International Journal of Current Advanced Research
ISSN: O: 2319-6475, ISSN: P: 2319-6505, Impact Factor: SJIF: 5.995
Available Online at www.journalijcar.org
Volume 6; Issue 10; October 2017; Page No. 6795-6802
DOI: http://dx.doi.org/10.24327/ijcar.2017.6802.1018

Research Article

MODULATION DETECTION FOR A NEW MULTI-USER ULTRA WIDE BAND SYSTEM BASED ON M-OAM

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A R T I C L E I N F O

Article History:

Received 15th July, 2017
Received in revised form 19th August, 2017 Accepted 25th September, 2017
Published online 28th October, 2017

Key words:

IR-UWB based on M-OAM, DS-MGF-UWB, Modulation detection.

A B S T R A C T

In a wireless communication system, especially in the field of transport, the possibility of multi-useris present in the same frequency band. To ensure best quality of information exchange and a high data rate, it necessary to establish an efficient communication management algorithm.
This paper presents an original multiple access technique that provides good performances for several and various users simultaneously. A model based on the principle of Cognitive Radio that is able to detect the modulation typewith the presence of noise is also described.

INTRODUCTION

Transportation system covers two types of communication: vehicles to vehicles (V2V) and vehicles to infrastructure (V2I) links. These vehicles should share different kinds of information with different priority, and different level of importance. Therefore data reliability and high data rate are the main constraints to develop an intelligent inter-vehicles communication system.

The main context of Intelligent TransportationSystem (ITS) is to optimize the use of the usual means of transport.This optimization achieves safer use of transport and best sharing of several resources. Various systems based on Ultra Wide Bandtechnology (UWB) have already been implemented in ITS for main three applications: short range radar, localization systems and communications V2V & V2I [3]. In this paper a new communications system Impulse Radio IR-UWB (Impulse Radio UWB) is proposed,it'sbased on a new modulation M-OAM (Orthogonal Amplitude Modulation) which offers the highest data rate with low complexity of implementation [2][5]. This system is dedicated to theshort range wireless applications, especially ITS and multimedia communications. Cognitive Radio (CR) is one aspect of communication system for ITS.Itis an emerging wireless communications technology that treats the efficiency of current radio spectrum usage. It can intelligently sense and interpret the communication environment. It adapts the transmitting and receiving parametersin order to provide the most efficient bandwidth and ensure execution autonomy.

The proposed system provides high data rate UWB system by using M-OAM modulation with a high number of users simultaneously by implementing a new multi-user technique DS-MGF-UWB, which overcomes the limitations of existing techniques DS-UWB and MFG-UWB[10]. The main objective of the proposed work is to develop an algorithm that permits to detect the modulation type used by each user with the presence of noise. Modulation detection algorithm can help to distinguish the modulation type of the signal at thereceiver, with minimum a priori information [16].

The remainder of the paper is organized as follows. Section2 details the M-OAM modulations that exploited the Modified Gegenbauer Function (MGF) andincreases the data rate. Then, Section 3 describes the principle of Cognitive. The principle of the proposed and the algorithm of modulation detection are explained intelligentin Section 5. Section 6 analyzed the results of the simulation under Matlab and of the experimental tests in real conditions. Section 7 summarizes the results andpresents the prospects.

UWB System Based on M-OAM modulation

UWB is a Radio technology that modulates impulse based waveforms instead ofcontinuous carrier waves. Ultra Wideband Advantages are summary as follow [5][18]:

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Capacity

- Possibility of achieving high throughput

Low power and Low cost

- Can directly modulate a baseband pulse
- Can be made nearly all digital
- High capacity with lower Tx power levels

Fading robustness

- Relatively immune to multipath effects
- Path delay ~1ns > pulse duration

Position location capability

- Developed first as radar technology

The proposed IR-UWB system that presentedin Figure 1 is Based on continuous transmission of very short-time impulse radio which have very large bandwidth of the order of a few GHz, it not require the use of an additional carrier modulation. It is characterized specially by an original OAM modulation which provides high data rate and low complexity compared to classical UWB modulations [10][11]

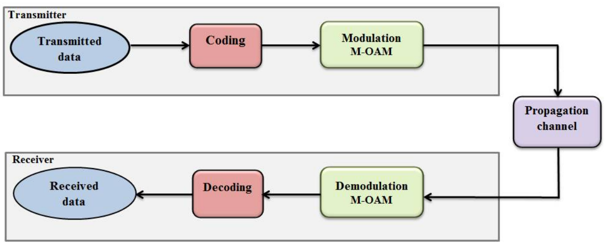

Figure 1 Block diagram of the proposed UWB system based

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UWB Waveforms

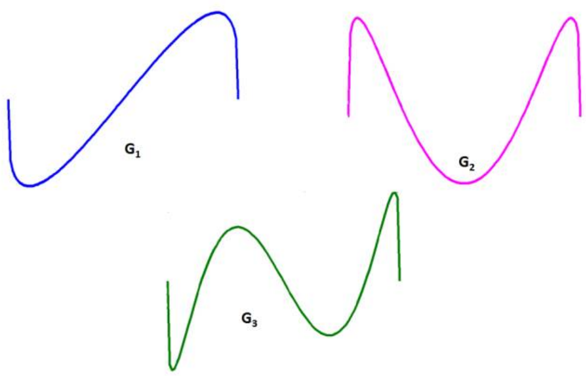


Figure 2 Third orders of Gegenbauer

Many types of waveforms could be used to generate the UWB. According to a previous work [10], the orthogonal polynomials MGF gives better performances in term of bit error rate. These polynomials are defined in theinterval [-1,1].They satisfy the differential equation 1 withβ=1 [1][3][4][6]. Figure 2 illustrates an example of third orders of MGF waveforms [12][13][14]:

$$
\begin{aligned}
&(1-x^2)\ddot{G}(n,\beta,x)-(2\beta+2)x\dot{G}_n(x) \\
&-n(n+2\beta+2)G_n(x)=0
\end{aligned}
\quad (1)
$$

With: β>-1

$\dot{G}$: The first derivate of G

$\ddot{G}$: The second derivate of G

n : Order of Gegenbauer polynomial

M-OAM modulation

The mean idea is to exploit the principle of the QAM Modulation, by replacing Cos by an order of Gegenbauer polynomials and sin by a second order [3][17]. Let take 16-OAM as an example, the chosen waveforms for this modulation are G_1 and G_2:

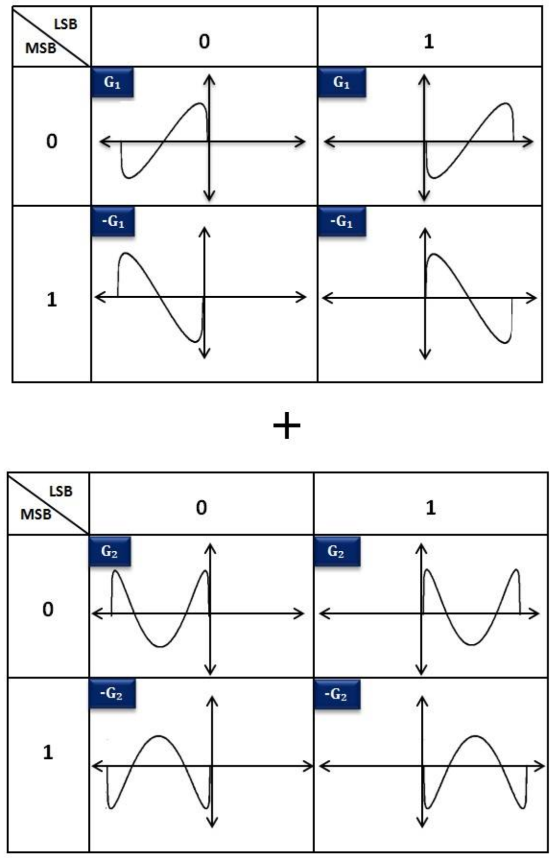
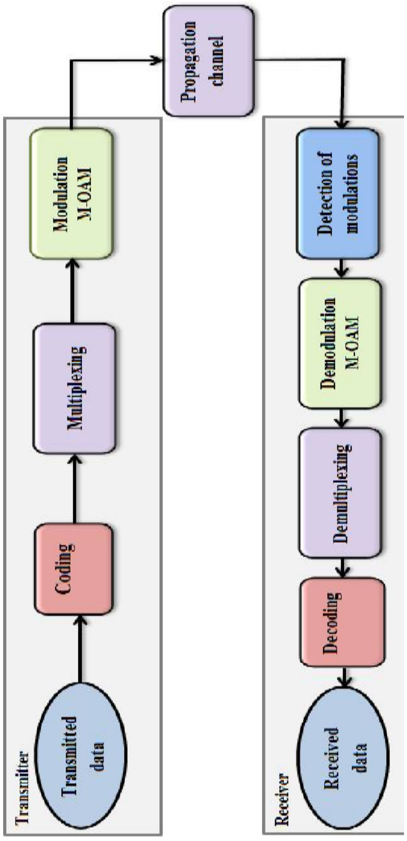


Figure 3 The symbols of 16-OAM modulation

The principle of the 16-OAM modulation consists on transmitting 4 bits/symbol (2 bits/sub-symbol). There are sixteen possible combinations of pulse for this modulation. For each sub-symbol, the first bit presents the position of the pulse and the second bit presents the phase. Two levels are used in this case, for example G_1 and G_2. The transmitted signal is the sum of the three obtained signals.

Consequently, modulation 16-OAM multiplies the data rate by a factor of four compared to a classical UWB system. The possible combinations of the pulse for this modulation are illustrated in Figure 3.

The data rate offered by the others modulations are given in Table 1.



n	M states	Modulation	Data rate
2	4	4-OAM	2D
3	8	8-OAM	3D
4	16	16-OAM	4D
5	32	32-OAM	5D
6	64	64-OAM	6D

The originality of this work is based on the combination of the UWB and the cognitive radio in order to develop an intelligent multi users system. The receiverof the proposed system isable to detect the modulation exploited on the transmission. The next section described the principle of the Cognitive Radio.

Cognitive Radio

The IEEE tasked the IEEE 1900.1 group to define cognitive radio, which came up with the following definition [7] [19]: "A type of radiothat can sense and autonomously reason about its environment and adapt accordingly".

This radio could employ knowledge representation, automated reasoning, and machine learning mechanisms in establishing, conducting, or terminating communication or networking functions with other radios.

Cognitive radios can be trained to dynamically and autonomously adjust its operating parameters.

The following are some general capabilities found in most of the definitions [9][16]:

1. ***Observation:*** whether directly or indirectly, the radio is capable of acquiring information about its operating RF environment.
2. ***Adaptability:*** the radio is capable of adapting to different electromagnetic environments and different channel conditions.
3. ***Intelligence:*** The radio has the ability to apply information towards a specific goal, such as improved performance.

Based on the principle of cognitive radio, the proposed algorithm is able to identify the type of the modulation used at the transmission to adapt the process to the required decoding technique.

Proposed system associating multiple access and the modulation detection

Proposed algorithm of modulation detection

According to Figure 6, to identify the type of the used modulation (4-OAM, 6-OAM, 64-OAM or no OAM modulation used), the employedwaveforms should be exploited.

- G_1 is used for BPSK
- G_1 is used for PPM
- G_1 is used for 4-OAM
- G_1 and G_2 are used for 16-OAM
- G_3, G_4 and $G_5$are used for 64-OAM

To detect the used modulation, the first step consists to correlate the received signal with G_1. We decide:

BPSK:if the distance between the results peaks is the same.

PPM:if results peaks are positives and the distance between themis different.

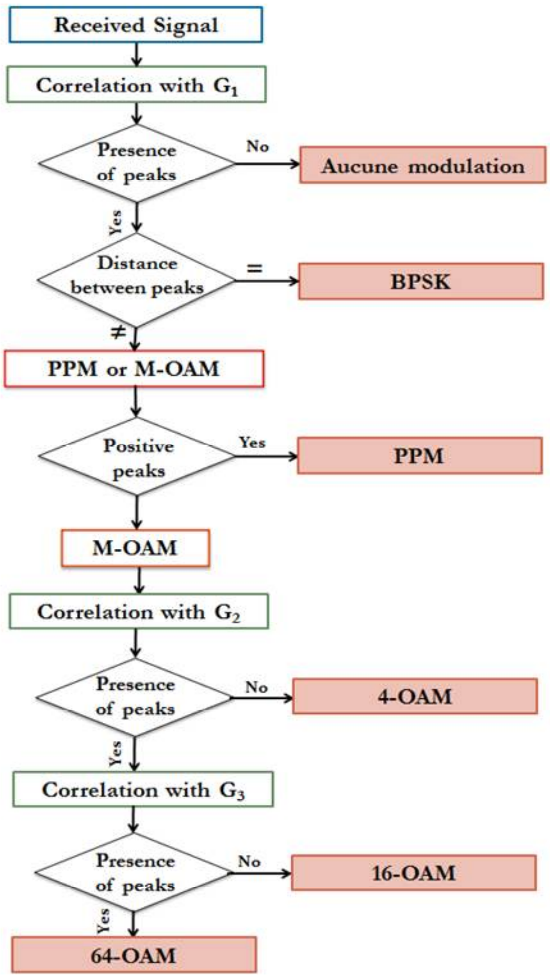


Figure 4 Block diagram of modulation detection

4-OAM: if the distance between the results peaks is different and they are positives and negatives.

16-OAM: the correlation with $G_2$is executed; finding the peaks means that the used modulation is 16-OAM.

64-OAM: according to the results of the algorithm 16-OAM algorithm part, if there are any peaks, the received signal is correlated with G_3, G_4 and G_5. If the peaks are detected, the used modulation is 64-OAM.

No OAM modulation used: if no peak is found through all previous correlations that mean that there is any M-OAM modulation used for the system.

Design of the multi-user systemDS-MGF-UWB

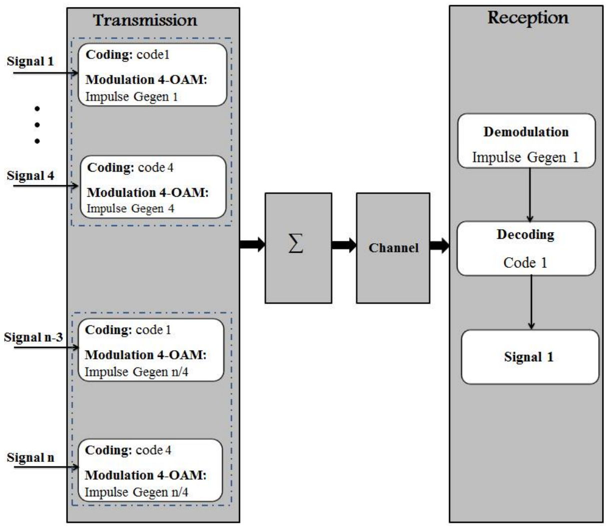


Figure 5 Block diagram of the new DS-MGF–UWB system

According to a previous work [10], the architecture of the new DS-MGF-UWB system is based on combining two existing technologies: DS-UWB (Direct Sequence Ultra Wide Band) and MGF-UWB (Modified Gegenbauer Function Ultra Wide Band). This choice allows exploiting the double orthogonally of Gold codes and MGF waveforms [10].

At the same time, good performancesare ensured in terms of BER. This approach were tested by simulations and validated by experiments. The block diagram of the system is illustrated in Figure 5. This figure shows the blocks of the transmitter, the channel and the receiver.

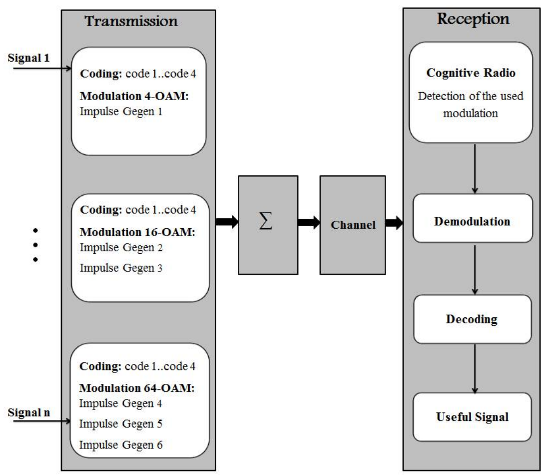


Figure 5 Block diagram of modulation detection for DS-MGF–UWB system

The principle of this new system is to create sub-groups of n users. In each sub-group, the user signals are spread with the DS-UWB technology and modulated with the same Gegenbauer waveform. Between the subgroups, we change the order of MGF waveforms.

The results of [10] show that the choice of number of users per group depends on the length of the spreading code used and that the best orthogonality of MGF waveform is presented for the first seven degrees. Subsequently, with this new technique, it possible to move from N users presented in a DS-UWB system to 7×N users with the new system and with the same performance by the classical system of N users.

Unique waveforms for each modulation		
Cases	***Combinations***	***Number of users***
Case 1	**(1)4-OAM**	**1**
Case 2	**(1)4-OAM+(1)16-OAM**	**2**
Case 3	**(1)4-OAM+(1)16-OAM+(1)64-OAM**	**3**
Case 4	**(2)4-OAM+(1)16-OAM+(1)64-OAM**	**4**
Case 5	**(2)4-OAM+(2)16-OAM+(1)64-OAM**	**5**
Case 6	**(2)4-OAM+(2)16-OAM+(2)64-OAM**	**6**
Case 7	**(3)4-OAM+(3)16-OAM+(3)64-OAM**	**9**
Case 8	**(4)4-OAM+(4)16-OAM+(4)64-OAM**	**12**
Case 9	**(8)4-OAM+(4)16-OAM+(4)64-OAM**	**16**
Case 10	**(4)4-OAM+(8)16-OAM+(4)64-OAM**	**16**
Case 11	**(12)4-OAM+(4)16-OAM+(4)64-OAM**	**20**

New modulation detection algorithm

According to Figure 6, the proposed intelligent receiver of the system IR-UWB based on M-OAM is able to identify the used modulation by each user [8][15][19].

The principle of this system consists to create N sub-groups, where N depends on the number of users. In each subgroup, the user signals are modulated by the same Gegenbauer waveform and each user is defined by a special Gold code.

Simulations and experimental results

According to a previous experimental test [10], the better results are given by the use of the first seven waveforms orders and fourth gold code orders. G_0 don't give the same performances but can be used in case of need of a large number of users.

The performance of the system is computed for the three modulations 4-OAM, 16-OAM and 64 OAM. To prove the efficiency of the proposed algorithm is to calculate BER (Bit Error Rate) according to the SNR (Signal to Noise Ratio) directly after the detection.

The simulated cases can be divided into two sub-groups:

- ***Sub-group 1:*** Unique waveforms for each modulation (Table 2).
- ***Sub-group 2:*** Same waveform can be used in several modulations (Table 3).

Same waveforms used in several modulations		
Cases	*Combinations*	*Number of users*
Case 12	(1)4-OAM+(1)16-OAM+(1)64-OAM	3
Case 13	(2)4-OAM+(2)16-OAM+(2)64-OAM	6
Case 14	(3)4-OAM+(3)16-OAM+(3)64-OAM	9
Case 15	(4)4-OAM+(4)16-OAM+(4)64-OAM	12

Table 3 The simulated cases1sub-group 2

Simulation Results

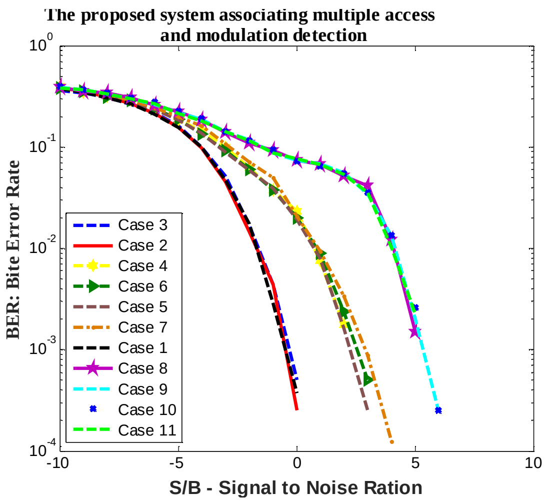


Figure 7 The proposed system associating multiple access and modulation detection: sub-group 1

In these simulations, simultaneous transmissions of multiple users shared the same channel. Each user is assigned to a unique combination (Gold code C_i, Gegenbauer order G_i).

Figure 7 shows that the best performances are given for the cases 1, 2 and 3. They are de same because we higher double orthogonality.Concerning the cases

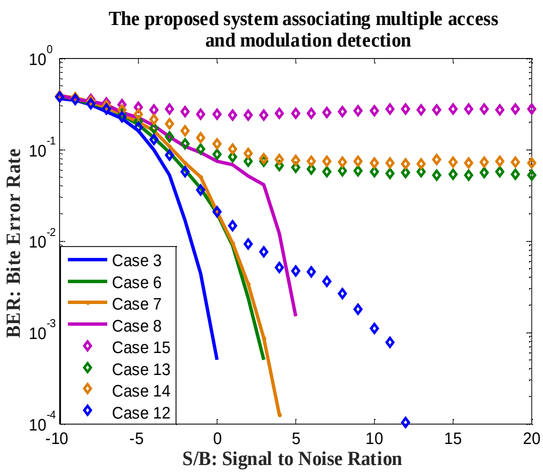


Figure 8 The proposed system associating multiple access and modulation detection: sub-group 2

4,5,6 and 7, the number of users increases to 9 and the performances degrade because the codes those are not orthogonal one hundred percent. The performances degrade more for cases 8, 9, 10 and 11 due to exploitation of the waveform G_0 but it possible to have 20 users.

To conclude, the new system allows good modulation detection for a multiuser system that exploit the modulations (4-OAM, 16-oam AND 64-OAM). Good communication is insured for 20 users and the data rate can be multiplied by two, by four and even by six.

To determine the limit of the proposed system, we decided to use the same waveforms in several modulationsas mentioned in Table 3 with the intention to have more users. As mentioned in Figure 8, except for the result of three userswhich can be considered acceptable, the other casesgive very degraded and unacceptable results. These results are due to the lack of orthogonality of the waveforms.

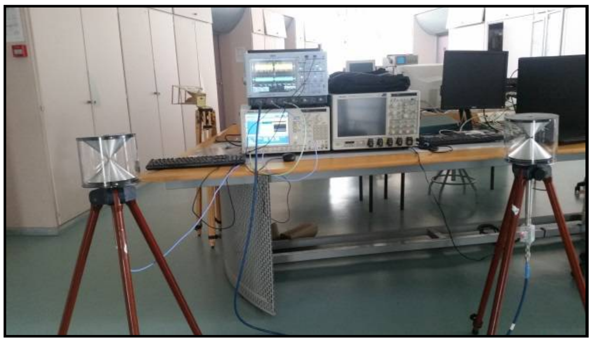
Experimental results

The experimental tests are performed in IEMN-DOAE laboratory to consider the effects of a real channel. This architecture presented in Figure 9 is composed of a pulse generator provides pulses with a bandwidth which exceeds 3 GHz, two omnidirectional antennas, an amplifier and an oscilloscope having a bandwidth of 6 GHz.

To establish the de proposed system in real conditions, we choose two scenarios according the results of simulations:

- S1: (2)4-OAM
- S2: (2)4-OAM+(2)16-OAM+ (2)64-OAM

The useful user is modulated by 4-OAM with first order of Gold codes. The amplitude of pulses is 1V and the width 550ps. The transmitter and receiver are on the same axis at a distance of 2m.



Description of the manipulation device

The generator: The arbitrary wave form generator shown in Figure 10 provides the ability to generate signals in a simple way. The originality of this generator is to have two ways to transmit the signals: we can do it from removable media or via the local network. The characteristics of the generator are in summary:

- The kind: AWG7102
- The bandwidth of the generated pulses exceeds 3 GHz with a resolution of 1 ps
- The sample rate is 10 G sample/s on two channels or 20 sample/s on one channel
- The depth of 10 bits

Biconical antennas: They are used omnidirectional type RS0460 as mentioned in Figure 11. They have omnidirectional radiation pattern perpendicular to the axis of the conesand zero electric along the axis of the cones. The polarization is linear and thetypical maximum gainfor this type of antenna is 3 dBi.

The characteristics of Biconical antennas are insummary:

- Type : omnidirectional
- The frequency band: 0.4 GHz to 6 GHz
- The antenna factor: 25 to 44 dB/m
- The gain: from -3 to 3 dBi
- Maximum continuous power: 100 Watts
- Impedance: 50Ω

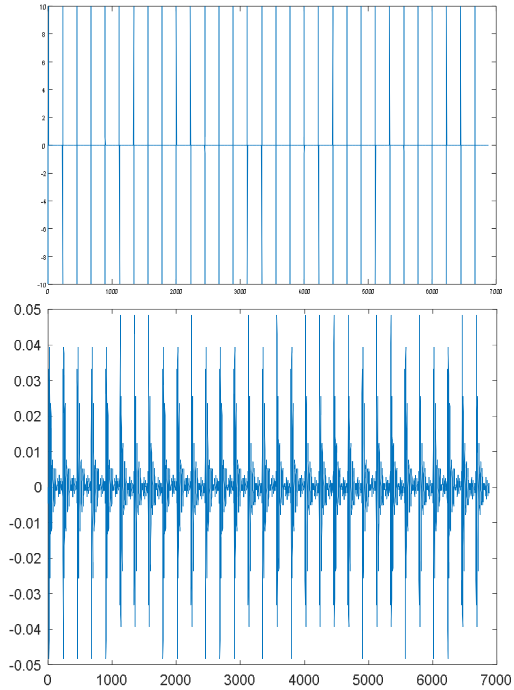
The Amplifier: it is placed atthe output of the receiving antenna and before the oscilloscope input channel, the purpose of adapting the signal to the reception. The amplifier amplifies the received signal, which is a very adequate function to achieve our experiments.

The characteristics of the Amplifier presented in Figure 13 are in summary:

- Type: BBV 9742
- Power supply: 12-15V / 100mA
- Frequency range: 9 kHz - 4 GHz
- Noise Factor: 4.5 dB
- Impedance Input / Output: 50Ω

Figure 12 The amplifier

The Oscilloscope: it's a measuring instrument for the acquisition of signals before computer processing. It is mainly characterized by a bandwidth of 12 GHz with very fast sample rates up to 40 Gech/s. In our experiments, it is the sample rate of 20 Gech/s was used. The oscilloscope is controlled by a processing unit in order to extract and process the results of different tests from Matlab files generated by the oscilloscope.



The characteristics of the Oscilloscope shown in Figure 12 are in summary:

- Series: 8620A
- Bandwidth: 6 GHz
- Sampling rate 20 GSa/s on 4 channels
- Standard memory: 64 Mpts/Ch
- Resolution: B bits
- Sensitivity between 2 mV and 1 V/div

With the intention of binding between the transmitting antennas and generators, different lengths (1m-5m) of cable N/SMA are used. Other connector cables N/SMA also helped to connect the amplifier to the receiving antenna and the oscilloscope. To ensure synchronization between the transmission and reception, a 1m long cable was used to trigger the generator to the oscilloscope, based on the clock generator. The transmit antenna is connected to the generator with a cable length 4m. Another 5m long cable is used to connect the oscilloscope to the receiving antenna.

Three users sent different information modulated on 4-OAM by using different waveforms and different codes. In order to control the sent bit by a special user, we sent the word "**UWB**". The conversion of UWB" from Ascii value to Binary value gives "[01010101010101011101000010]".

To ensure the synchronization between the transmitter and the receiver, and finding the beginning of the data sent, a training sequence is used at the beginning of each packet. This training sequence is known and sent separately in the first time as mentioned in Figure 14.

The waveform G_1 is also sent through antennas in order to obtain the correct form that underwent to real deformations. The received waveform is given in Figure 15.

After the recovery of the signal as mentioned in Figure 15, the proposed algorithm is applied to detect the modulation type and execute the adequate demodulation for the useful user.

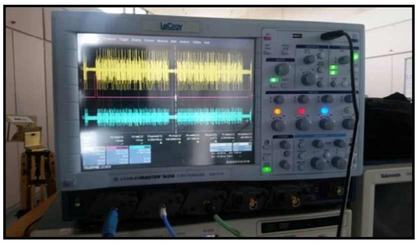
After decoding and dispreading of the received data, the result is calculated in term of Bit Error Rate. For the First scenario, the BER is about7 10^{-3} and for the second scenario the BER is about 7.5 10^{-2}. The degradation result at the second scenariois caused by themulti-user interferences.

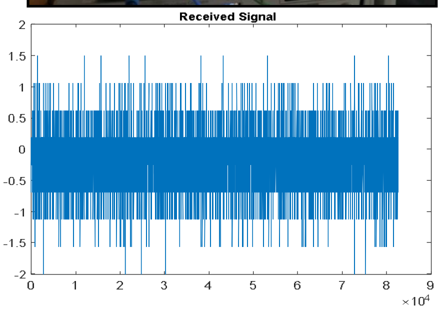
The test results provethat the proposed technique of modulation detection is operational into real conditions of propagation channel.

CONCLUSION

UWB communication systems offer flexibility in terms of modulations and receiver architectures. The particularity of the proposed intelligent system is characterized by the implementation of the high data rate modulation M-OAM. As required in performance and rate, a modulation and a fixed architecture can be adopted.

Cognitive radios have emerged to solve the current wireless communication system problems by exploiting opportunistically the existing electromagnetic spectrum.





The ability of cognitive radios to quickly adjust in diverse wireless environments, make it an ultimate spectrum aware communication paradigm.

The proposed algorithm permits to detect the type of each user modulation. Then to realize the demodulation automatically and have one adaptive receiver for all users instead of several receivers for each user.

As prospects, we propose the implementation of an adequate equalizer with the intention of reducing the effects of multi-user interferences.

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How to cite this article:

Lamyae Maatougui *et al* (2017) 'Modulation Detection For a New Multi-User Ultra Wide Band System Based On M-Oam', *International Journal of Current Advanced Research*, 06(10), pp. 6795-6802.
DOI: http://dx.doi.org/10.24327/ijcar.2017.6802.1018

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