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3 authors:

Honfoga Anne-Carole
Université de Mons

Michel Dossou
University of Abomey-Calavi

Véronique Moeyaert
Université de Mons

Comparison of low complexity demapper algorithms applied to rotated constellation in DVB-T2

Anne-Carole Honfoga
Electromagnetism and Telecommunications Department
University of Mons
Mons, Belgium
anne-carole.honfoga@umons.ac.be

Michel Dossou
LETIA (of Polytech. Sch. of Abomey-Calavi)
University of Abomey-Calavi
Calavi, Benin
michel.dossou@epac.uac.bj

Véronique Moeyaert
Electromagnetism and Telecommunications Department
University of Mons
Mons, Belgium
veronique.moeyaert@umons.ac.be

***Abstract*—Signal Space Diversity (SSD) technique was adopted in Digital Video Broadcasting-Terrestrial, second generation (DVB-T2) standard ten years ago in order to increase system performance over fading channels. This technique consists in rotated and cyclic Q-delayed M-Quadrature Amplitude Modulation (QAM) and has been proposed without taking into account the complexity induced by the demapper. Due to the complexity of the hardware implementation, the features of this technique have not been effectively exploited for network deployment. Therefore, several low complexity algorithms have been proposed during the last decade in the scientific literature in order to reduce the number of metrics and operators used in the demapping process. This paper proposes an exhaustive overview of all the nine DVB-T2 demapping algorithms existing up to now in the literature by comparing them in terms of parameters, performance and percentage of reduction obtained.**

***Index Terms*—DVB-T2, rotated constellation, cyclic Q delay, fading channel, Signal Space Diversity (SSD).**

I. Introduction

The demand of high data transmissions over fading channel has been the subject of many wireless communications systems during the last two decades. In order to overcome these challenges, several signal processing techniques like Forward Error Correction (FEC) codes, geometrical and probabilistic constellations, diversity and interleaving techniques have been recently proposed in modern communications systems such as: DVB-T2 [1] and Advanced Television Systems Commitee, third generation (ATSC 3.0) [2]. Indeed, DVB-T2 provides a minimum capacity increase of thirty per cent when compared to DVB-T and a flexible robustness for transmitted service. DVB-T2 is the European terrestrial digital broadcasting system second generation standard published by European Telecommunications Standards Institute (ETSI) in 2009 [3]. Due to Bit Interleaved Coding Modulation (BICM) [3] scheme and new techniques like FEC coding or SSD [4] included in this system, its performance is greater than DVB-T one [3].

BICM is the coded modulation scheme whose principle and performance have been described by Zehavi [4] over fading channel. SSD technique has been firstly introduced in [5], [6] and proposed for DVB-T2 transmissions in order to increase the diversity order of BICM scheme and the signal robustness while maintaining the system spectral efficiency. This technique gives maximum gain when used with low constellation sizes (4-QAM) and higher Code Rates (CRs) (CR=$4/5$ and CR=$5/6$). Conversely, the gain is more reduced for high constellation sizes (256-QAM) and lower code rates [3]. The performance gain obtained using (4-QAM, CR=$1/2$) and (16-QAM, CR=$1/2$) are respectively $3.4\,\mathrm{dB}$ and $2.8\,\mathrm{dB}$ in Single Frequency Network (SFN) environment [7].

SSD technique consists in the rectangular QAM constellation rotation and the cyclic Q delay. The constellation rotation induces a correlation between I and Q components of each QAM symbol and the cyclic Q delay insertion introduces the independence between I and Q channel coefficients. Although the SSD technique increases the robustness of the transmitted signal, the demapper complexity increases. Indeed, during the demapping process, euclidean distance computed between constellation symbols and received symbols, must include I and Q channel coefficients. This requires the computation of two dimensional euclidean distance (2D-demapper) and induces the increase of the complexity detection process when compared to the detection process using classical QAM constellation (1D-demapper). Furthermore, iterative decoding has been the demapper proposed in DVB-T2 [3] standard as the alternative to the common used method Max-Log demapper in order to increase the rotated constellation performance. But this algorithm is more complex for hardware implementation [8] and is used for software implementation [9].

However, many detection process algorithms have been proposed in the literature in order to deal with the hardware complexity induced by the common used method Max-Log detection. These algorithms are based on two kinds of complexity reduction. While, some algorithms are based on the reduction of the number of euclidean distance computed in the Logarithm Likelyhood Ratio (LLR) bit computation [10], [11], [12], some focused on complexity of euclidean distance [15] and the others focused on both complexity reduction of the euclidean distance computation and number of euclidean distance to compute [13], [14], [16], [17], [18]. Indeed, this comparison does not exist in the scientific literature.

In this paper, low complexity demappers proposed for DVB-T2 are compared in terms of number of metrics and operators used and percentage of reduction obtained. Therefore, DVB-

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T2 system has been explained (section II). This is followed by SSD techniques presentation and the 2D-demapper relevance (section III). Demapper algorithms are compared (section IV), followed by the discussion (section V) and the paper ended up by the conclusion (section VI).

II. DVB-T2 System Description

A. DVB-T2 blocks diagram

DVB-T2 system is based on many blocks such as: Physical Layer Pipe (PLP) multiplexing, Bose-Chaudhuri-Hocquenghem (BCH) and Low Density Parity Check (LDPC) codings, QAM, rotated constellation, Cyclic Q delay, interleaving techniques, Orthogonal Frequency Division Multiplexing (OFDM) modulation (Fast Fourier Transform (FFT) operation and Cyclic Prefix (CP) insertion) and Multiple Input Signal Output (MISO). Ref [1] and [3] defines the DVB-T2 modem architectures which parameters are given in table I. The performance are evaluated after QAM demapping, LDPC decoder and BCH decoder using Bit Error Rate (BER) which computes the number of binary errors transmitted to the total number of transmitted bits. Also, Modulation Error Ratio (MER) which is used to indicate the modulation quality of the received signal can be computed before the QAM demapper [19].

TABLE I
DVB-T2 System Parameters

FFT mode	1K, 2K, 4K, ((8, 16, 32)K and ext)
Modulation	4, 16, 64, 256-QAM
FEC frame	long (64800 bits), short (16200 bits)
CR LDPC	1/2, 3/5, 2/3, 3/4, 4/5, 5/6
Bandwidth	1.7, 5, 6, 7, 8, 10 MHz
CP	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4

B. Channel models

DVB-T2 standard defines many generic simulation fading channel models such as Rician, Rayleigh, Rayleigh with erasure, Typical Urban 6 and 0dB echo channels [3]. Among all of these channels listed above, Rayleigh channels with and without erasure and 0dB echo channel are usually used. In the following section, SSD technique will be presented in detail.

III. SSD Technique Description

A. Rotated constellation concept

The constellation rotation concept has been introduced in the DVB-T2 standard in order to improve the performance of the system. Before the adoption of this concept in DVB-T2, some works have been done and prove the performance of the joint use of constellation rotation and FEC techniques (Turbo and LDPC codes) [20]. Moreover, the performance of the joint use of SSD technique and BICM modulation in broadcasting systems have been proven while showing the advantage of SSD technique as being a repeating code and defining the criteria for the choice of rotation angle [21].

Indeed, QAM symbols are constructed using Gray mapping. After that, a rotation technique is applied to the classical constellation and creates a correlation between I and Q components. When, this operation is followed by a cyclic Q delay addition, channel coefficients applied to transmitted symbols become independent. Fig. 1 presents the rotated constellation. As noticed on this figure, a rotation angle Φ is applied to the

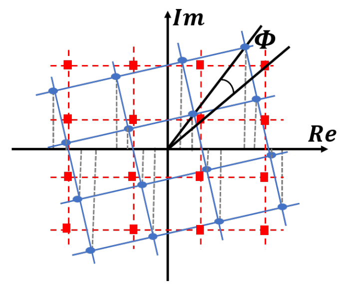

Fig. 1. Classical QAM and rotated constellation (adapted from [12])

classical symbols (red color) and each rotated constellation symbol (blue color) includes the unique I and Q components. If S represents a complex symbol from a classical QAM, I_s and Q_s denote respectively the In-phase and Quadrature symbols components.

$$S = I_s + j.Q_s \tag{1}$$

During the rotation, S is multiplied by $e^{j\Phi}$ and becomes Z.

$$Z = I_z + j.Q_z = (I_s + j.Q_s).e^{j\Phi} = (I_s + j.Q_s)(sin\Phi + j.cos\Phi)$$

$$I_z = I_s.cos\Phi - Q_s.sin\Phi; Q_z = I_s.sin\Phi + Q_s.cos\Phi$$

The addition of a cyclic Q delay consists in performing a time delay of Q_z components of all transmitted symbols. This operation is carried out on the scale of one LDPC frame and consists in inserting a delay of a QAM symbol duration on Q components of all the symbols. For example, if Z_1, Z_2, Z_3, Z_4 denote the symbols after constellation rotation and we suppose that the LDPC frame length is 4.

$$Z_1 = I_{z_1} + j.Q_{z_1}; Z_2 = I_{z_2} + j.Q_{z_2}$$

$$Z_3 = I_{z_3} + j.Q_{z_3}; Z_4 = I_{z_4} + j.Q_{z_4}$$

After cyclic delay, Z_1, Z_2, Z_3, Z_4 become X_1, X_2, X_3, X_4.

$$X_1 = I_{z_1} + j.Q_{z_4}; X_2 = I_{z_2} + j.Q_{z_1}$$

$$X_3 = I_{z_3} + j.Q_{z_2}; X_4 = I_{z_4} + j.Q_{z_3}$$

By this way, complex symbols which undergo OFDM modulation do not contain their own Q components. Indeed, I and Q components go through different subcarriers. Therefore, the fact that these two subcarriers carry the same information on the channel leads to consider the SSD technique as a repeating code. When one of the subcarriers is attenuated or erased, the information contained in this subcarrier can be recovered because the same information is found on the second subcarrier. On the receiver side, the channel coefficients of components I and Q of each transmitted symbol are independent.

B. 2D-Demapper relevance

In the previous section, SSD technique advantages and principles have been presented. It is shown that the use of the channel coefficients becomes mandatory when computing euclidean distance in the LLR expression as Zero Forcing (ZF) or Minimum Mean Square Error (MMSE) equalizers can not be done before the demapping process. Then, a 2D-demapper is needeed when constellation rotation is used. In this section, the 1D and 2D demappers.

1) Complexity analysis of 1D and 2D demapper

Let us consider a 16-QAM including the constellation diagram and binary data ($b_0b_1b_2b_3$) presented on fig. 2.(a). As noticed on this figure, the I and Q components (blue color) projected on the real and imaginary axes follow the gray mapping. The bits with even index contain the I component and the bits with odd index contain the Q component. The hamming distance between adjacent I or Q components is equal to 1. In order to compute the LLR for each bit, euclidean distance is computed between I components or Q components. This means that when constellation rotation is not applied, the LLR computation takes into account only the component (I or Q) on which the half of the symbols bits is represented [3]. This means that the euclidean distance is 1D distance. Fig. 2.(b) presents the 1D-demapper where k and l represent

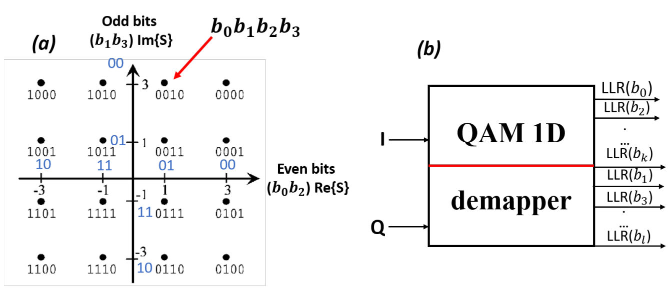

Fig. 2. Classical QAM symbols and 1D-demapper

respectively the even and odd index. The number of candidate points needed for euclidean distance computation is $2^{(\frac{m}{2}+1)}$ with m the number of bits per symbol.

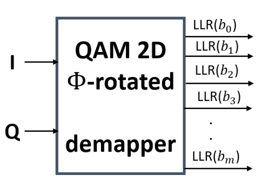

Fig. 3. 2D-demapper (adapted from [3])

When rotated constellation is used, instead of the use of only one component in LLR bit computation, both I, Q components and their respective channel coefficients are needed for LLR bit computation and then the euclidean distance. This leads to the use of 2D-demapper (fig. 3). The number of euclidean distance is 2^m. When compared to the number needed for 1D-demapper, the complexity increases by $2^{\frac{m}{2}}$ [13].

2) Exact LLR computation and Max-Log demapper

Let us consider:

- X, the transmitted symbol with components I_x and Q_x.
- R, the received symbol with components I_r and Q_r and without channel equalization.
- ρ_I et ρ_Q, fading channel coefficients respectively for I and Q components.
- b_i, the bit on which the LLR is computed.
- C_i^0 and C_i^1, the set of constellation points for which the i^{th} bit can take 0 or 1 values.
- σ^2 the power of Additive White Gaussian Noise (AWGN)

One can compute 2D euclidean distance using equation (2).

$$Dist^2 = (I_r - \rho_I I_x)^2 + (Q_r - \rho_Q Q_x)^2 \quad (2)$$

$$LLR(b_i) = \ln(\sum_{x \in C_i^1} e^{-\frac{Dist^2}{2\sigma^2}}) - \ln(\sum_{x \in C_i^0} e^{-\frac{Dist^2}{2\sigma^2}}) \quad (3)$$

And one can compute LLR bit with equation (3). As noticed on this equation, exponential operator is used and is more complex to realize in hardware implementation. Also, the calculation of the LLR uses all the points of the constellation since C_i^0 and C_i^1 are subsets of dimension $2^{\frac{m}{2}}$. In order to deal with exponential operator, Max-Log approximation presented in equation (4) is used.

$$\ln(e^{a_1} + ... + e^{a_k}) \approx= \max_{j=1...k} a_j ; a_j = \frac{Dist^2}{2\sigma^2} \quad (4)$$

By inserting this equation in expression (3), the LLR formula becomes equation (5).

$$LLR(b_i) = \frac{1}{2\sigma^2}[min_{x \in C_i^0} Dist^2 - min_{x \in C_i^1} Dist^2] \quad (5)$$

This expression allows to avoid an exponential operator. However, the number of candidate points used is still the same. The more the size of the constellation increases, the more the complexity increases. For example, when 256 constellation size is used, the number of euclidean distance is also 256. In order to reduce the complexity of computation, many low complexity demappers are proposed in the scientific literature. All of them reduce the Max-Log demapper algorithm complexity by reducing the number of metrics or the complexity of the euclidean distance expression. The following section compares these algorithms.

IV. Low complexity demapper algorithms

The Max-Log demapper algorithm is proposed in DVB-T2 standard for hardware implementation and algorithms proposed in the literature focused on the demapper complexity reduction. When some algorithms reduce only the QAM demapper complexity, the last algorithm presented in this paper (cf IV.C.5) reduces the demapping complexity and increases the signal robustness and then the system performance. This section presents firstly those algorithms that reduce the number of euclidean distance, secondly those which reduce the complexity of computation of euclidean distance and lastly the algorithms for both reductions. Nevertheless, it is useful to first compute the Max-Log complexity.

Indeed, the complexity of euclidean distance presented in equation (2) is computed in term of number of real multiplications (RM) and real sums (RS). As noticed on this equation, 4 RM and 3 RS are needed. For the sake of simplicity, we denote the number of candidate points which represents the number of euclidean distances or metrics. The LLR bit computation for symbol of constellation size 256 using equation (5) induces $(4 * 256 + 8) = 1032$ RM, $(3 * 256 + 8) = 776$ RS and $(256 * 8) = 2048$ real comparisons (RC). Indeed, the real comparison operator is used due to the presence of the min operator in the equation. This operator induces the comparison between all the euclidean distances computed between the received symbol and the symbols of the individual subset C_i^0 and C_i^1 in order to choose the small distance for the two subsets.

A. Algorithms based on number of candidate points reduction

1) Demapper proposed by Perez Calderon et al, 2011 [10]

These authors proposed the choice of constellation quadrants which are taken into account depending on the quadrant on which the received symbols belong to. Indeed, there are four quadrants on QAM constellation. Depending on the quadrant in which the received symbol is located, the 2D euclidean distance can be computed on a reduced subset of constellation points instead of all the constellation points. These subset of constellation points are carefully determined by computing the histogram of minimum 2D distance and then identifying the received symbols which are more likely to be at the minimum distance for a specific quadrant. The constellation points with a greatest occurrence probability are grouped into a subset for this particular quadrant. By using histogram of minimum distance, authors conclude that in the case where the received symbol belongs to quadrant 2 (Q2), the candidate points must belong to Q2 and the neighboring quadrants Q1 and Q3. This means that the number of candidate points decreases by 25%. Furthermore, some points of Q1 and Q3 could be removed. This induces also the decrease of the number of candidates points by 6%, 12.5%, 19% and 25%. However, the more the number candidate points decreases, the more the system performance decreases. For all the foregoing, the subset of candidate points which reduced the points by $25\% + 6\% = 31.25\%$ is the selected subset with negligible impact (loss $< 0.2\,\mathrm{dB}$) on system performance for constellation size of 256.

2) Demapper proposed by Stefano Tomasin et al, 2012 [11]

These authors proposed an algorithm which consists in identifying the constellation points whose euclidean distance is very close to the received symbol. Indeed, it consists in the separation of the constellation diagram into different sectors of size $(2.2^{\frac{m}{2}})$ delimited by real values M_c. After this separation, it will be necessary to identify the real value M_c close to the real part of the symbol received. Once this value is identified, the constellation points on which euclidean distance will be computed is between the two values of M_c close to the M_c value previously identified. This region includes $2^{(\frac{m}{2})}$ constellation points. This algorithm reduces the number of candidate points by 93.75% with negligible performance loss for constellation size of 256. When compared to the algorithm proposed by Perez Calderon in 2011, this algorithm further reduces the complexity than the previous presented (cf IV.A.1).

3) Demapper proposed by Perez Calderon et al, 2013 [12]

These authors proposed a complexity reduction algorithm based on sub-quadrants identification instead of quadrants in [10]. It is based on the selection of the sub-quadrants among the four quadrants of the constellation. Instead of computing the distance between the symbol received and all the other constellation points, they first compute the probability of appearance of the received symbols of a sub-quadrant in the other sub-quadrants. Then, the constellation points with a high probability of occurrence is maintained. The choice of the subset of candidate points has a significant impact on the system performance. These candidate points are likely to be at a minimum distance from the received symbol. This algorithm reduces the number of candidate points by 78% with a negligible performance loss for constellation size of 256. When compared to the quadrant demapping algorithm firstly presented (cf IV.A.1), this algorithm further reduces the number of candidate points lying on the subset which induces a better percentage of complexity reduction.

B. Algorithm based on the euclidean distance complexity reduction

The research group of Perez Calderon authors proposed in 2014 the Manhattan approximation as an alternative to the euclidean distance in the LLR expression [15] in order to reduce the hardware implementation complexity. As noticed on the 2D euclidean distance formula, the RM operator is more complex to realise than the RS. By reducing the number of RM, the demapper complexity is further reduced. This algorithm focuses on the number of RM reduction and then presents better performance algorithms than previously presented. Indeed, Manhattan distance means equation (6) instead of equation (7).

$$Dist_{Manhattan} = (I_r - \rho_I I_x) + (Q_r - \rho_Q Q_x) \quad (6)$$

$$Dist_{euclidean} = \sqrt{(I_r - \rho_I I_x)^2 + (Q_r - \rho_Q Q_x)^2} \quad (7)$$

The use of Manhattan distance allows to reduce the number of RM by 99.2% with a negligible performance loss. Instead of 2^{m+1} RM, only 4 RM are used.

C. Algorithms based on the number of candidate points and euclidean distance complexity reduction

In the previous subsection, algorithms based on only euclidean distance number have been presented. In this part, algorithms which reduce both the number of candidate points and euclidean distance computation are presented.

1) Demapper proposed by Meng Li et al, 2009 [14]

These authors proposed a sub-region demapping algorithm and presented the FPGA design and prototyping. This algorithm reduces the number of Euclidean distances by breaking down the constellation into 2D sub-regions and simplifies the algorithm of euclidean distance computation. This reduces the complexity by decreasing the number of RM.

Indeed, depending on the signs of I_r and Q_r, four sub-regions have been identified. Each sub-region includes a quadrant and the constellation points which are closer to the quadrant. This method reduces the number of euclidean distances by 60% and 69% respectively for constellation sizes of 64 and 256. Instead of 64 and 256 candidate points used to compute euclidean distances, respectively 25 and 81 is used. Moreover, a linear approximation of euclidean distance presented in equations (8), (9) and (10) are used is order to exploit real comparisons instead of RM in equation (2) which decreases again the complexity with a negligible performance loss. Let us consider $a = I_r - \rho_I I_x; b = Q_r - \rho_Q Q_x$ and suppose that a and b are positives. The euclidean distance between two points is defined as $\sqrt{a^2+b^2} = a\sqrt{1+(b/a)^2}$. By supposing that a is the maximum of the two values, the ratio b/a is smaller than one. A linear approximation of the Euclidean distance can be performed using these equations.

$$Dist = \sqrt{a^2+b^2} \tag{8}$$

$$if, (min(a,b) \leq \frac{max(a,b)}{4}), Dist = max(a,b) \tag{9}$$

$$else, dist = max(a,b) + (min(a,b) - max(a,b)/4)/2) \tag{10}$$

2) Demapper proposed by Kitaek et al, 2012 [13]

These authors proposed a complexity reduction algorithm which computes the LLR by using a key observation for 2D LLR contours of bits as a function of channel coefficients ρ_I and ρ_Q under AWGN and Rayleigh channels. When compared to the algorithm previously presented, this algorithm reduces the demapper complexity without performance loss. When only AWGN channel is used, it is supposed that $\rho_I = \rho_Q$ and the LLR contours appear as rotated, like the rotated constellation. The demapping process is done in two steps. In the first stage, when Rayleigh channel is used, according to the channel coefficients values ($\rho_I < \rho_Q$ or $\rho_I > \rho_Q$), the LLR of bits from the high channel coefficient between I and Q is determined firstly using a LLR lookup table whose values are obtained using a shift. The other LLRs are computed in the second stage using the sub-region of $2^{\frac{m}{2}}$ candidates points. This algorithm reduces the complexity by 87.5% for constellation size of 64 without performance loss. Indeed, this performance loss is equal to 0 when the performance of the proposed algorithm is compared to the Max-Log demapper performance and the difference in terms the ratio between the binary energy and the noise at a BER of 10^{-2} after QAM demapping using parameters such as a 64-QAM, rayleigh channel with 5% of erasure event has not been noticed.

3) First demapper proposed by Jianxiao Yang et al, 2015 [16]

These authors proposed a soft demapping algorithm derived and implemented over a FPGA platform. It reduces the number of candidate points from 2^m to $2^{(\frac{m}{2}+1)}$. This induces 75% and 87.5% of complexity reduction respectively for constellation sizes of 64 and 256. Also, euclidean distance complexity has been reduced by using a low complexity approximation (equation (11)).

$$Dist = max(|a|,|b|) + (\frac{1}{2} + \frac{1}{16} + \frac{1}{32}).min(|a|,|b|) \tag{11}$$
$$a = I_r - \rho_I I_x; b = Q_r - \rho_Q Q_x$$

Using this equation, the 2 main RM and 1 RS in equation 7 are replaced by 1 RM and 3 RS. This allows to further reduce the complexity.

4) Second demapper proposed by Jianxiao Yang et al, 2015 [17]

These authors proposed a sphere demapping algorithm which induces the computation of $2^{\frac{m}{2}}$ euclidean distances instead of 2^m for the Max-Log demapper. Moreover, they proposed new rotation angles Φ different from angles proposed in DVB-T2 standard. These angles are $\alpha = arctan(\frac{1}{2^{\frac{m}{2}}})$ with $m = 2, 4, 6, 8$. These angles have some properties which allow to reduce the complexity of euclidean distance computation and then to increase DVB-T2 system performance. Indeed, based on the structural properties of the rotated QAM constellations, a dedicated low complexity Max-Log called "sphere-demapper" is designed and its radius implies the exact amount of involved constellation points. This algorithm achieves a complexity reduction by more than 60%.

5) Demapper proposed by Tarak Arbi et al, 2018 [18]

These authors complete the work previously done in [17] (IV.C.4) by studying properties of these angles when Rayleigh channel with erasure is used. Furthermore, they proposed a reduced version of the sphere decoding algorithm well suited to the channel with erasure event (when one of the received symbol component (I or Q) has been completely lost). Using this algorithm the hardware implementation complexity is reduced and a performance gain is obtained. Indeed, using the rotation angles proposed, the constellation points are uniformly projected on I and Q axis. This confers some properties to the constellation. This algorithm is proposed using the angle properties and allows to increase the signal robustness. Using this algorithm, the complexity is reduced by 60%. Moreover, using Rayleigh channel with erasure event of 15%, a performance gain obtained at a BER of 10^{-6} respectively 0.1 dB, 0.5 dB and 0.75 dB for 4, 16 and 64-QAM.

V. Discussion and analysis

For all the foregoing, we can notice that many low complexity demapper algorithms have been proposed in order to have a low cost receiver and a high autonomy. Nevertheless, these algorithms proposed different reduction methods. For algorithms which are presented by the same group of research, the method proposed always outperforms the first version. This is the case of the research group of Perez Calderon which last algorithm (Perez-Calderon et al, 2014) outperforms the previous (Perez-Calderon et al, 2013) by the percentage of the complexity reduction of 21.2% and which in turn outperforms the first (Perez-Calderon et al, 2011) by 46.75%.

Moreover, the last algorithm of all of the presented algorithms (cf IV.C.5) reduces the complexity and increases the signal robustness allowing to get a gain of $0.75dB$ at a BER of 10^{-6} for 64-QAM and in the worse reception condition (Rayleigh with erasure event). This algorithm could be the better than the other as the other algorithms do not increase the signal robustness but only decrease the demapping complexity.

TABLE II
COMPARATIVE TABLE OF DEMAPPING ALGORITHMS

Authors	Channels	Const	Percent
Algorithms based on number of candidate points reduction			
Perez-Calderon et al, 2011 [10]	Rayleigh with erasure of 15%	256	31.25%
		–	–
Stefano Tomasin et al, 2012 [11]	Rayleigh without and with erasure of 20%	64	87.5%
		256	93.75%
Perez-Calderon [12] et al, 2013	P1, 0dB echo, Rayleigh with erasure of 15%	256	78%
		–	–
Algorithm based on the euclidean distance complexity reduction			
Perez-Calderon [15] et al, 2014	AWGN, P1, 0dB echo Ray with erasure of 15%	256	99.2%
		64	99.2%
Algorithms Based on the number of candidate points and the computation of the euclidean distance			
Meng Li et al, 2009 [14]	Rayleigh without and with erasure of 15%	64	$\geq 60\%$
		256	$\geq 69\%$
Kitaek Bae [13] et al, 2012	AWGN and Rayleigh with erasure of 5%	64	87.5%
		–	–
Jianxiao Yang [16] et al, 2015	Rayleigh	256	$\geq 87.5\%$
		64	75%
Jianxiao Yang [17] et al, 2015	Rayleigh without and with erasure of 15%	256	$\geq 60\%$
		64	$\geq 60\%$
Tarak Arbi [18] et al, 2018	Rayleigh without, with erasure of 5 % and 15%	256	$\geq 60\%$
		256	$\geq 96\%$

VI. CONCLUSION

In this work, we presented the SSD technique used in DVB-T2 and compared low complexity algorithms proposed for hardware implementation of the demapper. These algorithms have been characterized by the kind of complexity reduction obtained. We can conclude that recently proposed algorithms present better performance in terms of percentage reduction and gain when Rayleigh channel with erasure is used. Table II gives a summary of all of these algorithms.

This paper gives a deep comparison of algorithms allowing the manufacturer to have a broadband complete view and to make a good choice for the hardware implementation. Moreover, it gives a compliant detail about rotated constellation and the kind of demapper needed when it is used. As this technique allows to increase the frequency diversity and the signal robustness, its use in DVB-T2 could allow broadcasters to optimize their network by using receivers which include a reduced complexity demapping algorithm.

In future works, these algorithms could be presented by comparing their performance using the same parameters and in unified reception condition using BER, Error Vector Magnitude (EVM) and MER and the number of operators used.

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