Simplified Rotated Constellation Demapper for Second Generation Terrestrial Digital Video Broadcasting

Darío Pérez-Calderón, Vicente Baena-Lecuyer, Ana Cinta Oria, Patricio López, and Jose García Doblado

Abstract—**The constellation rotation and cyclic Q-delay technique has been adopted in second generation terrestrial digital video broadcasting to provide signal space diversity, improving the system performance under severe multipath propagation environments. The main drawback of this technique is the hardware complexity introduced in the demapping process compared to non-rotated constellations. In this brief, we present a simplified demapper that reduces up to 78% the number of required operations with almost no performance degradation compared to the results of the ideal max-log demapper.**

Index Terms—**Demapper, orthogonal frequency division multiplexing (OFDM), rotated constellations, second generation terrestrial digital video broadcasting (DVB-T2).**

I. Introduction

THE RECENT development of the second generation terrestrial digital video broadcasting (DVB-T2) standard [1] and the availability of free frequencies in the UHF band after the analog television switch-off in Europe enable the television operators to offer new services with the current network planning, such as high definition television (HDTV) transmissions or new datacasting services. For this purpose, the DVB-T2 specification was developed with state of the art technology providing a high capacity increase over the existing digital video broadcasting terrestrial (DVB-T) standard [2].

The new DVB-T2 standard, as its predecessor DVB-T, uses the orthogonal frequency division multiplexing (OFDM) modulation technique, but it adds new transmission modes with huge OFDM block size (32K and 16K) to improve the bandwidth efficiency and the performance over single frequency networks (SFNs). In addition, a higher order constellation (256-QAM) has been appended. This constellation combined with the new low density parity check (LDPC) error correction scheme [3], [4] offers an increased throughput with performance roughly comparable with the 64-QAM constellation in DVB-T. DVB-T2 also specifies a transmitter diversity method, known as Alamouti coding [5], which defines a multiple input - single output (MISO) system that improves the coverage in small scale SFNs. Finally, in order to improve the performance in severe multipath propagation scenarios, the DVB-T2 standard introduces a technique called constellation rotation and cyclic Q-delay (RQD).

The RQD technique, originally suggested in [6], was studied in [7], [8] as a method to improve the diversity order of a bit interleaved coded modulation (BICM) scheme over fading channels. In [9] the authors presented a study about the application of this technique to advanced forward error correcting (FEC) code solutions such as turbo or low density parity check (LDPC) codes, whereas in [10] the RQD method was applied to multi-carrier code division multiple access (MC-CDMA) systems.

The RQD method is also known as signal space diversity (SSD), since the final purpose is to lead to additional diversity that achieves a redundancy in information bits of the coded modulation. This solution improves the receiver performance when severely faded channels are encountered.

Despite the advantages of the RQD technique, its main drawback in DVB-T2 systems is the high complexity of the required log likelihood ratio (LLR) demapper. This demapping process requires the calculation of 2-D squared Euclidean distances from the received point to all the ideal constellation points to obtain the LLR metrics [11], for a 256-QAM this means that 256 2-D distances must be computed for each received constellation point.

In this brief, we present a simplified demapper for the rotated constellations with application to DVB-T2 receivers that outperforms the ones already presented in [12], [13]. The proposed demapper reduces the number of required operations and consequently, the hardware resources consumption with almost no receiver performance degradation.

The rest of this brief is organized as follows. Section II introduces the principles of the rotated constellation technique and its implementation in DVB-T2 systems. In Section III, the standard demapping process is described whereas our proposed method is presented in Section IV. Simulation results are shown in Section V, and finally, the conclusions are summarized in Section VI.

Manuscript received January 23, 2012; revised October 12, 2012; accepted October 19, 2012. Date of current version February 20, 2013. This work was supported in part by the Spanish Government under Project TEC2010-17029. This paper was recommended by Associate Editor P. A. Buceta.

The authors are with the Department of Electronic Engineering, Escuela Superior de Ingenieros, University of Seville, Seville 41092, Spain (e-mail: dperez@gte.esi.us.es; baena@gte.esi.us.es; cinta.oria@gte.esi.us.es; plopez@gte.esi.us.es; josegardo@gte.esi.us.es).

Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/TBC.2012.2226805

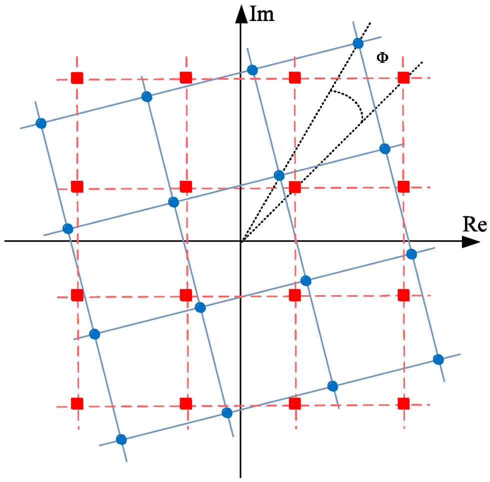

Fig. 1. Rotated and classic 16-QAM constellation. Square points: conventional constellation. Circle points: constellation points after rotating.

II. Rotated Constellations in DVB-T2

The RQD technique has been introduced in the DVB-T2 standard as an optional feature to improve the receiver performance in selective channels, especially in propagation scenarios with deep fadings or erasure events. This technique is performed after forming the constellation in the DVB-T2 transmitter, that is, before the cell and time interleavers and after the bit interleaver [1].

First, the RQD technique applies a certain rotation angle (ϕ) in the complex plane to the classic signal constellation, as shown in Fig. 1, where a rotated 16-QAM constellation and its corresponding conventional constellation are depicted.

From Fig. 1, it can be observed that due to this rotation, each new component, in-phase (I) or quadrature (Q), has enough information by its own to determine which was the transmitted symbol.

After the rotation, an interleaving process is performed between I and Q components to transmit both in different carriers and different time slots. In the DVB-T2 specification, the interleaving process is implemented within a FEC block through a cyclic delay of one subcarrier (called cell in DVB-T2) over the Q component. This cyclic delay is easily removed at the receiver side delaying the I component by one OFDM cell.

The interleaving process guarantees that both the I and Q components of the symbol are affected by independent fading. Thus, if one of the components is erased or affected by a deep selective fading of the channel, the other component can be used to recover the information. Note that in a non-rotated constellation the information would be lost, since both components suffer the same fading when the signal propagates through the channel.

The optimum rotation angle depends on the chosen constellation and also on the channel type. However, the DVB-T2 standard [1] specifies a single rotation angle according to the constellation size. Each chosen angle represents a compromise of the system performance for channels with different fading conditions.

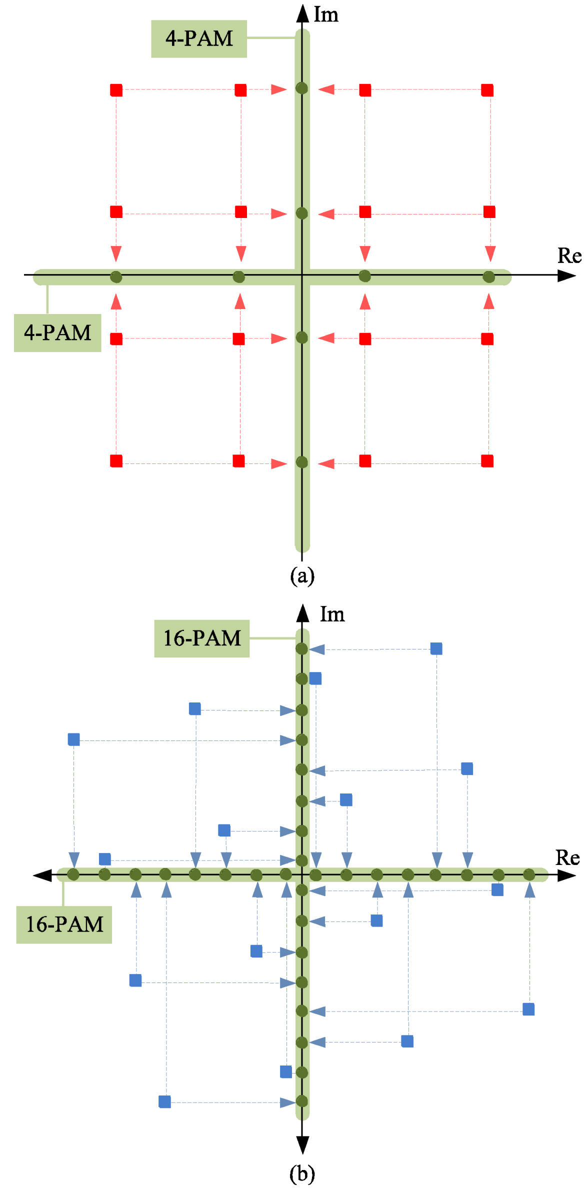

Fig. 2. Constellations and projections. (a) Classic 16-QAM constellation with projections in axis (2×4-PAM). (b) Rotated 16-QAM constellation with projections in axis (2×16PAM). Circle points: projections on axis. Square points: points of the classic or rotated 16-QAM constellation.

After the rotation and the cyclic delay, the resulting constellation is similar to a higher order constellation, but with optimized spectral efficiency. This can be observed when the rotated constellation points are projected to the I and Q axis. For example, in an M-QAM constellation, if the RQD technique is used, the number of projections on each axis is M instead of $\sqrt{M}$. In addition, since DVB-T2 specifies the use of Gray symbol mapping, the I and Q components of a non-rotated constellation can be mapped separately as two independent $\sqrt{v}M\text{-}PAM$. In the case of an M-QAM rotated constellation, the result is equivalent to map two related M-PAM. An example for a 16-QAM constellation is represented in Fig. 2.

In conclusion, the RQD technique introduces a higher degree of diversity to improve the DVB-T2 receiver performance, mainly in propagation scenarios with deep fading conditions or erasures events. Simulations [14], [15] show that the RQD technique provides a gain that can vary from 0.2 dB to several dBs depending on the order of the constellation, the code rate (CR), and the channel model when compared to the conventional QAM constellations.

III. Demapping Process

The LDPC decoding process carried out in a DVB-T2 receiver requires soft decisions or LLR metrics, which must be calculated by the demapper block. For non-rotated constellations, a conventional 1-D demapper as the one shown in [16] can be used in the receiver. However, in the case of rotated constellations, each LLR metric is a function of both I and Q components, requiring the calculation of 2-D squared Euclidean distances [11]. Therefore, a 2-D LLR demapper is needed in the receiver, replacing the classical 1-D demapper.

The DVB-T2 implementation guidelines [11] describe the main concepts of this demapper and propose the usage of the typical max-log approximation in order to reduce its complexity. For the sake of completeness, the LLR value for bit b_i when receiving the constellation point $I+jQ$ is reproduced in (1), where σ^2 is the noise variance, C_i^0 and C_i^1 are the sets of the constellation points where bit b_i is 0 and 1 respectively, ρ_I and ρ_Q are the channel amplitude fading factors, and finally I_x+jQ_x are the ideal constellation points.

$$LLR(b_i) \approx \frac{1}{2\sigma^2}\left[\min_{x\in C_i^0}\left((I-\rho_I I_x)^2+\left(Q-\rho_Q Q_x\right)^2\right) - \min_{x\in C_i^1}\left((I-\rho_I I_x)^2+\left(Q-\rho_Q Q_x\right)^2\right)\right] \quad (1)$$

Each term of the previous equation represents the minimum squared Euclidean distance between the received point and the ideal constellation point when propagated through the channel.

Even with this approximation, the hardware complexity of the 2-D LLR demapper is considerably high when compared with non-rotated constellations. Considering a 256-QAM, for each received point 256 2-D squared Euclidean distances are required to compute the LLR values, that is, 1024 multiplications.

In order to reduce the complexity of this demapper, two different approaches are possible. The first one consists in using an approximation for the computation of the Euclidean distances [12]. The second approach is based on the reduction of the sets C_i^0 and C_i^1, i.e., it reduces the number of Euclidean distances required to compute each LLR value [12], [13].

Note that both approaches are complementary and can be used at the same time. For the rest of this brief we will focus only on the second approach.

IV. Proposed Demapper

In [13], depending on the quadrant in which the received point lies in the complex plane, the 2-D distances are computed to a reduced subset of the entire constellation, decreasing the number of required operations and so the hardware complexity of the demapper. If the subsets are carefully selected, simulations in [13] show that this method has a negligible impact on system performance while still reducing the hardware complexity.

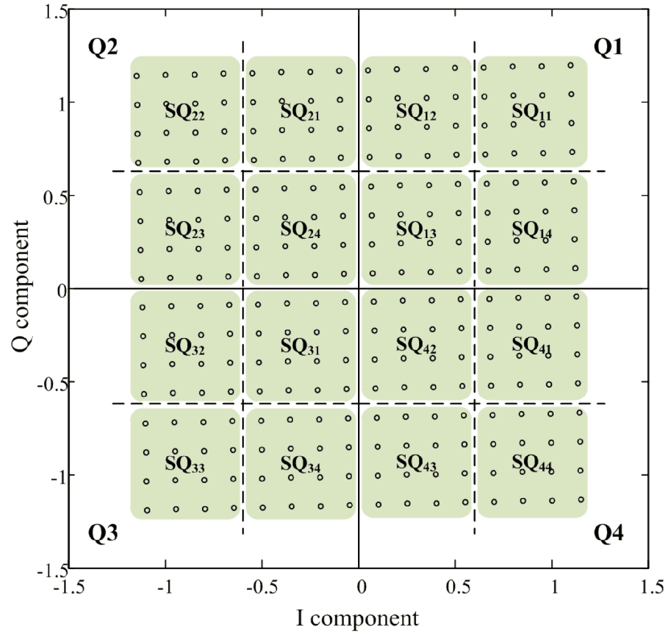

Fig. 3. Subquadrants in the complex plane in a 256-QAM rotated constellation.

These subsets are easily determined by analyzing the histogram of the minimum 2-D distances. That is, for all the points received in a particular quadrant, the constellation symbols that are more likely to be at the minimum distance are determined. Then, the subset for this particular quadrant is composed of the symbols with greater occurrence probability.

In this brief, we use a technique similar to the one proposed in [13] but applied to subquadrants instead of quadrants. That is, depending on the subquadrant where the symbol is received a subset is selected and used to compute the LLR values.

Note that the quadrant is easily determined using the sign of the in-phase and quadrature components of the received point. Once the quadrant is known, the subquadrant can be obtained performing a simple subtraction and analyzing the resulting sign.

Fig. 3 depicts the quadrants (Q) and subquadrants (SQ) assignment for a 256-QAM rotated constellation. Although there are 16 subquadrants, only 4 subsets are actually required, which correspond to the four subquadrants of any quadrant. The rest can be derived from these four due to the symmetries of the constellation.

In [13] theses subsets are selected to minimize the Euclidean distances. For smaller subsets, which is the case when applying this method to subquadrants instead of quadrants, the minimum 2-D distance criteria is not appropriate since it does not guarantee the presence of both 1 and 0 symbols in the subsets, leading to higher errors in the LLR values.

In this brief, we use a different method, the subset points take into account both the closest 0s and the closest 1s for each bit of the received point. In order to determine these four subsets, 4 histograms have to be computed, one for each subquadrant of a quadrant. An example of these histograms is shown in Fig. 4 for the particular case of a point received in SQ_{11} subquadrant. For the sake of brevity only the histograms of the subquadrants with more significant occurrence probability are shown. In the particular case of the quadrant Q3 and the subquadrant SQ_{13} these probabilities were almost zero.

Therefore, when receiving a point in SQ_{11}, the probability that the closest point falls in Q3 is almost zero. That is, it seems that all the points belonging to this quadrant can be ignored in the computation of the LLRs with a negligible performance loss. This means a reduction of a 25% in the number of distances to be calculated and confirms the results presented in [13]. Additionally, from our analysis based in subquadrants, points in SQ_{13} also seem to be negligible which would be an additional reduction of a 6.25%. However, the size of the subsets can have a big impact on the system performance. The definition of these subsets will be analyzed carefully by means of system simulations in the following section.

V. Simulation Results

The impact of the proposed demapper on the system performance has been analyzed via bit error rate (BER) curves at the output of the LDPC decoder of a DVB-T2 system. The results have been obtained by using the DVB-T2 Common Simulation Platform (CSP) [17], which is a simulation model developed and verified by the DVB-T2 technical module. Unless otherwise stated, all the simulations presented here have been obtained for a 256-QAM, a LDPC block size of 64 800 b, ideal channel estimation, the less robust code rate specified in DVB-T2 standard (CR of 5/6), an intermediate one (3/4), and the most robust (1/2).

The procedure we have used to determine the optimum subsets is as follows. First, the histograms for the four subquadrants have been computed transmitting 10^9 constellations points over an ideal Rayleigh channel. This number is more than enough to have an appropriate resolution. As stated in the previous section these histograms have to take into account not only the closest symbol but the closest symbol with a 1 in the bit under study and also the closest one with a 0. Second, for each subquadrant, the constellation points are sorted based on the results of the histograms. That is, for each subquadrant we now have a vector with all the points of the constellation, 256 points in the case of a 256-QAM, sorted by their occurrence probability. Finally, the subsets are defined from these vectors keeping the N points with a higher probability.

In order to determine the minimum value of N, simulations have been run for different channel scenarios and different coding rates. All the loss results presented in this brief have been measured at a BER of 10^{-6}.

For the sake of simplicity we have used the same number of points for each subset. However, after a deeper analysis of the histogram and the simulation results, we have found that the optimum value of N varies depending on the subquadrant. Nevertheless, in a real receiver, the complexity of the demapper will be determined by the maximum value of N so it would have no benefits to use a different value for each subquadrant.

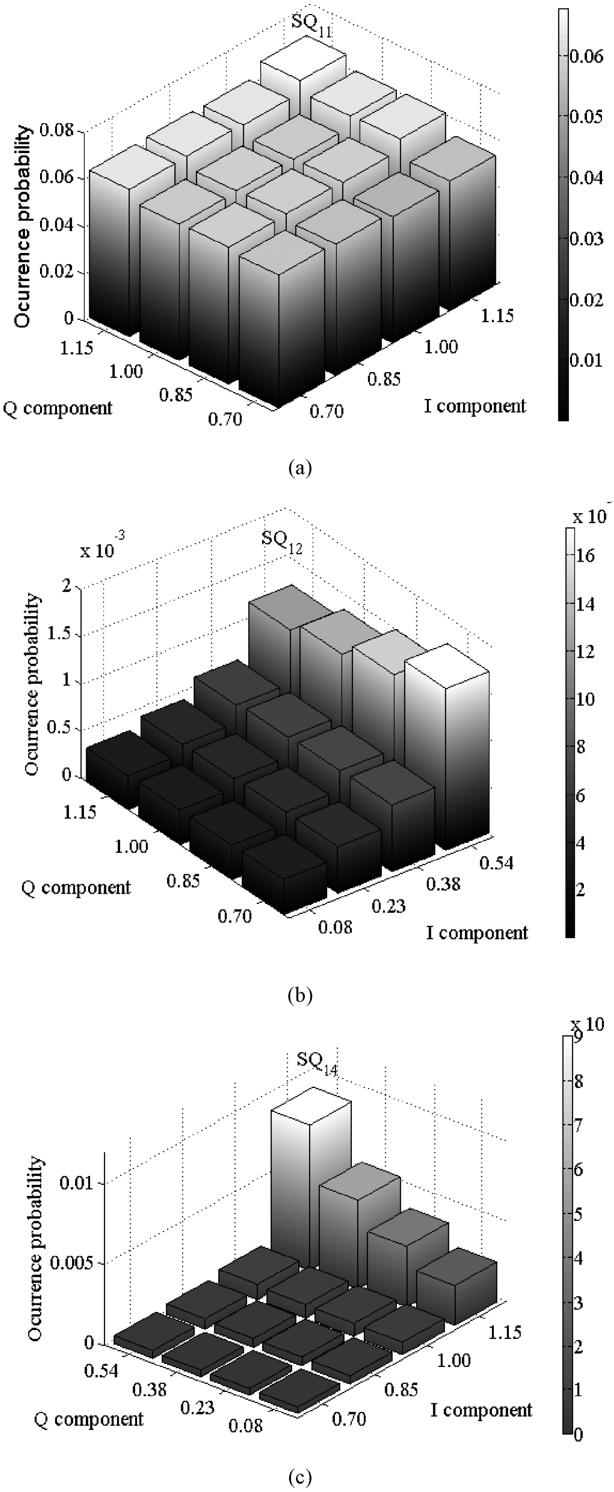

Fig. 4. Histogram of a rotated 256-QAM constellation. (a) SQ_{11} subquadrant. (b) SQ_{12} subquadrant. (c) SQ_{14} subquadrant.

The results have been divided in three subsections: the first one for the more realistic channels like the typical P1 channel defined in [2] or even the 0 dB echo channel, the second one for the worst case scenario defined in [11], a Rayleigh Memoryless channel with Erasures (RME), and finally, in the

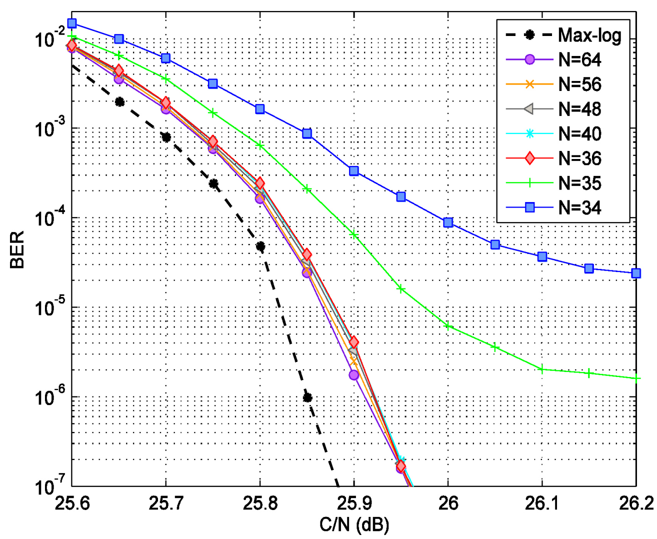

Fig. 5. BER against C/N curves for a 256-QAM constellation, a CR of 5/6, and the P1 channel.

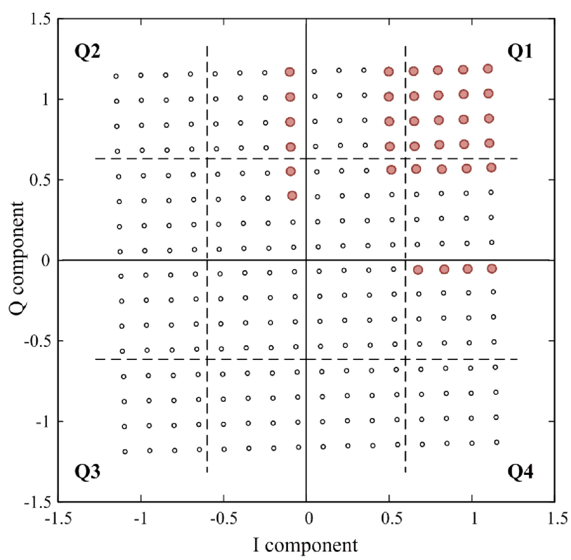

Fig. 6. Resulting subset for SQ_{11}.

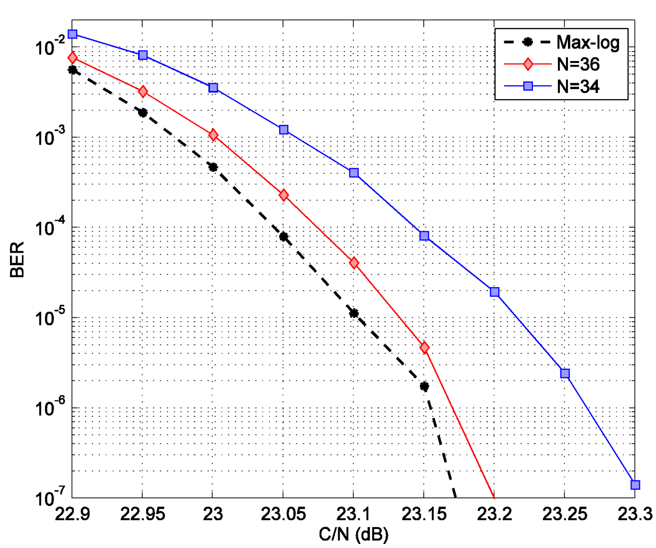

Fig. 7. BER against C/N curves for a 256-QAM constellation, a CR of 3/4, and the P1 channel.

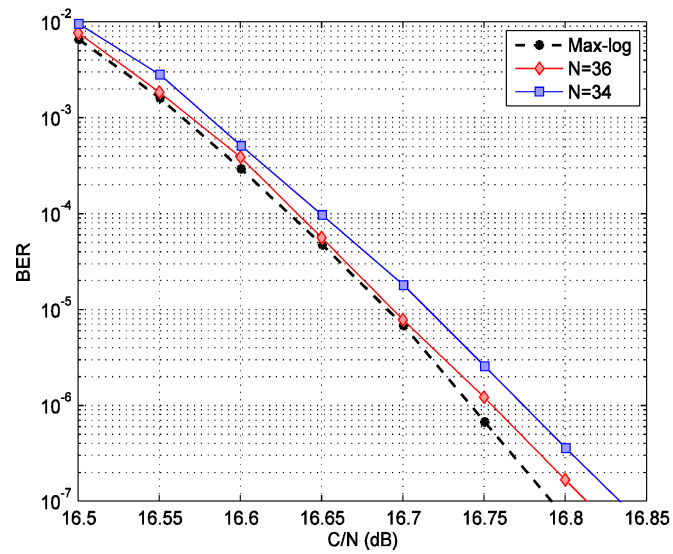

Fig. 8. BER against C/N curves for a 256-QAM constellation, a CR of 1/2, and the P1 channel.

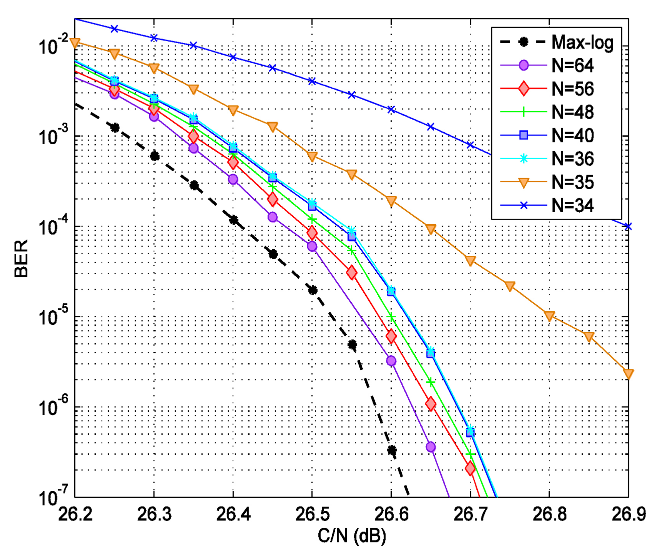

Fig. 9. BER against C/N curves for a 256-QAM constellation, a CR of 5/6, and the 0 dB echo channel.

third subsection the impact of a real channel estimator is analyzed.

A. Results for the P1 and the 0 dB Echo Channels

Fig. 5 shows the BER curves of the system for different values of N, a CR of 5/6, and the P1 channel. The results for the ideal max-log demapper are also shown for comparison purposes. From this figure it can be seen that with only 36 points, the performance degradation of the system in terms of carrier to noise rate (C/N) is negligible (under 0.1 dB). Just for illustrating purposes, the resulting subset for SQ_{11} and $N = 36$ is depicted in Fig. 6.

Figs. 7 and 8 show the BER curves for the code rates 3/4 and 1/2 respectively, both for the P1 channel. Each figure shows the curves for $N = 36$ and $N = 34$. Comparing these figures to Fig. 5, it can be seen that the losses are lower, that is, the

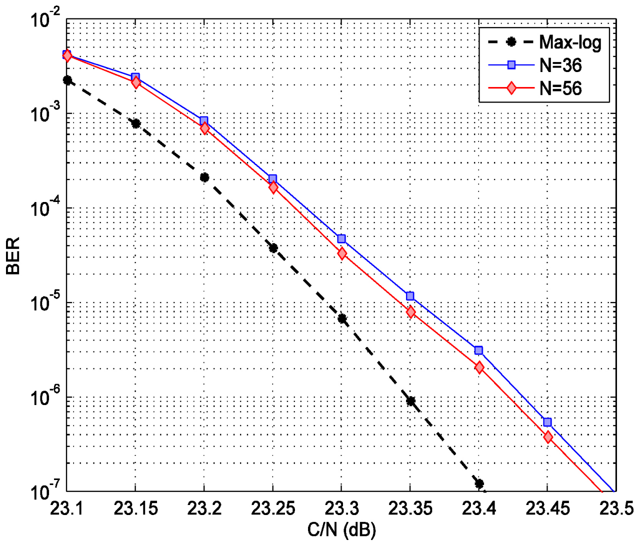

Fig. 10. BER against C/N curves for a 256-QAM constellation, a CR of 3/4, and the 0 dB echo channel.

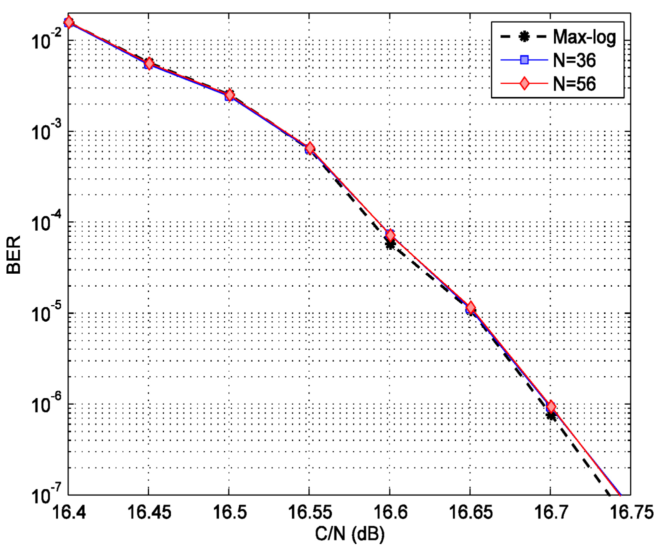

Fig. 11. BER against C/N curves for a 256-QAM constellation, a CR of 1/2, and the 0 db echo channel.

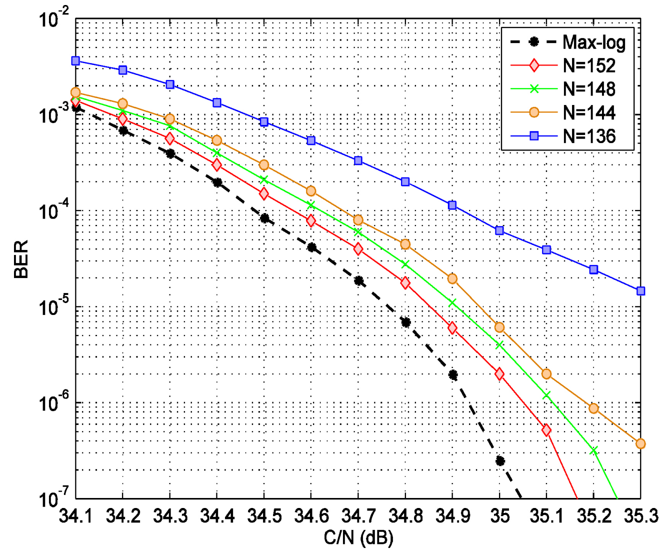

Fig. 12. BER against C/N curves for a 256-QAM constellation, a CR of 5/6, and the RME channel.

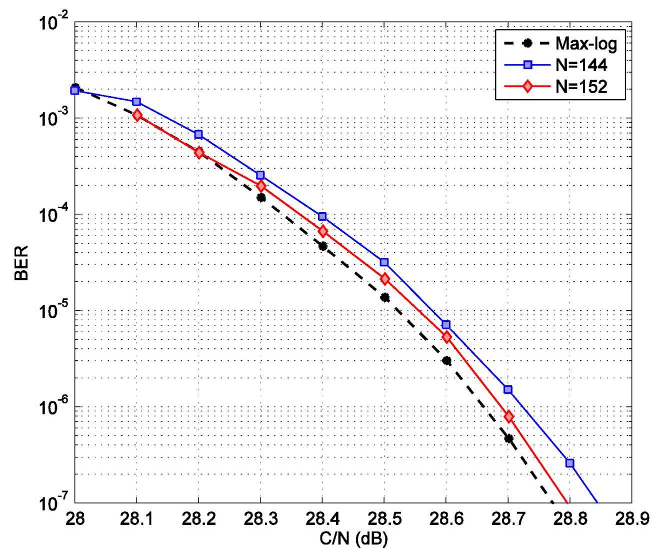

Fig. 13. BER against C/N curves for a 256-QAM constellation, a CR of 3/4, and the RME channel.

lower the code rate the less the difference between the max-log approximation and the proposed method.

Fig. 9 shows the same results but for a 0 dB echo channel with a 95% echo delay for a CR of 5/6. In this case it can be seen that with only 56 points, the performance degradation of the system in terms of C/N is as before, under 0.1 dB.

Figs. 10 and 11 show the BER curves for the code rates 3/4 and 1/2 respectively, both for the 0 dB echo channel. Each figure shows the curves for N=56 and N=36. As in the P1 channel case, when comparing these figures to Fig. 9 it can be seen that the lower the code rate the less the difference between the Max-log approximation and the proposed method.

In conclusion, in the case of these channels, the size of the subsets can be reduced to only 56 points, a 22% of the total number of points of the constellation. In terms of complexity reduction, the number of 2-D Euclidean distances are reduced a 78%, which outperforms the results already presented in [12], [13].

B. Results for the RME Channels

Fig. 12 shows the BER curves of the system for different values of N, a CR of 5/6, and for an RME channel with 15% of erasure events. The results for the ideal max-log demapper are also shown for comparison purposes. From this figure it can be seen that for a performance degradation under 0.1 dB this channel require subsets with a minimum of 152 points.

Due to the harder propagation conditions of the RME channel, the subsets need more points in order to show a negligible performance loss. Anyway, in terms of complexity reduction, the required number of 2-D Euclidean distances is still greatly reduced; a 41% reduction is obtained.

Figs. 13 and 14 show the BER curves for the code rates 3/4 and 1/2 respectively, both for the RME channel. Each figure shows the curves for N = 152 and N = 144. As in the previous subsection, it can be seen that these more robust code rates

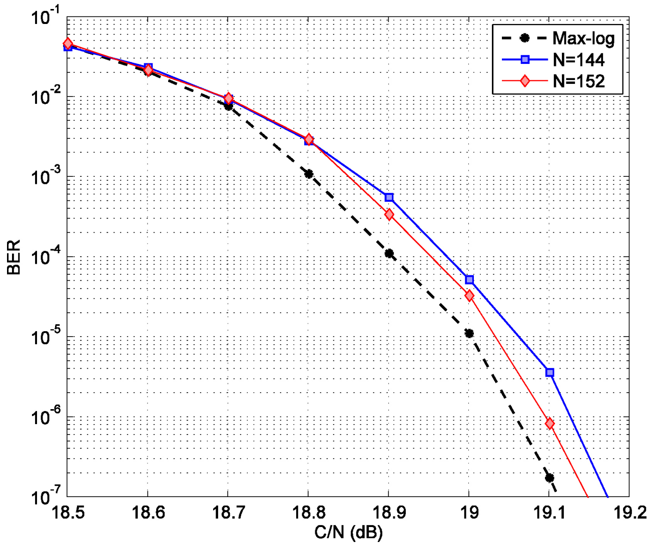

Fig. 14. BER against C/N curves for a 256-QAM constellation, a CR of 1/2, and the RME channel.

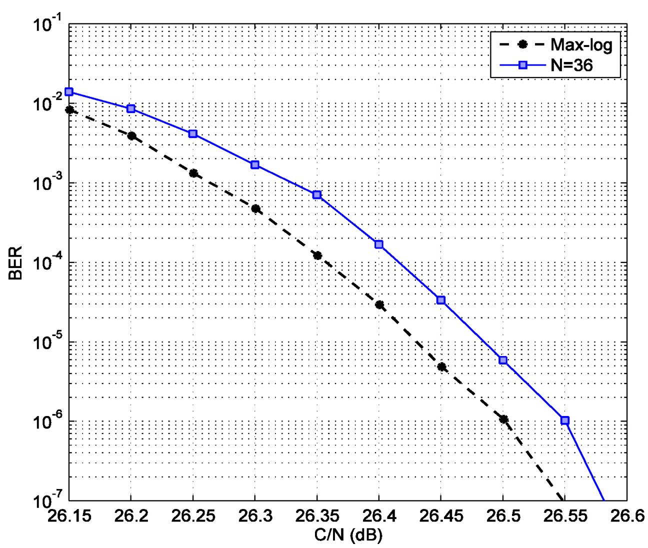

Fig. 15. BER against C/N curves for a 256-QAM constellation, a CR of 5/6, 2-D channel estimator, and the P1 channel.

show lower losses so the optimization of the subsets can be done focusing on the worst case code rate, that is, CR 5/6.

As stated earlier, the RME channel is clearly the worst case propagation scenario defined in [11]. In fact, it does not correspond to a real channel but it allows testing the DVB-T2 systems in very hard propagation conditions. That is, this channel is very unlikely to occur, so a low cost receiver could use the subsets found for the P1 or the 0 dB echo channels.

C. Real Channel Estimation Effect

The aim of this subsection is to show the impact of the real channel estimation on the proposed method. A 2-D pilot aided channel estimator based on Wiener filters [18] has been added to the CSP. Simulations have been run for the P1 channel, different code rates (5/6, 3/4 and 1/2) and the PP1 pilot pattern [1].

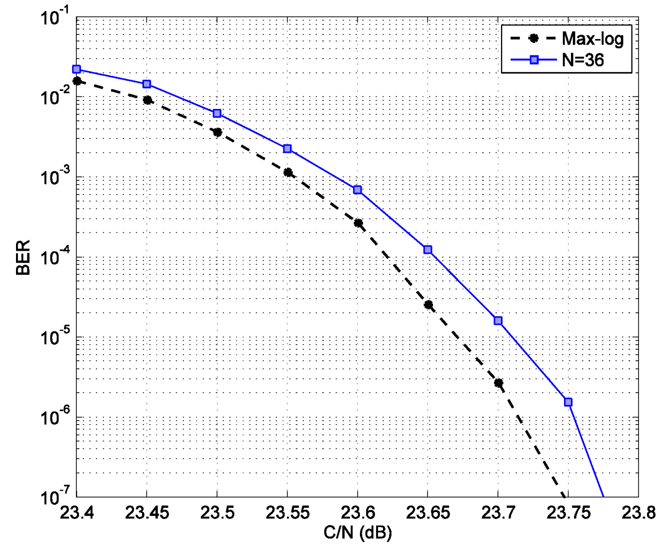

Fig. 16. BER against C/N curves for a 256-QAM constellation, a CR of 3/4, 2-D channel estimator, and the P1 channel.

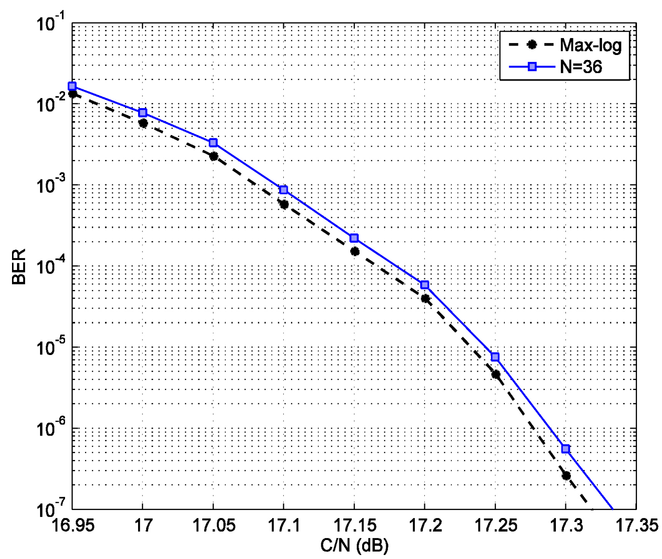

Fig. 17. BER against C/N curves for a 256-QAM constellation, a CR of 1/2, 2-D channel estimator, and the P1 channel.

Fig. 15 shows two BER curves for CR 5/6, one for the ideal max-log demapper and one for our proposed scheme with N = 36. In both curves the receiver uses the 2-D channel estimator. When compared with the results of Fig. 5 (ideal channel estimation) a loss of 0.65 dB can be denoted. According to [11] a performance loss of 0.41 dB can be expected due to the pilot boosting, so the losses of the real channel estimator can be estimated to be 0.24 dB.

From Fig. 15 it can be seen that the performance loss between the max-log demapper and the proposed scheme is almost the same as the one with ideal channel estimation shown in Fig. 5. The same conclusions can be drawn from Figs. 16 and 17, where the same curves are depicted for CR 3/4 and 1/2 respectively.

VI. Conclusion

In this brief, the implementation of the RQD technique in the new emerging DVB-T2 standard has been analyzed. Although this technique improves the receiver performance in selective channels, especially in propagation scenarios with deep fadings, it can introduce serious complexity problems in the hardware implementation of the demapper.

A demapper for rotated constellations has been proposed with application to DVB-T2 receivers with reduced hardware complexity. Simulation results show that when compared to the ideal log-max demapper, a reduction in the number of required operations of 78% can be achieved with almost no performance degradation even when using real channel estimation.

References

[1] *Digital Video Broadcasting (DVB); Frame Structure, Channel Coding and Modulation for a Second Generation Digital Terrestrial Television Broadcasting System (DVB-T2)*, European Telecommun. Standard Institute ETSI York EN 302-755 V.1.1.1., Sep. 2009.

[2] *Digital Video Broadcasting (DVB); Frame Structure, Channel Coding and Modulation for Digital Terrestrial Television*, European Telecommun. Standard Institute ETSI York EN 302-744 V.1.4.1., 2009.

[3] R. G. Gallager, "Low-density parity-check codes," *IRE Trans. Inform. Theory*, vol. 8, pp. 21–28, Jan. 1962.

[4] T. Richardson and R. Urbanke, "The renaissance of Gallager's low-density parity-check codes," *IEEE Commun. Mag.*, vol. 41, no. 8, pp. 126–131, Aug. 2003.

[5] S. Alamouti, "A simple transmit diversity technique for wireless communications," *IEEE J. Sel. Areas Commun.*, vol. 16, no. 8, pp. 1451–1458, Oct. 1998.

[6] K. Boullé and J. C. Belfiore, "Modulation scheme designed for the Rayleigh fading channel," in *Proc. CISS*, Mar. 1992, pp. 288–293.

[7] X. Giraud, E. Boutillon, and J. C. Belfiore, "Algebraic tools to build modulation schemes for fading channels," *IEEE Trans. Commun.*, vol. 43, no. 3, pp. 938–952, May 1997.

[8] J. Boutros and E. Viterbo, "Signal space diversity: A power- and bandwidth-efficient diversity technique for the Rayleigh fading channel," *IEEE Trans. Inf. Theory*, vol. 44, no. 4, pp. 1453–1467, Jul. 1998.

[9] C. Abdel Nour and C. Douillard, "On lowering the error floor of high order turbo BICM schemes over fading channels," in *Proc. IEEE Global Commun. Conf.*, Nov. 2006, pp. 1–5.

[10] F. M. Assis and E. S. Sousa, "Rotated constellation MC-CDMA system," in *Proc. IEEE Global Commun. Conf.*, vol. 1B. Dec. 1999, pp. 996–1001.

[11] *Implementation Guidelines for a Second Generation Digital Terrestrial Television Broadcasting System (DVB-T2)*, DVB document A133 (draft ETSI TR 102 831 V0.10.00), Dec. 2009.

[12] M. Li, C. Abdel Nour, C. Jégo, and C. Douillard, "Design of rotated QAM mapper/demapper for the DVB-T2 standard," in *Proc. IEEE Workshop Signal Proc. Syst*, Oct. 2009, pp. 18–23.

[13] D. Pérez-Calderón, V. Baena-Lecuyer, A. C. Oria, P. López, and J. G. Doblado, "Rotated constellation demapper for DVB-T2," *Electron. Lett.*, vol. 47, pp. 31–32, Jan. 2011.

[14] C. Abdel Nour and C. Douillard, "Rotated QAM constellation to improve BICM performance for DVB-T2," in *Proc. ISSSTA*, Aug. 2008, pp. 354–359.

[15] D. Pérez-Calderón, C. Oria, J. García, P. López, V. Baena, and I. Lacadena, "Rotated constellation for DVB-T2," in *Proc. DCIS*, 2009, pp. 187–191.

[16] K. S. Kim, K. Hyun, C. W. Yu, Y. O. Park, D. Yoon, and S. K. Park, "General log-likelihood ratio expression and its implementation algorithm for gray-coded QAM signals," *ETRI J.*, vol. 28, no. 3, pp. 291–300, Jun. 2006.

[17] O. Haffenden, "The common simulation platform," *BBC Research White Paper 196*, May 2011.

[18] P. Hoeher, S. Kaiser, and P. Robertson "Two-dimensional pilot-symbol-aided channel estimation by Wiener filtering," in *Proc. ICASSP*, vol. 3. Apr. 1997, pp. 1845–1848.

Darío Pérez-Calderón was born in Jerez de la Frontera, Spain. He received the Telecommunication Engineering degree from the University of Seville, Seville, Spain, in 2009.

Since 2008, he has been with the Department of Electronic Engineering, Escuela Superior de Ingenieros, University of Seville. His current research interests include orthogonal frequency division multiplexing systems and diversity techniques for communication systems, especially techniques applied to DVB standards.

Vicente Baena-Lecuyer was born in Athis-Mons, France. He received the Telecommunication Engineering and Ph.D. degrees from the University of Seville, Seville, Spain, in 1997 and 2001, respectively.

Since 1997, he has been with the Department of Electronic Engineering, Escuela Superior de Ingenieros, University of Seville. His current research interests include orthogonal frequency division multiplexing systems, especially digital video broadcasting systems.

Ana Cinta Oria was born in Huelva, Spain. She received the Masters and Ph.D. degrees in telecommunication engineering from the University of Seville, Seville, Spain, in 2005 and 2010, respectively.

Since 2005, she has been with the Department of Electronic Engineering, Escuela Superior de Ingenieros, University of Seville. Her current research interests include orthogonal frequency division multiplexing systems, especially digital video broadcasting systems.

Patricio López was born in Oviedo, Spain. He received the Telecommunication Engineering degree from the University of Seville, Seville, Spain, in 2008.

Since 2008, he has been with the Department of Electronic Engineering, Escuela Superior de Ingenieros, University of Seville. His current research interests include orthogonal frequency division multiplexing systems, especially digital video broadcasting systems.

Jose García Doblado was born in Huelva, Spain. He received the Telecommunication Engineering degree from the University of Seville, Seville, Spain, in 2008.

Since 2006, he has been with the Department of Electronic Engineering, Escuela Superior de Ingenieros, University of Seville. His current research interests include digital signal processing, especially digital video broadcasting.