TELKOMNIKA Telecommunication, Computing, Electronics and Control
Vol. 18, No. 5, October 2020, pp. 2362~2370
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v18i5.16295

The efficient interleaving of digital-video-broadcasting-satellite 2nd generations system

Mohammed Jabbar Mohammed Ameen[1], Hussam Jawad Kadhim[2]
[1]College of Engineering, The University of Babylon, Iraq
[2]College of Science for women, The University of Babylon, Iraq

Article Info

Article history:

Received Apr 9, 2020
Revised May 1, 2020
Accepted May 11, 2020

Keywords:

16-APSK
32-APSK
BCH
BER
FEC
Interleaver
LDPC
QPSK
SNR

ABSTRACT

The DVB-S2 system is designed as a toolbox to permit the execution of the satellite programs. Interleaver is an essential part of the DVB-S2 system. The current general block interleaver in DVB-S2 is not best, which leads to high BER and maybe not satisfy the requirements of the system. The purpose of this paper is to study the several interleaver types and comparative analyses are done between them to find which of these give better performance. Simulations results obtained prove that the 2D interleavers minimize BER more than other interleavers of DVB-S2. Further, the performance of 2D interleaver is better on a system that required a low SNR.

Corresponding Author:

Mohammed Jabbar Mohammed Ameen,
Department of Electrical Engineering,
College of Engineering, The University of Babylon,
Najaf road, Hillah, Babel, Iraq.
Email: mohammedalsalihy@yahoo.com

1. INTRODUCTION

DVB-S2 or digital-video-broadcasting-satellite 2nd Generations provides for the broadcast and high-definition television (HDTV), data content sharing out, internet services, and military communications data link [1]. The DVB-S2 system determines about three mains ideas are: finest transmitting performance, complete flexibility and complexity at the receiver acceptable. To accomplish better tradeoff between performance and complexity, capacity can increase around 30% over first generations, DVB-S2 exploits later improvements in forward-error-correction (FEC) and modulation schemes [2]. An example of interactive point-to-point programs is the adaptive-coding-modulation (ACM) which permits for optimizing parameters of the transmissions to meet the requirements of the terminal such as changes in channel conditions. This outcomes in an additional raise in the spectrum usage efficiency for the 2nd over 1st generation, which permit the optimizing in space part layouts, therefore capable of the decrease in the operating cost of satellite services [3, 4].

DVB-S2 has appropriate active FEC technique use as a basis on the successive concatenation of BCH and low-density parity check (LDPC) codes. This combination of FEC configuration with addition to high order modulations (8PSK, 16-APSK, and 32-APSK) which gives greater spectral efficiency and therefore high data rate to the required system [5, 6]. The first code is the BCH code, which forms a major category of active error correction cyclic codes. This category of codes is a wonderful application of the Hamming code when multiple error correction required. For the second LDPC code, which implies that reasonable structure assign to be the noise threshold near to the theoretical of Shannon limits for the symmetrical memoryless channel. Error-correcting codes theory introduced considerable code constructions with related decoding algorithms. The applications with powerful error-correcting abilities are required extremely complex decoder solutions [7, 8].

When data transmitted over wireless channels, it may confront extreme conditions; particularly burst errors. Burst error control in the wireless transmission system is especially significant in numerous applications. If the data rate increases, BER also increases. The methods that can be used to minimized or remove the burst errors by data interleaving. There are some basic interleaving strategies like block and convolutional interleaving which can be expressed as a one-dimensional term. The performance of these interleavers is bounded. Thus, there is a requirement to find strong interleavers. Chaotic and zigzag mapping techniques can be applied to construct powerful interleavers, which can be expressed as a two-dimensional term (2D). The Chaotic interleaver technique based on chaotic Baker map, whereas, the zigzag mechanism is rearranged the input bits in a matrix by zigzag manner. Another merit of the 2D interleaving technique is it can accomplish a grade of encryption in the transmitted information which adds extra security to the system [9, 10].

The motivation of this paper is to improve the performance of the DVB-S2 system by minimizing BER to fulfill the reduction in BER for a certain SNR. We investigated different interleaving data strategies for the DVB-S2 system. We compare the bit error rate (BER) performance to show that it's better. To achieve this, simulation models have been made and executed utilizing MATLAB R2018b. The following part quickly depicts the DVB-S2 system model. Section 3 presents the mechanism and kinds of interleaver. Memory and time delay parameters present in section 4. In section 5, simulation parameters are scheduling. Computer outcomes are introduced in section 6. Finally, conclusions are pointed out in section 7.

2. SYSTEM MODEL

DVB-S2 system model that has been implemented using Matlab is illustrated in Figure 1. At the transmitter side, random data is chosen as an information source. Two-level of encoding BCH and LDPC are used then interleaved by interleaving technique and finally, modulate data using QPSK, 16APSK, and 32APSK for transmitting via AWGN channel. At the receiving side, the received data is now demodulated and deinterleaved respectively. Therefore, can decode using LDPC and BCH decoder respectively. Accordingly, that first information could make recouped.

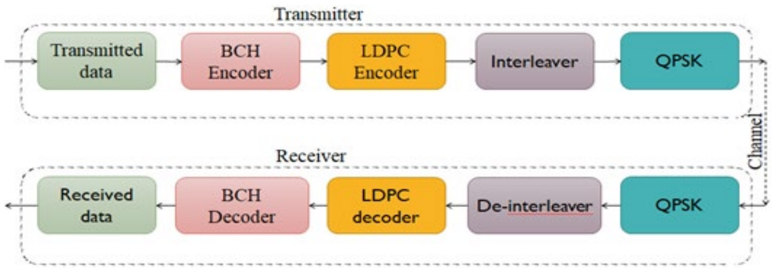

Figure 1. System model

3. WORKING PRINCIPLE AND TYPES OF INTERLEAVER

Interleaving design is not only to adjust to the channel, yet to alter the channel. By interleaving scheme, a burst error in the channel with memory is changed into an arbitrary independent error without memory to correct the errors [11, 12]. When a burst of continuous error occurs in the signal transmission operation, these errors will show up on a continuing segment of the code stream. After the interleaving process, the interleaved code turns out to be moderately discrete and randomized; these continuous errors can be transformed into somewhat separate errors. Generally, two traditional types of interleaves usually named to as block and convolutional. Block divided into many types as follow [13, 14]:

3.1. Matrix interleaver

It's a block type of interleaver, performs via filling a matrix with specific dimensions by the input bits in row by row until complete the matrix and then transmitting the bits in a matrix to the output port in form of column by column as shown in Figure 2. The row size (n) is named the span and the column size (m) is representing the depth. Therefore, an interleaver is characterized by n and m and indicate to as (n, m) matrix interleaver. The ability to dispersing burst error depends on both the value n and m [15].

3.2. General block interleaver

The elements pattern is rearranged according to the permutation vector which must be the same length of input elements without delete or iterating any elements. suppose that the input vector includes M elements, thus, the permutation vector has length M, as shown in Figure 3. The deinterleaver must use different permutation vector pattern in order to recover the original data. The scattering capability of burst errors depend on length M.

3.3. Random interleaver

Random Interleaver rearranges the input elements with a random permutation pattern. Due to this randomization of elements, the errors burst can be removed at the receiver and easily detected and corrected as illustrated in Figure 4. If the interleaver randomization degree is not a good generated, the performance of the system is degraded and the BER values obtained will be significant. Otherwise, if the interleaving patterns are generated with more random, at that point, lower values of BER are acquired for the value of the same parameter. IDMA system utilizes the random interleaver for users separation, so interleaver must fulfill the design rules [16, 17].

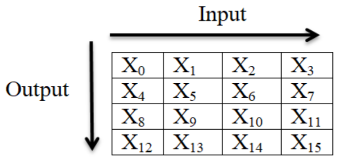

Figure 2. Matrix interleaver pattern

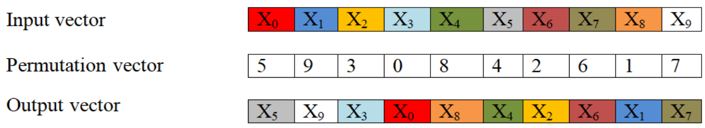

Figure 3. General block interleaver pattern

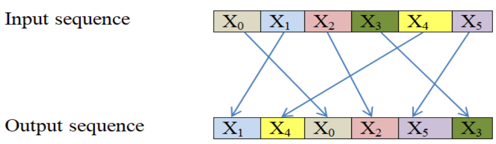

Figure 4. Random interleaver pattern

3.4. Chaotic interleaving

The easiest and generally famous interleaving technique is the block type. However, this type isn't effective with 2-D error bursts [18]. Accordingly, the requirement to use developed interleavers for this function. The discrete version of the 2-D chaotic Baker map is a perfect choice for this reason. The elements can be rearranged into a square matrix then randomized employing the chaotic Baker map [19, 20]. The algorithm of chaotic interleaving can be summarized as follows:

– The matrix dimensions MxM is partitioned into i many perpendicular rectangle shapes with height M and width m_k. in which $m_1 + m_2 + \ldots m_i = M$.
– These perpendicular rectangles would extend in the horizontal orientations and ordered perpendicularly to get an m_k x M horizontal rectangle.
– These rectangle shapes are accumulated as appeared in Figure 5 (a), where the base is put at left one and the upper part placed the right one.
– Every perpendicular rectangle m_k x M is split into n_i boxes with dimensions $\frac{M}{mk}$ x m_k including M points exactly.
– Finally, these boxes are reshaped column by column to form a row of elements as illustrated in Figure 5 (b) [21, 22].

3.5. Zigzag interleaver

Zigzag interleaving is considered appealing for maximum information rate requirements because of low encoding and decoding complexity level and perfect performance especially with the maximum data rate. The information symbols can be organized in a zigzag manner as shown in Figures 6 (a) and (b). Figure 6 (c) presents the zigzag interleaving operation when a 2-D error burst takes place as a shaded area. Figure 6 (d) indicates that this burst error becomes random. Subsequently, this burst error can be corrected somewhat by utilizing the mechanism of a single error correction. Thus, the Zigzag interleaving technique can remove 2D bursts of errors [17].

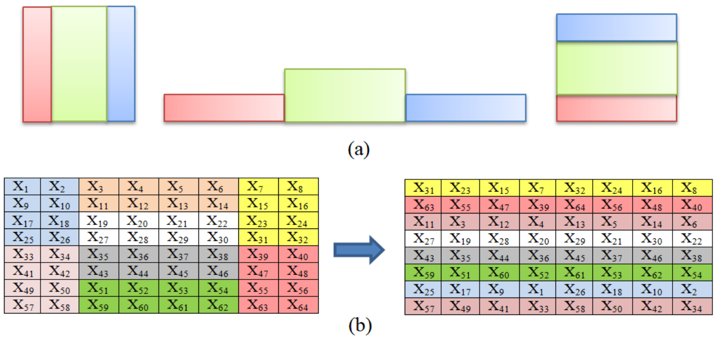

Figure 5. Chaotic interleaving; (a) baker map, (b) 8×8 matrix randomization

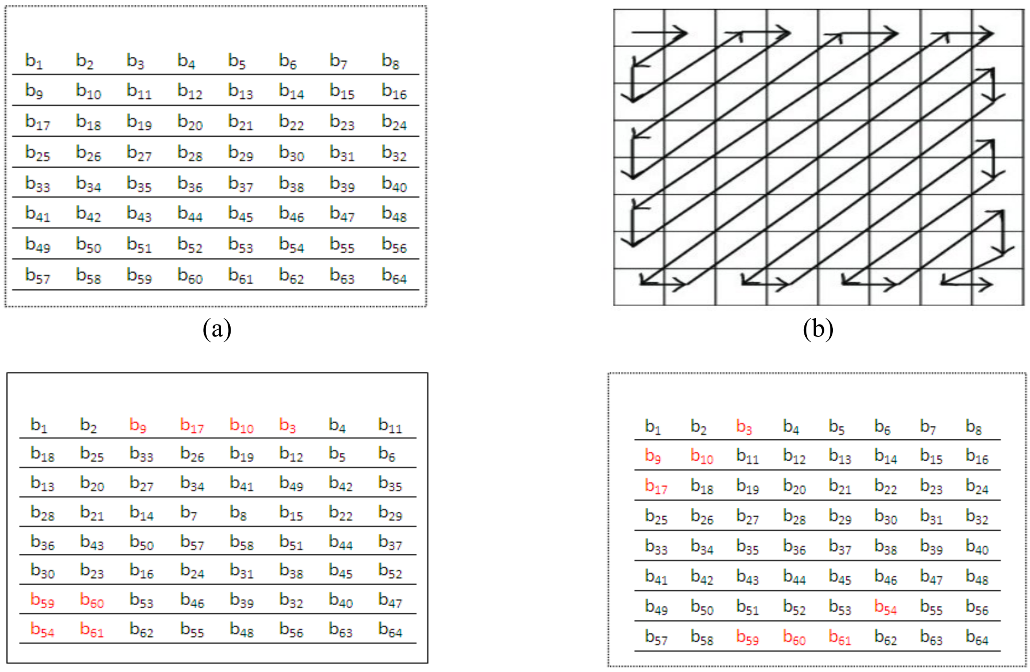

Figure 6. Zig-Zag Interleaving of 8×8 Matrix; (a) the 8×8 matrix, (b) zigzag randomization procedure, (c) zigzag interleaving operation, (d) error bursts removed after deinterleaving

3.6. Odd-even interleaver

The number of columns and rows should be odd count. At first, the symbols are left un-interleaved and encoded, but only the odd-location coded symbols are loaded. At that point, the symbols are randomized and encoded and only the even-location coded symbols are loaded, as shown in Figure 7. This interleaver designed for half code rate which is acquired by puncturing the two nonsystematic codes. The result has scattering capability of the burst errors of the code [23].

Odd-even interleaver output														
Encoder output without interleaving														
X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
Y_1	-	Y_3	-	Y_5	-	Y_7	-	Y_9	-	Y_{11}	-	Y_{13}	-	Y_{15}
Encoder output with row-column interleaving														
X_1	X_6	X_{11}	X_2	X_7	X_{12}	X_3	X_8	X_{13}	X_4	X_9	X_{14}	X_5	X_{10}	X_{15}
-	Z_6	-	Z_2	-	Z_{12}	-	Z_8	-	Z_4	-	Z_{14}	-	Z_{10}	-
Final Odd-even interleaver output														
Y_1	Z_6	Y_3	Z_2	Y_5	Z_{12}	Y_7	Z_8	Y_9	Z_4	Y_{11}	Z_{14}	Y_{13}	Z_{10}	Y_{15}

Figure 7. Operation of odd even interleaver

3.7. Algebraic interleaver

The Algebraic Interleaver reorganizes the symbols of its input sequence by using a permutation that is algebraically determined. The complexity and latency effect are minor in the algebraic interleaver consequently; it can be executed using simple blocks. The mathematical expression of algebraic interleaver is defined by $\Pi(k) = k\ MOD\ N$ where N is the interleaver length, $\Pi(k)$ take a value between [0, $N-1$] indicates the new placement to which index k is permuted and $MOD\ N$ represents modulo N arithmetic [24, 25].

3.8. Matrix helical interleaver

It minimizes the errors burst and increase the correction ability. In this type, the indices of interleaver are load regularly for generating helical interleaver. At first, helical interleaver elements are ordered column and row, and then elements can be loaded in diagonal as shown in Figure 8. The length of interleaver can be expressed as L= kr × kc, where kr and kc are the size of rows and columns respectively. The slope of diagonal referred to the array step-size parameter, as the amount by which the row index increases, the column index increases by one.

Input array

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16
17	18	19	20
21	22	23	24

output array

1	6	11	16
5	10	15	20
9	14	19	24
13	18	23	4
17	22	3	8
21	2	7	12

Figure 8. Operation of matrix helical interleaver

3.9. Helical interleaver

It permutes the sequence of the input symbols by putting them in a helical manner and afterward transmitting rows of the array to the output port as shown in Figure 9. The number of columns in the helical array can represent by M, thus, the array has M columns and unbounded rows. Let refer to the group size by N, then the block admits an input of length M·N at each time step and divisions the input into successive sets of N bits. Checking from the earliest starting point of the implementation, the block venues the kth sets in the array over column k mod M. The situation is helical because of the reduction modulo M and because the first bit in the jth set is in row 1 (j-1).b, where b is the helical array step-size [26, 27].

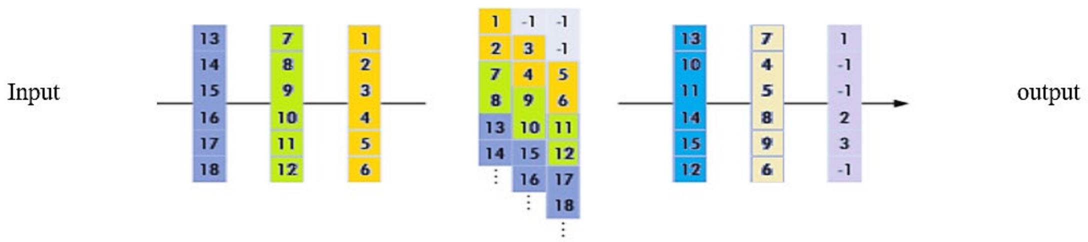

Figure 9. Operation of helical interleaver with parameter.
Number of columns = 3, group size = 2

3.10. Convolutional interleaver

As illustrates in Figure 10, it comprises of a counts of shift registers. Each of them contains a fixed time delay, which is multiples for a positive integer. Every new sequence to the input to the interleaver is fed to the following shift register and the past sequence in that register turns into output part of the interleaver. convolutional de-interleaver is accomplished by reversing the interleaver over its horizontal axis. The structure is similar except the longest delay line becomes at the top, and the no delay line becomes last. On the other hand, the de-interleaving process is analogous to interleaving mechanized [28].

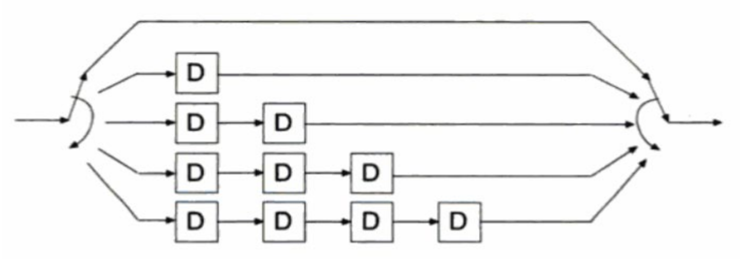

Figure 10. Operation of convolutional interleaver

4. MEMORY AND TIME DELAY PARAMETERS

The prime disadvantage of all block interleaver types mentioned in section 3 is the time delay resulted in each filling process of the interleaver. For array with M row by N column, interleaver/ deinterleaver end to end delay equal to 2MN-2M+2 symbol time. Memory requirements equal to 2MN end-to-end of the system. While, in convolutional interleaver, the memory requirements equal to M (N-1)/2, the end to end time delay is M (N-1) symbol. Therefore, it provides a reduction over block interleaver by around one-half in memory and time delay requirements. Time delay depends on interleaver depth and information rate. Therefore, it may be some seconds long for many transmission channels. This delay may be inappropriate for various applications [29].

5. SIMULATION PARAMETER

Table 1 summarizes the simulation parameters used for the different scenarios considered through simulation. These parameters were chosen based on the DVB-S2 standard. At first, the incoming original information with packet size 1504 are buffered to become 32208 bits and then passed to BCH encoder, the results output codeword length 32400 bits. For the LDPC encoder, the input of it is the output of BCH then, the output codeword length 64800. After concatenated codes, the bits are randomized using one of the types of interleaver mentioned in section 3 for each case and then modulation scheme. With respect to the APSK modulation scheme, code identifiers are 2/3 and 3/4 for 16 and 32 modulation orders respectively [30].

Table 1. DVB-S2 system parameter values for different interleavers and modulation schemes

Parameter		Values
Modulation Techniques		QPSK-16APSK-32APSK
Coding		BCH(32400,32208) ,LDPC(64800,32400)
	Matrix	Number of row = 324, Number of column=200
	Helical	Row of shift register = 100, Register length step = 648, Helical array step size = 1
	General block	Random Permutation vector
	Zig-Zag	Number of row = 256, Number of column = 256
Interleaving	random	Random Permutation
	Matrix Helical	Number of row = 324, Number of column = 200, array step size = 2
	Odd-even	Random even sequence of length = 32400
	Chaotic	Number of row = 256, Number of column = 256
	Convolutional	Row of shift register = 100, Register length step = 648
	algebraic	Number of elements = 64800, Multiplication factor = 1
Sample per frame		1504
Sample time		31.662 micro *second*
Channel Type		AWGN (additive white Gaussian noise)

6. NUMERICAL RESULT AND DISCUSSION

The performance analysis of several interleavers for DVB-S2 will be determined in this section. Figure 11 produces a performance comparison of all interleaver mention in section 3. At BER = 0.001, the SNR for 2D interleaver (chaotic or zigzag) about 0.73 dB whereas other interleavers reach 0.85 dB, the gain about 0.12 dB. Hence, the DVB-S2 system with 2D interleaver gives the best performance. In the same manner, Figure 12, At BER = 0.001, the SNR for 2D interleaver about 18 dB whereas other interleavers reach to 18.5 dB, the gain about 0.5 dB. Finally, in Figure 13, At BER = 0.0001, the SNR for chaotic and zigzag interleaver are 23.35dB and 23.25dB respectively whereas other interleavers reach to 23.85 dB, the gain about 0.5 dB. The reasons for obtaining minimum BER in 2D interleaver is due to the properties of the permutations generates by the Baker map and zig-zag algorithm that make a typical random permutation. The percentage reduction of SNR at BER = 0.001 is 2%, 3% and 14% for 32APSK, 16APSK and QPSK respectively. Therefore, the performance of the 2D interleaver is better at low SNR.

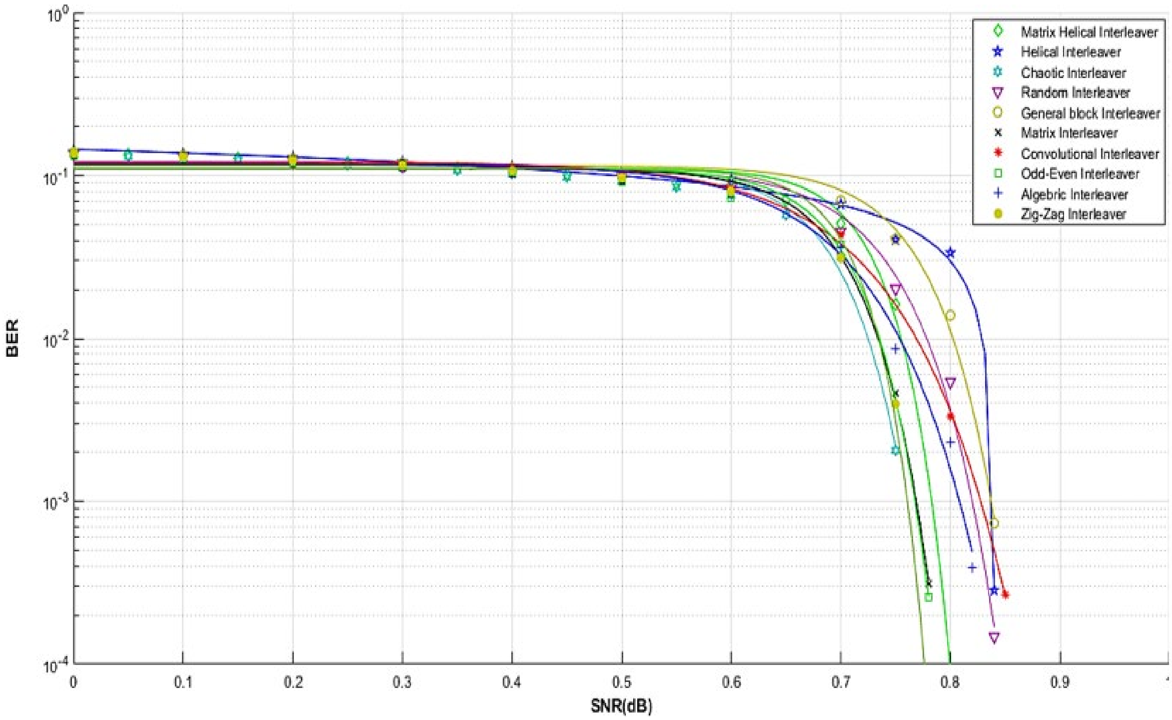

Figure 11. BER performance of DVB-S2 using different interleavers with QPSK modulation

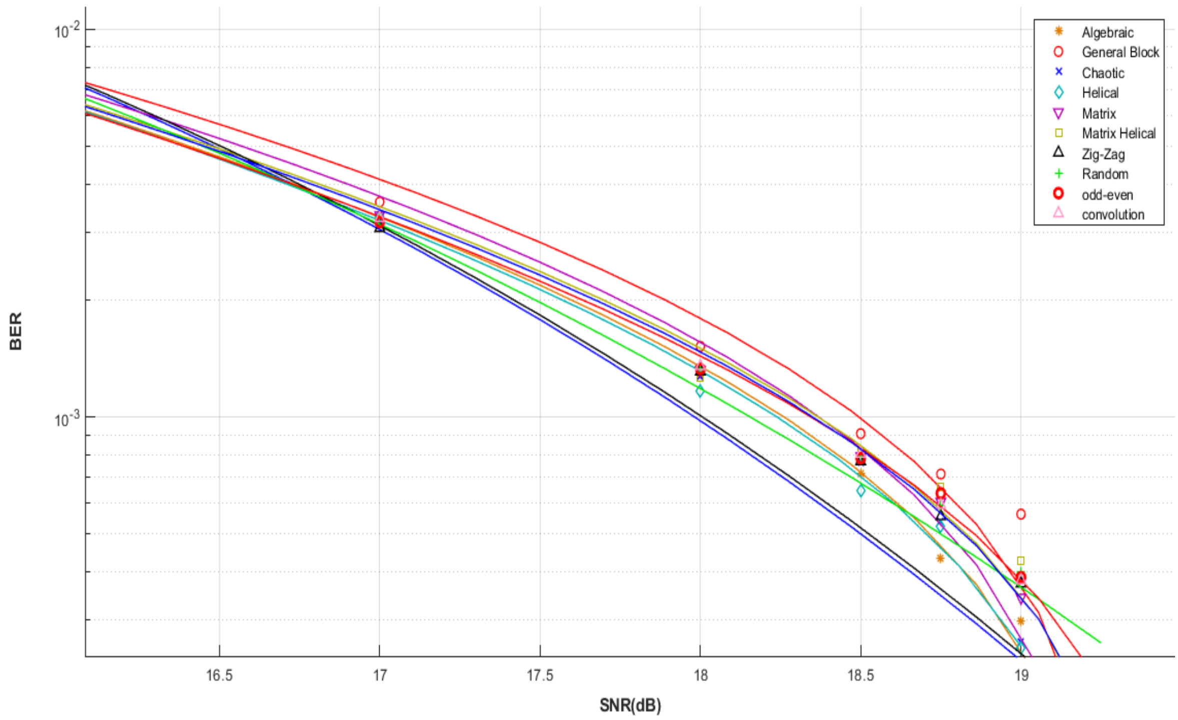

Figure 12. BER performance of DVB-S2 using different interleavers with 16-APSK modulation

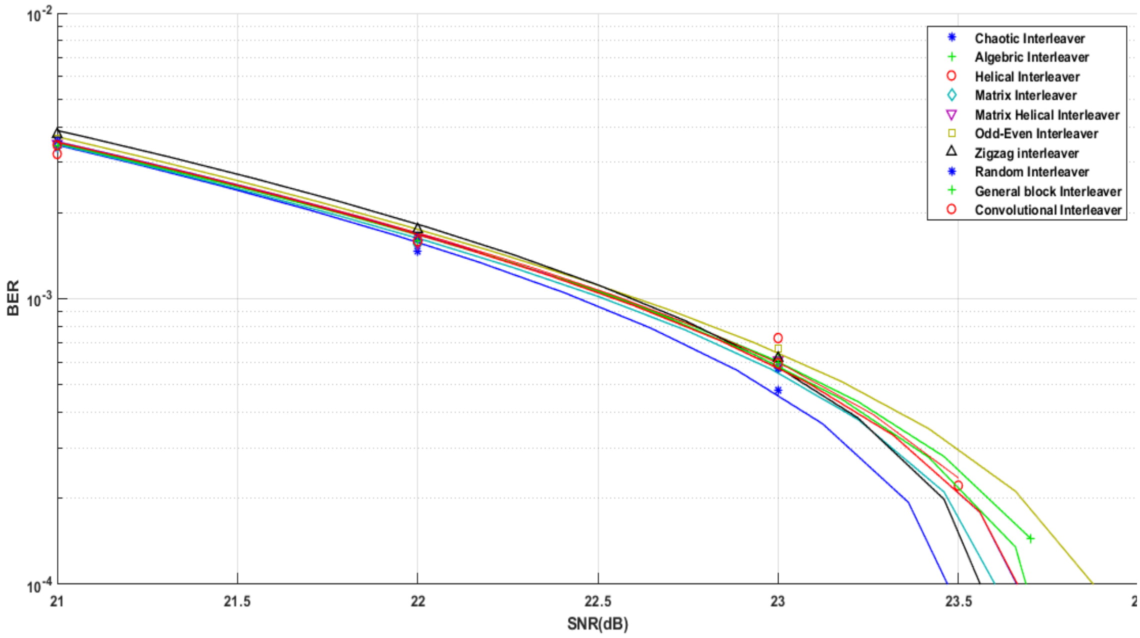

Figure 13. BER performance of DVB-S2 using different interleavers with 32-APSK modulation

7. CONCLUSION

In this paper, investigations of three modulation techniques (QPSK, 16APSK, and 32APSK) are achieved with several interleavers. BER is evaluated concerning the above modulation techniques over an AWGN channel. The reason for doing this simulation is to examine the performance of these interleavers in the DVB-S2 system. As we realize that the determination of effective interleaver is a basic issue. From the above analysis of interleavers, the 2D interleavers surpasses in terms of BER on all other types. So, we can claim that 2D interleaver (chaotic or zigzag) gives better performance.

REFERENCES

[1] X. Xiang and M. C. Valenti, "Improving DVB-S2 performance through constellation shaping and iterative demapping," *2011 - MILCOM 2011 Military Communications Conference,* 2011.

[2] A. Morello and V. Mignone, "DVB-S2: The Second-Generation Standard for Satellite Broad-Band Services," *Proceedings of the IEEE,* vol. 94, no. 1, pp. 210-227, 2006.

[3] M. Gomes, G. Falcao, V. Silva, V. Ferreira, A. Sengo, and M. Falcao, "Flexible Parallel Architecture for DVB-S2 LDPC Decoders," *IEEE GLOBECOM 2007-2007 IEEE Global Telecommunications Conference*, 2007.

[4] S. Bera, and N. Sur, "Performance Evaluation of DVB System for Text Transfer," *European Journal of Advances in Engineering and Technology*, vol. 2, no. 5, pp. 62-65, 2015.

[5] S. Brisken, M. Moscadelli, V. Seidel, and C. Schwark, "Passive radar imaging using DVB-S2," *2017 IEEE Radar Conference (RadarConf),* 2017.

[6] K. El-Abbasy, B. Abdelhamid, and S. Elramly, "Performance evaluation of DVB-S2 and DVB-S2X systems," *2015 IEEE International Conference on Communication, Networks and Satellite (COMNESTAT)*, 2015.

[7] L. Haering and C. Kisters, "Signalling-assisted modulation classification in wireless OFDM systems with adaptive modulation and coding," *2013 IEEE International Conference on Communications (ICC)*, 2013.

[8] G. Faria and P. Hostiou, "Application of DVB-S2 for DVB-T & DVB-T2 Transport," *The 2011 Annual Technical Conference & Exhibition*, 2011.

[9] A. Morello and V. Mignone, "DVB-S2X: extending DVB-S2 flexibility for core markets and new applications," *International Journal of Satellite Communications and Networking*, vol. 34, no. 3, pp. 327-336, Sep 2015.

[10] E. M. El-Bakary, O. Zahran, S. A. El-Dolil, and F. E. Abd El-Samie, "Chaotic Maps: A Tool to Enhance the Performance of OFDM Systems," *International Journal of Communication Networks and Information Security*, vol. 1, no. 2, 2009

[11] V. Chaturvedi, "Performance Analysis for Different Interleavers in Various Modulation Schemes with OFDM over an AWGN Channel," *IOSR Journal of Engineering*, vol. 2, no. 4, pp. 760-767, 2012.

[12] B. Das, M. P. Sarma, K. K. Sarma, and N. Mastorakis, "Design of a few interleaver techniques used with gold codes in faded wireless channels," *2015 2nd International Conference on Signal Processing and Integrated Networks (SPIN)*, 2015.

[13] S. Sharma, P. C. Sau, and A. Shukla, "Performance survey of IDMA with different interleavers," *2014 International Conference on Signal Processing and Integrated Networks (SPIN)*, 2014.

[14] J. Sharma, S. Mishra, and N. Sharma, "An analysis of interleaver types for better BER performance in linear turbo equalizer," *2017 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS),* 2017.
[15] J. Jeong, Y. Jeon, and D. Yoon, "Blind Estimation of Block Interleaver Parameters using Statistical Characteristics," *Future Generation Information Technology 2016,* 2016.
[16] Y. Shen, G. Zhao, S. Zhang, Y. Li, and S. Li, "The Design of RA Code Pseudo-random Interleaver," *Journal of Physics: Conference Series*, vol. 1237, pp. 042024, 2019.
[17] B. Das, M. P. Sarma, and K. K. Sarma, "Different Aspects of Interleaving Techniques in Wireless Communication," *Advances in Systems Analysis, Software Engineering, and High-Performance Computing Intelligent Applications for Heterogeneous System Modeling and Design*, pp. 335-374, 2015.
[18] A. Beirami, H. Nejati, and W. Ali, "Zigzag map: a variability-aware discrete-time chaotic-map truly random number generator," *Electronics Letters*, vol. 48, no. 24, pp. 1537-1538, 2012.
[19] Z. A. El-Hamid, A. El-Henawy, F. A. El-Samie, H. El-Shenawy, and M. Samir, "FFT/DWT/DCT OFDM channel estimation using EM algorithm in the presence of chaotic interleaving," *2012 8th International Computer Engineering Conference (ICENCO)*, 2012.
[20] M. E. Elhameed Abd, M. A. M. El-Bendary and H. M. Abd Elkader, "An Efficient Chaotic Interleaving with Convolution Encoder and Decoder for Simplicity in LTE System," *International Journal of Networks and Communications,* vol. 8, no. 1, pp. 1-9, 2018.
[21] S. Vaidyanathan, A. Sambas, S. Zhang, Y. Zeng, M. A. Mohamed, and M. Mamat, "A new two-scroll chaotic system with two nonlinearities: dynamical analysis and circuit simulation," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 17, no. 5, pp. 2465-2474, Jan 2019.
[22] R. A. Mustafa, A. A. Maryoosh, D. N. George, and W. R. Humood, "Iris images encryption based on QR code and chaotic map," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 18, no. 1, pp. 289-300, January 2020.
[23] K. S. Arkoudogiannis and C. E. Dimakis, "Performance analysis of the odd–even uniform interleaver for turbo codes," *IET Communications*, vol. 13, no. 16, pp. 2469-2477, Aug 2019.
[24] O. Takeshita and D. Costello, "New classes of algebraic interleavers for turbo-codes," *Proceedings. 1998 IEEE International Symposium on Information Theory,* 1998.
[25] D. Hao and P. Hoeher, "Helical interleaver set design for interleave-division multiplexing and related techniques," *IEEE Communications Letters*, vol. 12, no. 11, pp. 843-845, 2008.
[26] S. Ramabadran, A. S. Madhukumar, N. W. Teck, and C. M. S. See, "Parameter Estimation of Convolutional and Helical Interleavers in a Noisy Environment," *IEEE Access*, vol. 5, pp. 6151-6167, 2017.
[27] B. Sklar, "Digital communications: fundamentals and applications," Upper Saddle River, NJ: Prentice Hall, 2001.
[28] J. Terry, J. Heiskala, "OFDM Wireless LANs: A Theoretical and Practical Guide," Sams Publishing, 2002.
[29] B. Sklar, "Digital communications: fundamentals and applications. Upper Saddle River," NJ: Prentice Hall, 2001.
[30] W. Fischer, "Digital Video and Audio Broadcasting Technology: A Practical Engineering Guide 3rd," *Springer*, 2009.

BIOGRAPHIES OF AUTHORS

Mohammed Jabbar Mohammed Ameen was born in Hillah-Iraq. He received a B. Se degree in electrical engineering from the University of Babylon in 2007 and an MSc degree in communications engineering from Al-Ahliyya Amman University in 2017, Jordon. He is working as a lecturer in the college of engineering/electrical department at Babylon University. He is currently working his Ph.D. degree at the electrical engineering department in the college of engineering at the University of Babylon. His research interests include IoT, MIMO, OFDM, FEC, and 5G, etc.
Email: mohammedalsalihy@yahoo.com.

Hussam Jawad Kadhim was born in Hillah-Iraq. He received the B. Se degree in electrical engineering from University of Babylon in 2007 and M. tech degree in Communication System Engineering in SHIATS-DU, Allahabad 2014. He is working as lecturer in college of science of women / computer department in Babylon University. He is currently working his PhD degree at electrical engineering department in college of engineering at University of Babylon. His research interests include IoT, power consumption, etc.
Email: hussamjwd@yahoo.com