phase modulation (BPM) with 65 Gb/s QPSK per channel. The aim of this work is to trace the interfering influence between the services of wireless and wired. Simulation results indicate that the performance of the UWB system is slightly degraded in the presence of CO-OFDM transmission, while the CO-OFDM system is not affected by the presence of UWB signals.

Keywords- *UWB Signal, Monocycle Pulse, CO-OFDM*

I. INTRODUCTION

Ultra wideband (UWB) communication is an emerging technology that utilized very low energy level for transmitting data over a wide part of the spectrum of radio [1]. The field of UWB communication almost remained restricted and limited to military and government uses until onset of February 2002 in which the Federal Communication Commission (FCC) has allocated 7.5 GHz (3.1-10.6) GHz for unlicensed use of UWB communication services with a transmitted power spectral density (PSD) of less than -41.3 dBm/MHz for indoor application [2]. UWB over fiber (UWBOF) attracts increasing interest in recent years to extend the coverage area of UWB services [3, 4]. Because of the exponential growth of global communication traffic, the quest for transmission over the long haul with high spectral efficiency has been studying intensively [5]. High order modulation formats and advanced signal processing are the key technology to increase the spectral efficiency (SE) in these advanced optical communication systems [6, 7]. Recently, optical orthogonal frequency division multiplexing has opened up to sophisticated modulation schemes and high order modulation formats for long haul optical communication systems [8]. The integration of optical OFDM with UWB formats attracted many interests in recent years due to tolerance to inter symbol interference (ISI) and multipath fading, the ability to provide multiple access inherent to multiband techniques, and capability of passing through walls while preserving communication [9]. In fact, coherent optical (CO-OFDM) is considered a promising candidate for future long haul capacity transmission system [10]. This is mainly due to advantage in overcoming transmissions impairments such as polarization mode dispersion and chromatic dispersion, in addition to its high spectral efficiency.

The aim of this paper is to address the potential of a merge of UWB wireless services into implement coherent optical orthogonal division multiplexing through DWDM system and to trace the interfering influence between the services of wireless and wired.

II. GENERATION UWB MONOCYCLE PULSE IN ELECTRICAL DOMAIN

A normal signal that can be taken into account as a basic function for UWB transmission can be generated in the simplest method by a pulse generator is a Gaussian pulse. The first derivative of Gaussian pulse represented the Gaussian monocycle pulse. The zero mean function of Gaussian expressed as [11]

$$g(t) = \exp\left(\frac{-2t^2}{\sigma^2}\right) \quad (1)$$

Where σ represented as full width the pulse of Gaussian corresponding to e^{-1} power point. The fundamental of Gaussian waveforms named electrical Gaussian pulse represented by $Y_{g1}(t)$ expressed as (2) [12]

$$Y_{g_1}(t) = K_1.\exp\left(-\frac{t^2}{\tau^2}\right) \quad (2)$$

Where K1 is a constant, τ represent the time delay difference, and $-\infty < t < \infty$. Additional waveforms can be generated by a sort of filtering of a Gaussian pulse. This filter works in a manner like to take the derivatives of equation (2). By taking the first derivative of Gaussian pulse, a Gaussian monocycle can be generated as in equation (3)

$$Y_{g_2}(t) = K_2.\frac{-2t}{\tau^2}.\exp\left(-\frac{t^2}{\tau^2}\right) \quad (3)$$

Where $Y_{g_2}(t)$ represent Gaussian monocycle and K20is a constant. Monocycle pulse has one zero crossing, so, for each additional derivative gives additional zero crossing. At any rate, if the value of time scaling factor τ is constant, the identical fraction bandwidth decreases by taking an extra derivative, while the center frequency increases. Figure (1) shows a Gaussian and monocycle pulse.

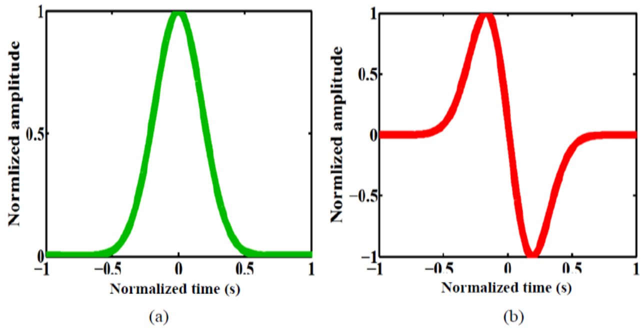


Figure 1. a) Gaussian Pulse, b) Monocycle pulse

III. SINGLE CHANNEL DESCRIPTION OF COHERENT OFDM FIBER TRANSMISSION LINK

The transmission link of this system that illustrates in figure (2) contains a number of spans; each span consists of SMF and DCF with 80km and 16km length, respectively. The simulation parameter of this system is listed in the table (1) using 65 Gb/s QPSK signaling.

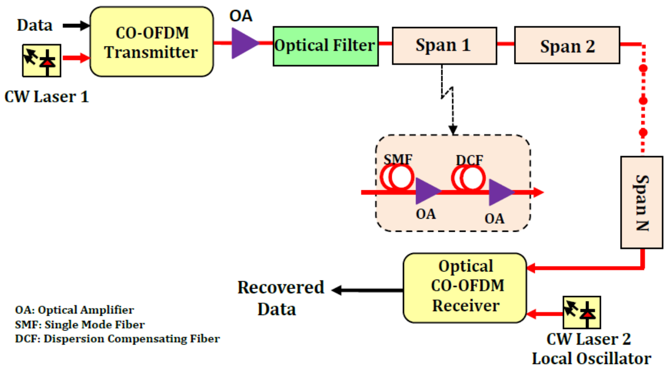


Figure 2. Block diagram of a transmission link of Coherent OFDM system

TABLE I. SIMULATED PARAMETER VALUE OF 65 GB/S QPSK FOR TRANSMITTER AND RECEIVER

Parameter	Value	Units
Bit per symbol for modulator/demodulator	2	Bit
Number of subcarriers	128	
Number of FFT/IFFT points	256	
Position array	64	
Transmitter laser power	-4	dBm
Transmitter laser frequency	193.1	THz
Booster amplifier gain	10	dB
Optical filter bandwidth	40	GHz
Local oscillator laser power	0	dBm
Local oscillator laser frequency	193.1	THz

The simulated signal channel system divides into two parts: CO-OFDM transmitter and CO-OFDM receiver.

A. *Transmitter structure*

This section consists of two main parts: RF OFDM transmitter and radio to optical (RTO) converter. In the RF OFDM transmitter that shown in figure (3) is build utilizing sequence generator. The transmitter consists of OFDM modulator and two low pass Roll off filter. The main work of this part: the signal is mapped onto QPSK modulator and converted from the frequency domain into the time domain by using IFFT [13]. While in the RTO converter that shown in figure (4) is installed using CW laser, X-coupler, two LiNb-MZM, and a power combiner. The work of this part that an optical (I/Q) modulator used to upshift the baseband OFDM [14, 15].

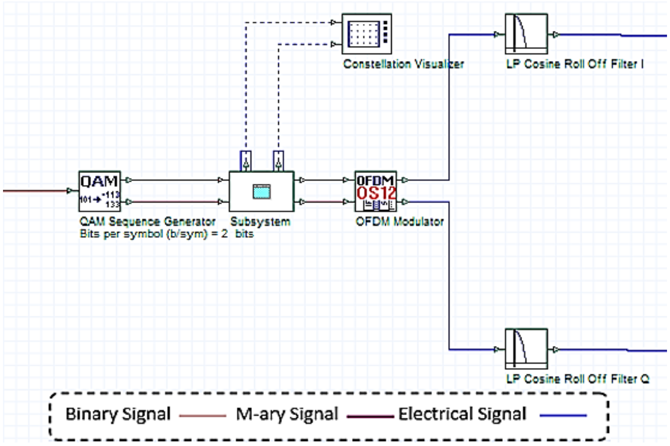


Figure 3. Block diagram of RF OFDM transmitter

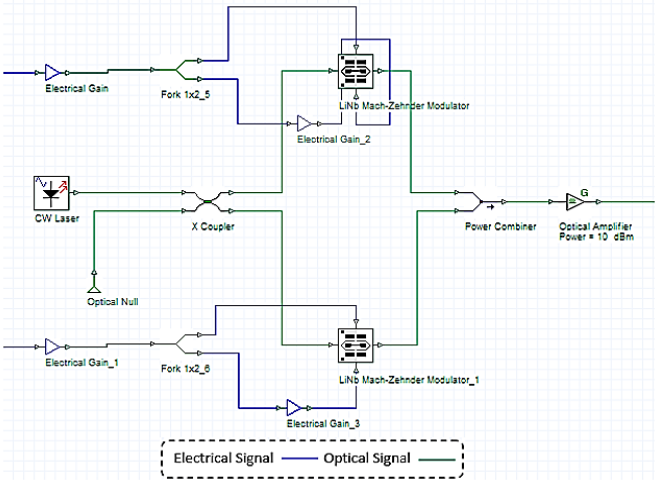


Figure 4. Block diagram of RTO up converter

B. Receiver Structure

After the signal pass through an optical fiber, it converts into an electrical signal. The receiver section is built with two parts as the section of transmitter: optical to radio converter (OTR) and RF OFDM receiver.

In the OTR converter that shown in figure (5) used to generate I and Q component after subtracting the output of photocurrent from the two photodiodes. While RF OFDM receiver is shown in figure (6), the RF signal is fed to an OFDM demodulator to sample by high-speed analog to digital converter and find the original symbol transmitted by FFT transformer [13]. Then by using QPSK decoder and NRZ pulse generator to generate and receive the electrical signal.

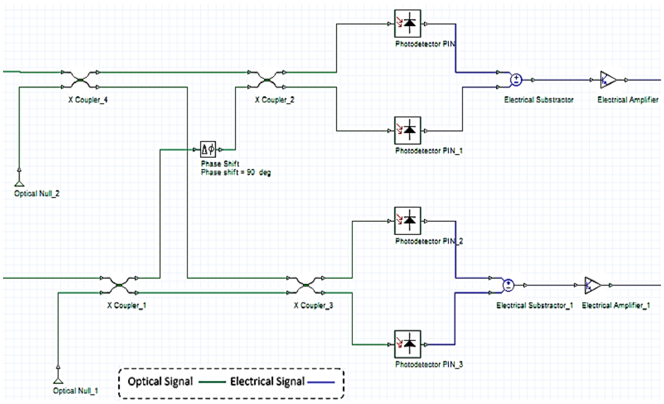


Figure 5. Block diagram of OTR down converter

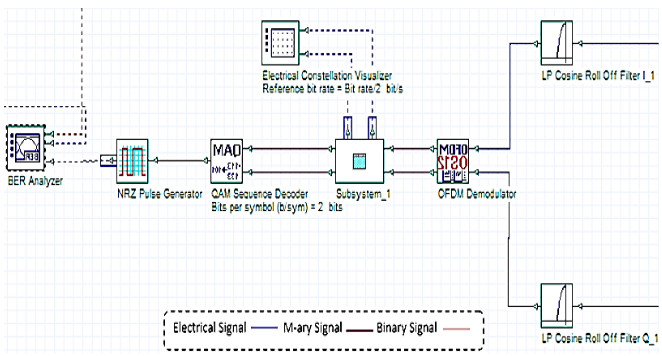


Figure 6. Block diagram of RF OFDM receiver

IV. SIMULATION RESULTS

One of a challenged since the presence of wireless services is an apportionment of wireless communication signals over implemented optical networks because of the services of wireless may influence the performance of the existing wired services. In this work, study the interfering effect between the signals of UWB and CO-OFDM. This work consists of three parts. Firstly, transmission single CO-OFDM signal through fiber transmission link to calculate the value of bit error rate (BER) corresponding to 10^{-9} of this system that considers for reference objective. After that, integration UWB wireless signal with single channel CO-OFDM. Finally, assess the performance of UWB wireless signal with a multi-channel CO-OFDM system.

A. Coherent OFDM Fiber Transmission link

As shown in figure (2), the transmission link contains a number of spans. Figure (7) represents the variance of BER with the number of spans that represent the length of the transmission link.

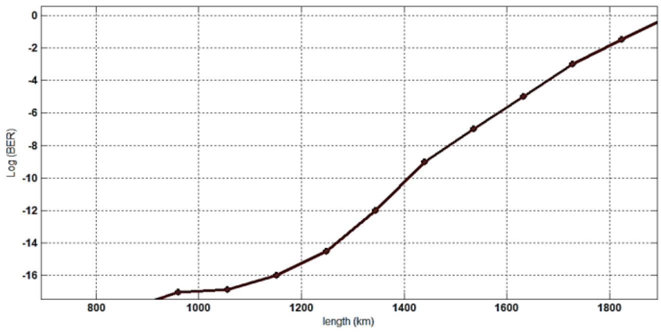


Figure 7. BER as a function of link length for a single channel CO-OFDM system

From the figure, it can conclusion to get a BER equal 10^{-9} at the receiver when the length of the transmission link is about 1440 km. Figure (8) represents the received constellation diagram after 1, 13, 15, and 17 spans and the corresponding value of BER at these distance are 1.2×10^{-17}, 8.1×10^{-15}, 2.3×10^{-9}, 4.3×10^{-5}, respectively.

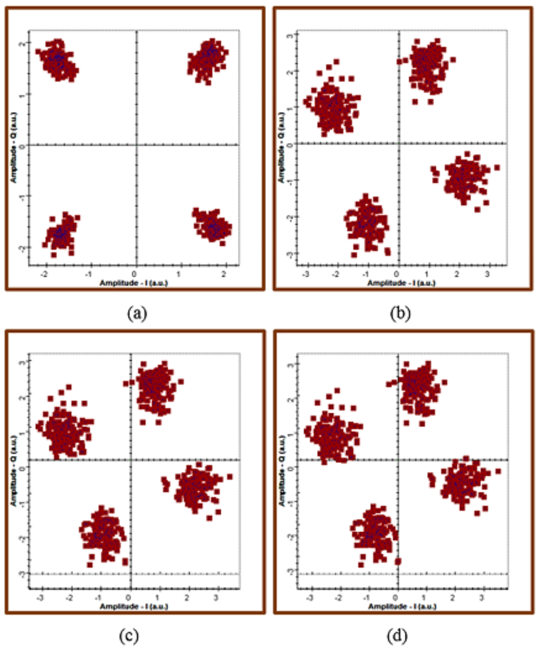


Figure 8. Constellation diagram of the received coherent OFDM after transmission over (a) one span (b) 13 spans (c) 15 spans (d) 17 spans

B. *Integration UWB Signal with Single Channel Coherent OFDM Using DWDM System*

The block diagram of UWB with CO-OFDM using 50 GHz DWDM system illustrated in figure (9). In the part of transmitter side, multiplexing UWB signal with CO-OFDM signal into DWDM multiplexer. The output of the multiplexer is launched into multi-span (SMF and DCF) optical link. The demultiplexer is used after the first span to obtain the signal of UWB.

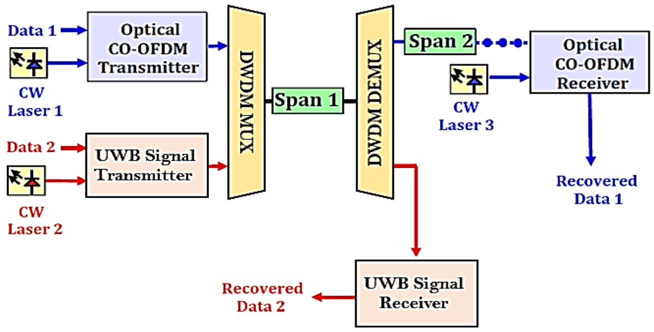


Figure 9. Block diagram of UWB with CO-OFDM /DWDM system

Table (2) list the BER for UWB monocycle for both OOK and BPM after transmission over one span without and with a CO-OFDM signal.

TABLE II. BIT ERROR RATE PERFORMANCE OF UWB SIGNAL AFTER TRANSMISSION OVER ONE SPAN (96 KM) WITH A SINGLE CHANNEL CO-OFDM SIGNAL

Modulation Formats	BER	
	Without CO-OFDM	With CO-OFDM
OOK	2.54×10^{-9}	2.98×10^{-9}
BPM	8.9×10^{-16}	1.29×10^{-15}

From the result of the table conclusion two points about the system performance of the channel DWDM system:

1- The BER of UWB signal with CO-OFDM is greater than without it, and therefore, the presence signal of CO-OFDM is affected slightly on the performance of UWB signal, on the contrary, the transmission of UWB signal will not effect on the transmission performance of the CO-OFDM because the BER is staying constant to 1.2×10^{-17} after transmission over one fiber span.

2- The performance of UWB signal is calculated by the measure of degradation that introduced to describe the normalized bit error rate BER_n. The measure of degradation (MOD) is defined as:

$$MOD = \log(BER_n) \quad (4)$$

Where,

$$BER_n = \frac{BER_{RC}}{BER_s} \quad (5)$$

Where BER_{RC} represent the received BER of each channel, and BER_s represent the BER identical to a single channel. If MOD equal to zero, that means BER=1, and this represents that the DWDM system inserts not any power penalty compared with the single channel. While, if MOD more than zero, that means the performance of the received channel is degraded compared with the single channel.

Therefore, the performance of UWB signal in BPM is degraded more than in OOK. This is clear in the measure of degradation of the two types that is equal to 0.16 in BPM compared with 0.069 in OOK. Figure (10) show eye diagram of the receiver UWB signals after transmission over 96 km for OOK and BPM merging with a CO-OFDM.

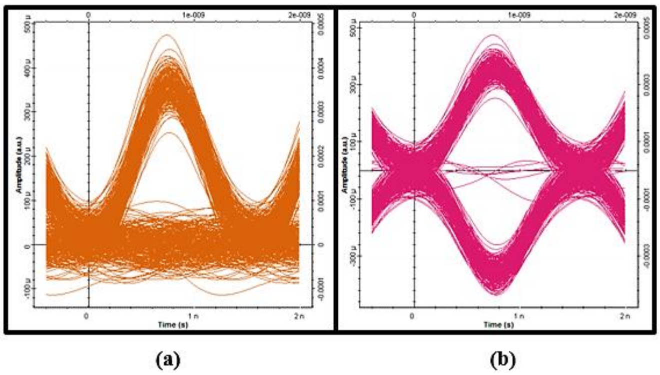


Figure 10. Eye diagram of the received signal for monocycle pulse after transmission over 96 km with CO-OFDM signal for (a) OOK (b) BPM

To show the spectrum of the multiplexed signal corresponding to OOK and BPM with CO-OFDM, figure (11) illustrates it.

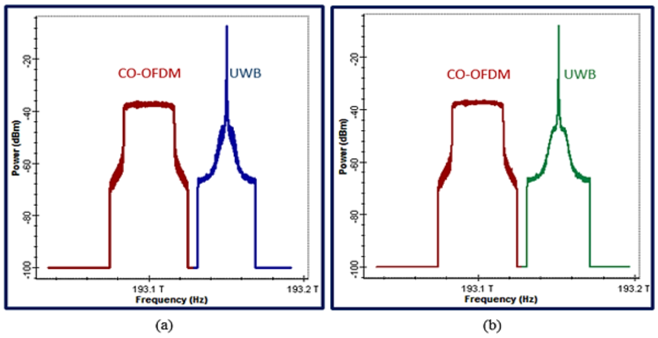
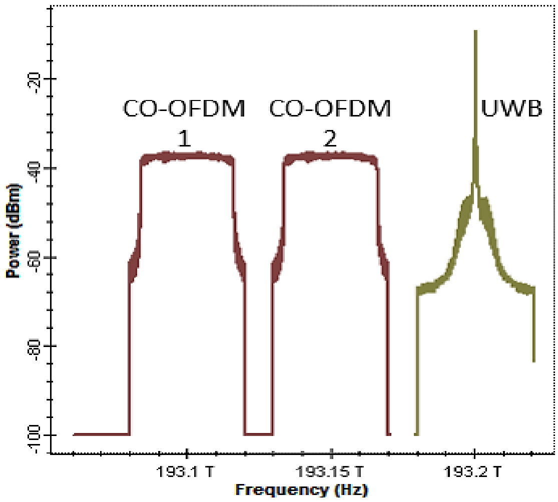


Figure 11. Spectrum of the optical signal generated by a multiplexed CO-OFDM signal with UWB signal monocycle pulse for (a) OOK (b) BPM

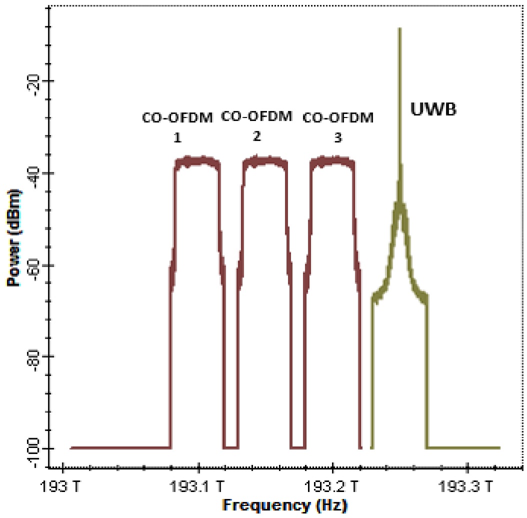
As shown in the figure above, there is frequency guard between CO-OFDM and UWB signal and this enables to recover safely the UWB signal without interfering with OFDM signal.

C. Performance of UWB Signal Multiplexing with Multi-Channel Coherent OFDM System

The simulation implementation in subsection (4.2) is repeated in this part but the difference here is using UWB signal once with two CO-OFDM and then with three CO-OFDM to research the effect of these signals on the performance of UWB signal. Figure (12) show spectrum of a multiplexed signal with two and three channel CO-OFDM with UWB-OOK signal.



(a)



(b)

Figure 12. Spectrum of the optical signal generated by multiplexed UWB monocycle OOK signal with, a) two-channel CO-OFDM system, b) three channel CO-OFDM system

Table (3) illustrates the effect of the presence of the signals of OFDM on the performance of the transmitted UWB signal by calculating the value of BER for two type modulation formats.

TABLE III. BIT ERROR RATE PERFORMANCE OF UWB SIGNAL AFTER TRANSMISSION OVER (96 KM) WITH TWO AND THREE CHANNEL CO-OFDM SIGNAL.

Number of CO-OFDM signals	Modulation formats	BER		MOD
		Without CO-OFDM	With CO-OFDM	
Two	OOK	2.54×10^{-9}	3.27×10^{-8}	1.1
	BPM	8.9×10^{-16}	1.33×10^{-12}	3.17
Three	OOK	2.54×10^{-9}	2.52×10^{-8}	0.99
	BPM	8.9×10^{-16}	3.09×10^{-13}	2.5

From the table notice that the performance of UWB signals increase degradation in the presence of the signal of CO-OFDM and this effect is increased and more pronounced for monocycle BPM signaling by calculating the value of the measure of degradation and show that is equal 3.17 and 2.5 in two and three channel, respectively. On the other hand, a CO-OFDM signal of two and three channel doesn't affect in the presence of UWB signal and its equal after one span (96 km) in two state 1.2×10^{-17}. Figure (13) show the BER as a function of total length for the three CO-OFDM channels.

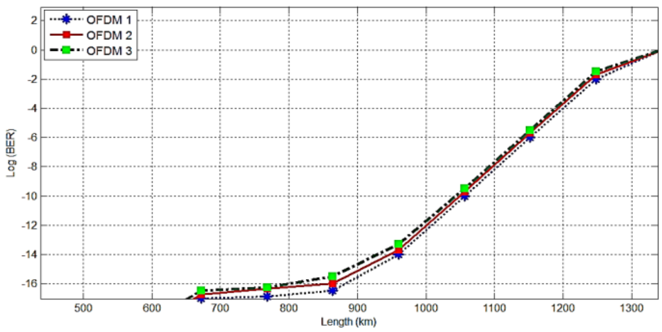


Figure 13. BER as a function of total length for three channels of OFDM in UWB-OFDM/DWDM system

V. CONCLUSION

The integration of UWB wireless services with coherent OFDM network using DWDM system have been investigated. Simulation results for this system have been shown transmission 1.25 Gb/s Gaussian monocycle with single or multi-channel CO-OFDM signal with 50 Gb/s channel spacing DWDM system. Simulation results show that in the presence of CO-OFDM transmission, the performance of the UWB system is slightly degraded and the degradation is more pronounced in BPM signaling. The MOD for this case is 0.16 compared with 0.06 in OOK signaling. While when presence two or three signal of CO-OFDM, the MOD in BPM is 3.17 and 2.5 while in OOK is 1.1 and 0.99 in the state of two and three signal of CO-OFDM, respectively. However, the BER of the CO-OFDM system is not affected by the presence of any type of UWB signals.

VI. ACKNOWLEDGEMENT

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