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DVB-T2 Energy and Spectral Efficiency Trade-off Optimization based on Genetic Algorithm

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Abstract

The performance of a DVBT2 system is affected by a set of parameters, and choosing these parameters is very difficult for anyone, even an expert. In this paper, a Genetic algorithm is used to find the optimal set of parameters: constellation, No. Of forward error correction FEC blocks, code rate, samples per frame, and signal-to-noise ratio SNR for different fading channels. The number of Generations and individuals is 100. The goal of this work is to enhance the system performance by achieving a trade between BER and throughput with the lowest possible SNR and iterations. An online supercomputer platform was used to run the MATLAB simulation of the suggested system, which was conducted using MATLAB R2021a. The results show a clear improvement of the system performance and a BER of less than 10-5 is obtained. The influence of population size on the GA performance is also investigated, population sizes between 50 and 200 are tested. The results show that reaching the optimal solution with the least possible number of iterations is achieved when the population size is 200 while poor results are obtained when the population size is 50. Thus, we have a system capable of finding the optimal set of parameters that are most affected by the genetic algorithm GA and the population size of 200 with the least possible number of iterations.

Keywords: DVB-T2, GA, Population Size.

1 Introduction

The second generation terrestrial broadcast technology, or DVB-T2, was developed by the Digital Video Broadcasting (DVB) group (EN302755, 2015). DVB-T2 offers broadcasters a significant degree of flexibility by introducing several novel technologies that are based on multi-carrier transmission OFDM. Improved Forward Error Correction (FEC) and modulation stages are just a few of the many characteristics of DVBT2, which enable bit rates ranging from a few Mbps to 50 Mbps, contingent on the accompanying throughput trade-off and system robustness. Because of its flexibility, DVB-T2 has already taken over as the main DTV standard in many European nations (Morgade et al., 2014). Improving the communications system has always been the focus of attention of researchers. Some of

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them tended to improve the system using constellation rotation and cyclic Q delay techniques (Nour & Douillard, 2008), (Polak & Kratochvil, 2012) and (Ghayyib & Mohammed, 2021), while others tended to use another technique. Astawa & Santoso, (2016), developed or evaluated the MIMO-OFDM transmission technology, which is a component of the DVB-T2 standard. Several Input Multiple Output (MIMO) techniques boost the capacity of communications by using multiple antennas on the transmitter and reception sides (Astawa & Santoso, 2016). A newly bit interleaved was designed by the author of (Kang et al., 2014) for higher order constellation which enhanced the decoding performance of the system. The author of (Samo et al., 2015) investigated the abilities of digital video broadcasting second-generation terrestrial standard with its additional profile T2-Lite which is an improvement on DVBT2. Ingun, 2014, presented the field trials and optimal parameters for DVB-T2 in Thailand. The test findings can serve as a reference for implementing DVB-T2 networks in Thailand's Digital switchover (DSO) process (Ingun, 2014). After examining previous research, it became clear that there are two separate types of studies: those that do not use optimization and so do not reach the best possible performance and those that use optimization but often encounter the difficulty of high job complexity. In this paper, we meticulously chose the parameters that influence the system to develop an optimal system that overcomes the problem of complexity. The DVBT2 system is affected by a large number of parameters, which have a varying impact on the system. The parameters that have a significant impact on the DVBT2 system are; constellation type, code rate, no. of FEC block, propagation, sample/frame, and SNR. Choosing the appropriate value for these parameters has a significant impact on the results especially the bit error rate BER and throughput. It is very difficult for anyone, even an expert, to choose the appropriate parameters for a specific application. Therefore, the object of this paper is to develop a system based on optimization that performs a specific function, which is choosing the optimum value for this set of parameters to ensure obtaining the best fitness, which means the lowest bit error rate, the most appropriate for the application, etc. and making a tradeoff between BER and throughput with the lowest possible SNR. To achieve this goal, the genetic algorithm was used, and because it is greatly affected by population size, several scenarios of population size were chosen: 50,100, 150, and 200, the system performance is tested in each scenario. Four different types of channels have been utilized: Ricean (DVBT-F), 0 dB Echo, Rayleigh (DVBT-P), and Additive White Gaussian Noise (AWGN) channels. The subsequent sections of the paper, following the introduction in Section 1, are as follows: Section 2 provides a concise summary of the Genetic algorithm. The proposed work is described in section 3. Lastly, the final two sections, namely the results and conclusions, are presented.

2 Genetic Algorithm (GA) and Population Size

In every area of business, including retail, banking, automotive, and healthcare, optimization is an important idea. The goal of optimization is to minimize or maximize the loss/cost function to identify a point, or combination of points, in the search space that provides the best answer to the given problem. The genetic algorithm is an optimization technique based on Darwinian evolution theory (Malasri, 1999). It was introduced by John Holland in the early 1970s (Tsoukalas & Uhrig, 1996). A genetic algorithm's main objective is to find the best solution for the given problem. Nearly optimum solutions are frequently acceptable since they are preferable to no solutions at all (Malasri, 1999). Figure 1 shows the structure of the Genetic algorithm:

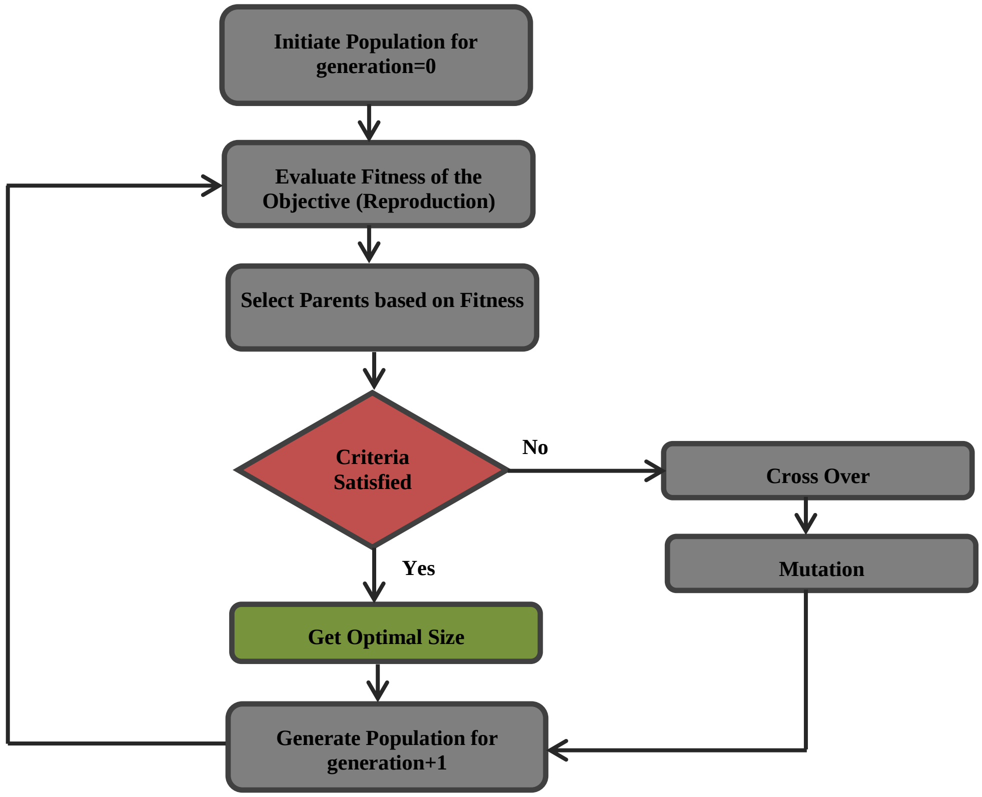

Figure 1: Structure of Genetic algorithm (Medium, 2022)

Initiate The Population

First, we should understand the meaning of population, chromosomes, and genes. The population or generation is a set of all potential solutions, or candidate solutions to start the search. Until it discovers an ideal answer, GA will iterate across several generations. Chromosome stands for a specific (candidate) solution present in the population. The single element of the decision variable that holds the position (locus) and value (allele) of the specific chromosome is called the Gene as shown in Figure 2. Random Initialization is the method used to start the first generation. Usually, the algorithm begins with a population that is generated at random. The magnitude of the decision variable determines the population size, which is based on the nature of the problem. Overall the generations, and the population remain the same (Medium, 2022).

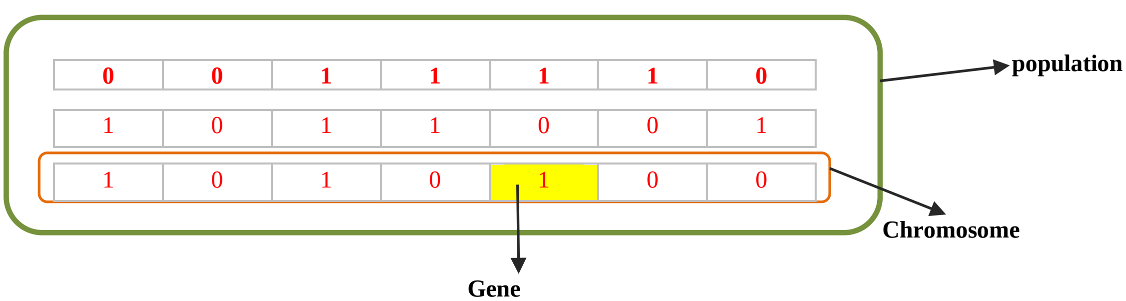

Figure 2: Population, Chromosome, and Gene Meaning (Medium, 2022)

Evaluate the Fitness

The fitness function assesses a potential solution's suitability for the goal. It assigns a fitness score, or likelihood value, to every individual, depending on which one will be chosen for reproduction. The fitness function needs to be computed quickly enough, and it is necessary to quantify the degree of fit of a given solution or the degree to which fit individuals can be generated from it (Medium, 2022).

Select Parents

Finding the best answer within a population is known as parent selection, and it reproduces the subsequent generation of solutions. It makes it easier for the following generation to naturally inherit the "good" features. This selection is crucial because it encourages individuals to come up with better, more suitable solutions, which eventually causes the algorithm to converge (Medium, 2022).

Crossover

New offspring are produced by crossover and the amount of genes carried from each parent is random. A new generation is created when certain genes from the two parent chromosomes overlap or combine. The child receives traits from both parents since it is the product of chromosome crossover between the parents. The offspring can inherit half of its genes from one parent and the other half from the other, and the percentage can fluctuate. Various techniques exist, such as uniform crossover, double-point crossover, and single-point crossover. The most common method for performing a crossover is uniform crossover as shown in figure 3 (Medium, 2022).

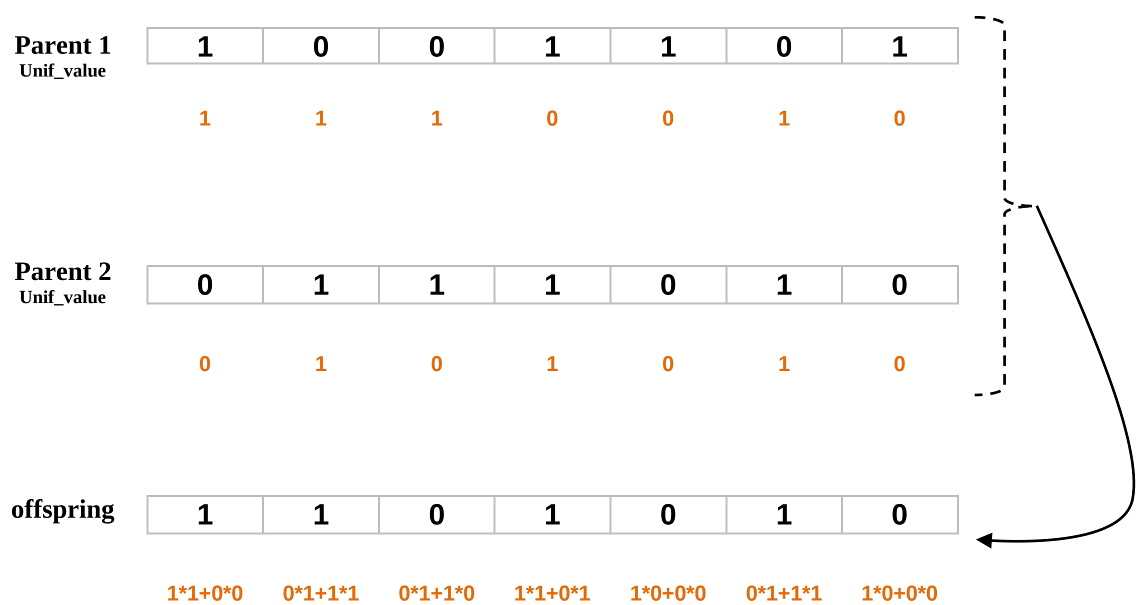

Figure 3: Cross-over Meaning in Genetic Algorithm (Medium, 2022)

Mutation

Mutation helps to include new characteristics into the gene, which maintains the diversity within the population and prevents premature convergence of the process. Mutation is the part of the GA which is related to the "exploration" of the search space. Hence, the mutation is essential to the convergence of the GA while crossover is not (Medium, 2022).

Criteria Satisfied

When the algorithm reaches convergence, that is, when it stops producing children that differ noticeably from the earlier generation, the algorithm ends (Medium, 2022).

Population Size

The population size is an important variable in genetic algorithms that directly affects the search space's capacity to find the best possible solution. It represents the number of individuals per generation. Many studies have shown that a big population increases the likelihood of accurately identifying the best solution. However, if the search space is small, it won't be a good idea to have a high population size (Rajakumar & George, 2013). Typically, researchers contend that a "small" population size could lead the algorithm to produce poor outcomes (Koumousis & Katsaras, 2006), (Pelikan et al., 2000), (Piszcz & Soule, 2006) While the procedure may need to spend more time computing a solution if the population is "large" (Koumousis & Katsaras, 2006), (Lobo & Goldberg, 2004), (Lobo & Lima, 2005).

3 Proposed System

Before presenting the proposed system, It is worth mentioning that the work presented in this article is complementary to the proposed system published in (Kadhim et al., 2023). The primary goal is to enhance the DVBT2 system by using optimization techniques. The proposed model is shown in Figure 4. As mentioned before, the system is affected by a significant number of parameters that have a certain range. It is difficult to choose the appropriate parameters of the system for certain circumstances because we will need a huge amount of complex mathematical operations. Therefore, the best scientific method to find the best solution for a set of parameters that have an impact on a particular system is the optimization method. The genetic algorithm, which was explained in detail in Section 2, was chosen as it is considered a proven and successful technique for solving this type of problem. The main object is to obtain the best tradeoff between BER and throughput with the lowest possible SNR, as the interest in both varies from one application to another. Obtaining a low BER is considered one of the most important things in any communications system because it specifies the accuracy of the system while obtaining high throughput is also considered the primary concern for communication systems, especially those that requires sending the largest number of data with the lowest percentage of errors. The document by (Haffenden, 2011) proposed a software model of a complete DVB-T2 chain that was started by SIDSA and AICIA, The main concern was how to link the genetic algorithm to the system proposed in this document. Many difficulties were faced to achieve this goal because the DVBT2 system is very complex. Finally, the algorithm was linked to the system, the parameters that have the most impact on the DVBT2 system were selected, and the range of these parameters was determined, which is considered the search area for the genetic algorithm as shown in Table 1.

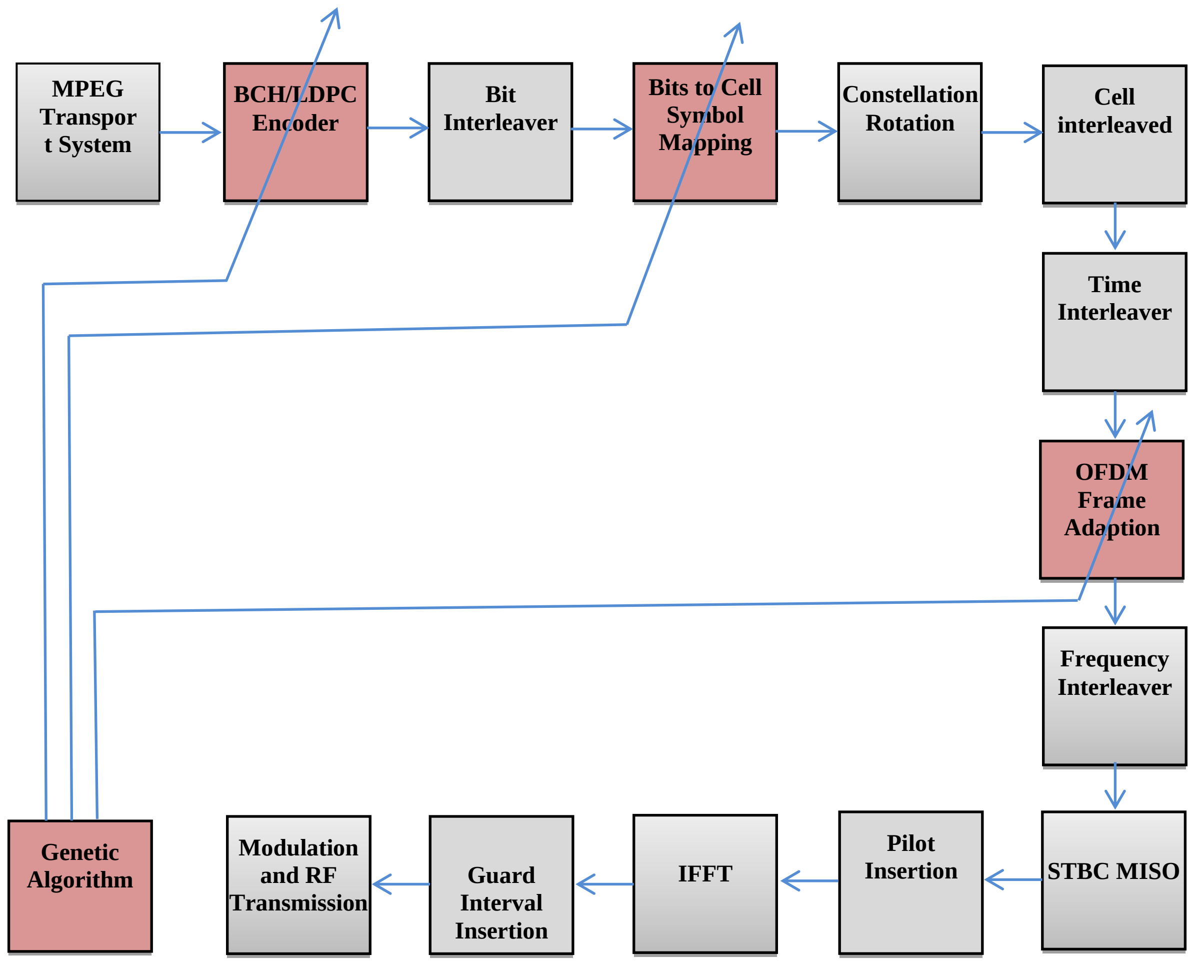

Figure 4: The Proposed Work of the Optimized DVB-T2 Transmitter

Table 1: DVB T2 and the Optimization Parameters and their Ranges

Parameter	**Ranges**
Constellation	QPK, 16-QAM, 64-QAM
No. of FEC Blocks	10:50
Code rate	1/2, 2/3, 3/4, 4/5, 5/6
Propagation	AWGN, DVB-T, DVB-P, 0DBECHO
Sample per Frame	100:1000
SNR	10:20
No. of Generations	100
No. of individuals per Generation	100

Figure 5 represents the flow chart of the proposed system, where the process is repeated 10,000 times (No. of Generation × No. of individuals per generation).

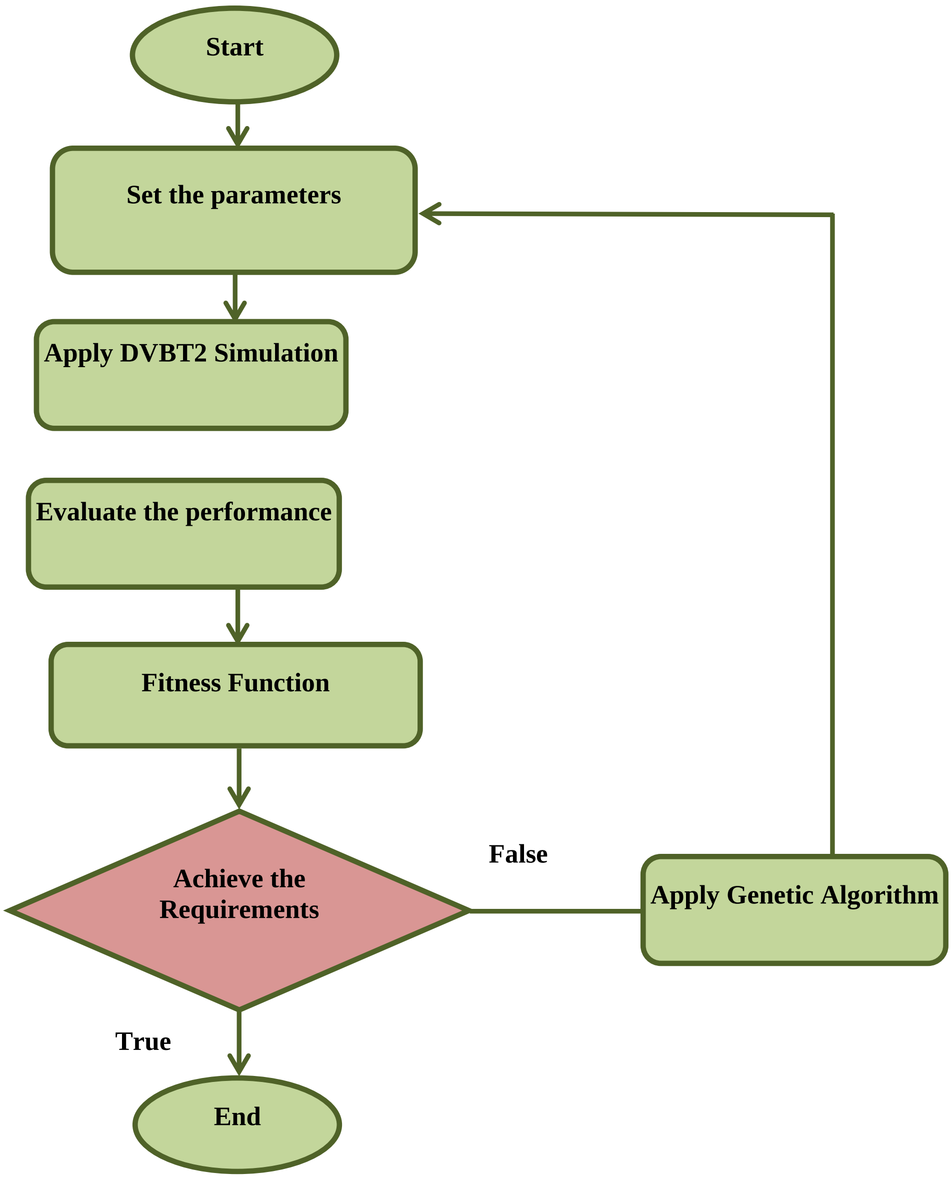

Figure 5: The Proposed Workflow Chart

The simulation of the suggested system was performed using MATLAB R2021a, simulating the proposed system using MATLAB software by conventional computers is a time-consuming task. Therefore, an online supercomputer platform was utilized to carry out the MATLAB simulation of the proposed system. The features of the online supercomputer are shown below in table 2:

Table 2: The Features of Online Supercomputer

SSD Disk space (GB)	**CPU**	**RAM**	**Bandwidth**	**Operating System**	**Database**
800 GB NVMe or 2TB SSD	10 Cores	60GB	Unlimited	Windows/Linux	MSSQL/ MySQL

The results must be calculated in two cases: in the first case, the weighted throughput and BER are 70% and 30% respectively, while in the second, the weight of throughput and BER are 30% and 70% respectively. The fitness function is given by the following formula:

$$\text{Fitness}=\alpha\times\text{normalized BER}+\beta\times\text{normalized}(1/\text{SNR})$$

Where:

$\alpha+\beta=1$

α is the required weight of BER and β is the required weight of SNR.

The primary objective is to achieve the minimum fitness, hence obtaining the optimal values for the parameter set. As mentioned previously in section 2, the genetic algorithm is affected by several factors, as it was found that population size has the greatest impact on it. Therefore, several cases of population size were chosen: 50, 100, 150, and 200, and the behavior of the DVBT2 system was studied in each case and this will be shown in the next section.

4 Results and Discussion

This part presents the results of the system's behavior after linking it with the genetic algorithm. The results of the simulated systems' performance will be presented via tables and graphs, utilizing the MATLAB R2021a application and an online supercomputer. The simulation includes two different scenarios: The first scenario includes giving the greatest importance to throughput at a rate of 70% and giving the BER a rate of 30 percent, while in the second scenario, the weight of throughput and BER is 30% and 70% respectively. Four different channels are used: AWGN, DVBT-F, DVBT-P, and 0 dB Echo. The results of the best parameters for the two scenarios mentioned above are illustrated in Tables 3 and 4 as shown below:

Table 3: Results Obtained when the Weight of Interest is 70% for throughput and 30% for BER

Channel	Best Coding	Best No. of FEC Blocks	Best Code Rate	SNR	Best No. of samples per Frame	BER	Throughput (Kb/s)
AWGN	64-QAM	20	2/3	14	240	1.16*10E-6	572.8
DVBT-F	16-QAM	19	4/5	12	235	1.02*10E-6	783.8
DVBT-P	16-QAM	20	2/3	12	229	1.16*10E-6	572.8
0dBecho	16-QAM	18	3/4	13	224	1.14*10E-6	652.4

Table 4: Results Obtained when the Weight of Interest is 30% for throughput and 70% for BER

Channel	Best Coding	Best No. of FEC Blocks	Best Code Rate	SNR	Best No. of samples per Frame	BER	Throughput (Kb/s)
AWGN	16-QAM	24	3/4	14	194	8.6*10E-7	869.9
DVBT-F	16-QAM	22	3/4	15	189	9.4*10E-7	797.4
DVBT-P	QPSK	23	2/3	15	184	1.01*10E-6	658.7
0dBecho	QPSK	21	1/2	16	181	1.48*10E-6	337.3

The BER rate was obtained after re-implementing the system in MATLAB by selecting the parameters for each case in the table manually. Throughput can be calculated by multiplying the code rate with the transmitted bits for each case in the tables. These parameters are considered to be optimal parameters, as changing any of them will lead to an increase in BER. For example, if the code rate in the first case of Table 3 was changed from 2/3 to 3/4, a BER of (0.0720) would be obtained, which is an unacceptable value for any communication system. Three figures 6, 7, 8 below show the channel response, the received signal before and after equalization, and the RQD block output for the first case of table 3 when the channel is AWGN, constellation is 64-QAM, No. of FEC blocks are 20, the code rate is 2/3, SNR is 14, and samples per frames are 240.

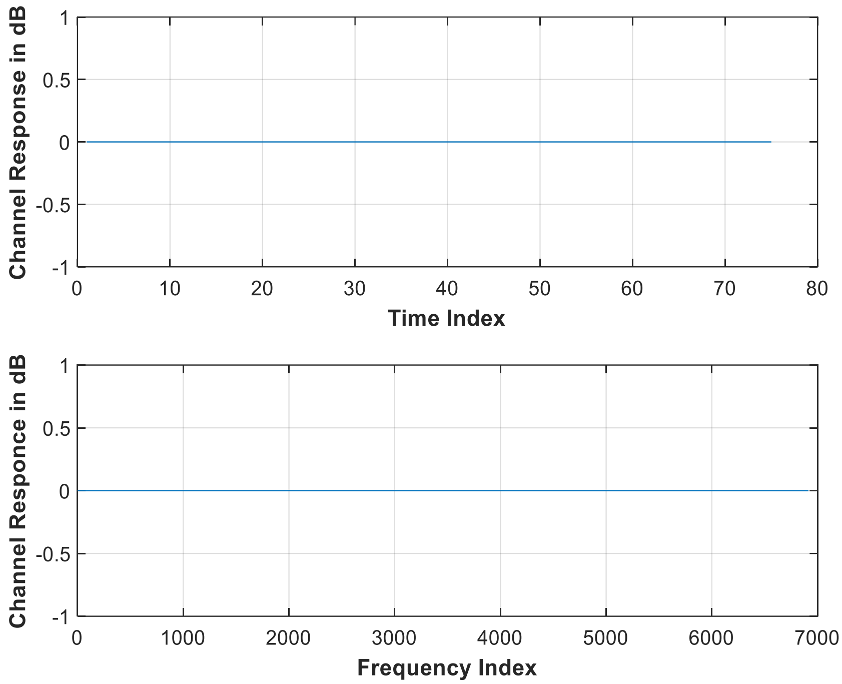

Figure 6: Channel Response in dB

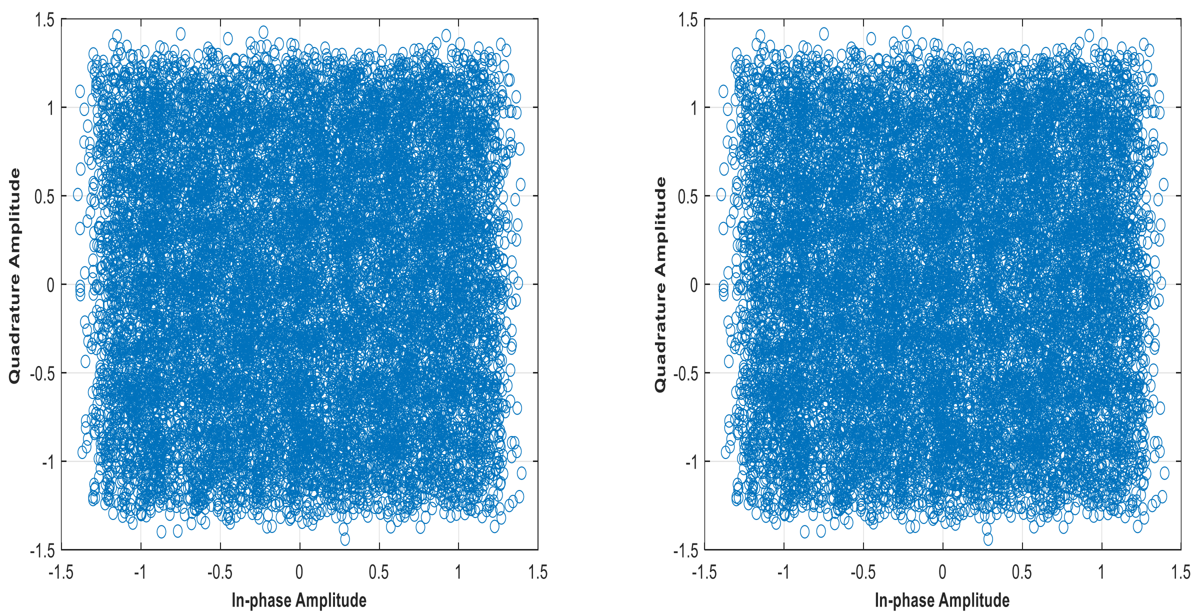

Figure 7: The Received Signal (a) Before Equalization (b) After Equalization

(a) (b)

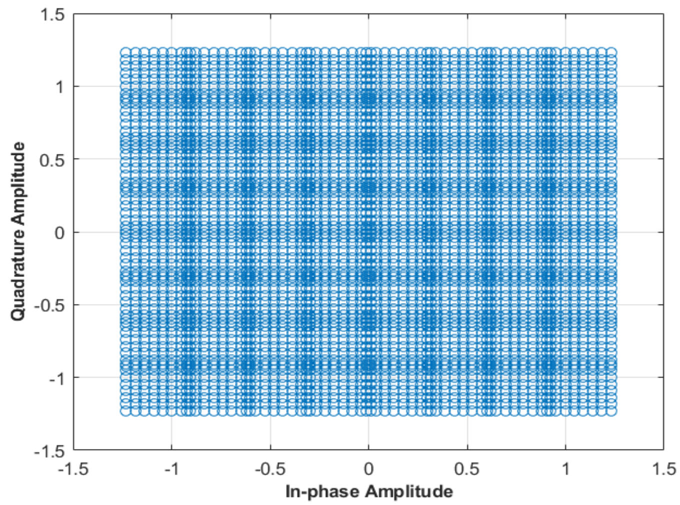

Figure 8: Constellation Rotation and Cyclic Q Delay Output

Figure 9 illustrates the relation between the BER and SNR when optimizing the performance of a QPSK modulation system before and after applying the technique of constellation rotation. The scenario considered involves a portable channel and a code rate of 2/3. The Bit Error Rate (BER) tends towards zero when the Signal-to-Noise Ratio (SNR) exceeds 5 dB.

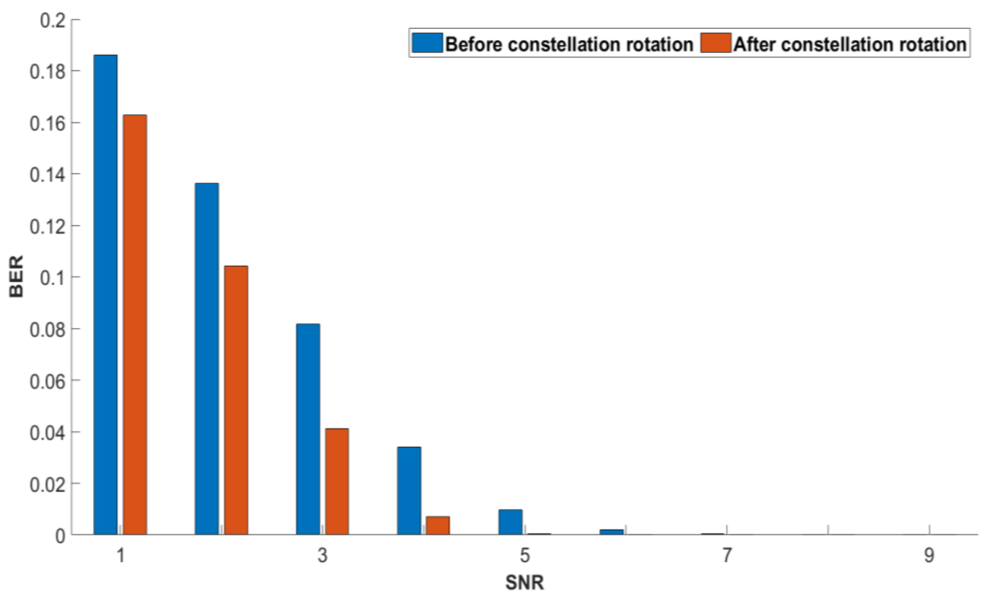

Figure 9: BER and SNR Relation When QPSK Modulation, Code Rate 2/3, and Portable Channel (DVBT-P)

As mentioned previously, the algorithm is affected by several factors and the population size has the greatest impact on it. Population size represents the number of individuals per generation that will help us reach the best fitness. The greater the number of individuals per generation, the more we can reach the best state with the least number of iterations. Figure 10 represents the system behavior with different values of population size.

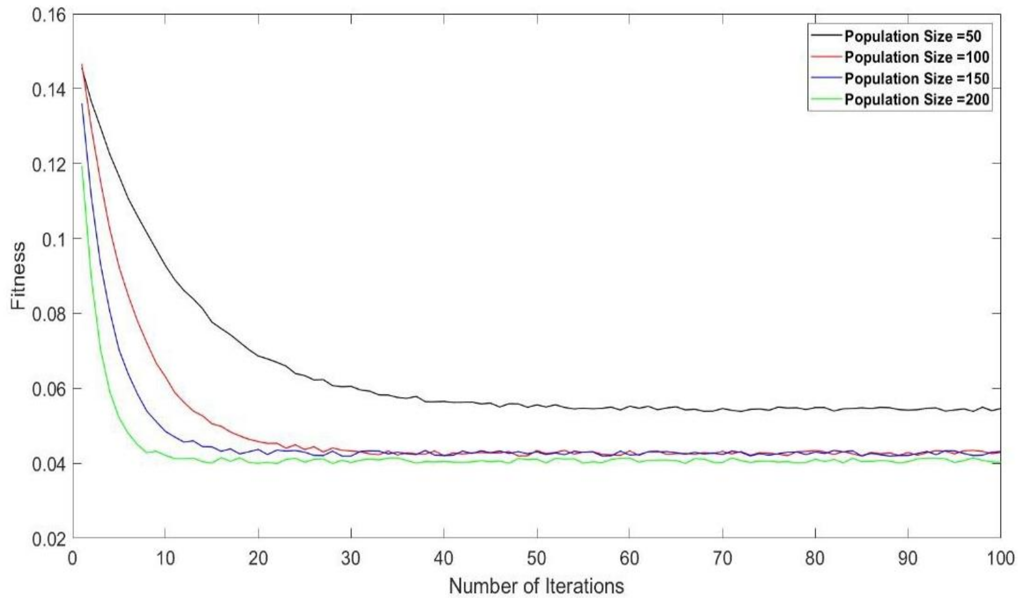

Figure 10: The Effect of Population Size on the Genetic Algorithm

The figure above shows the relationship between fitness which represents the minimum value and the number of iterations. It can be noticed that when the population size was 200, the algorithm was able to reach the best solution (optimum) with the lowest number of iterations (less than 10 iterations). The algorithm found the optimal answer when the population was 100 or 150, but it took a little longer than the scenario of 200 individuals (less than 12 iterations). Poor results were obtained when choosing a population size of 50, So it can be said that the optimal solution was obtained when the population size was 200.

5 Conclusion

The best selection of the parameters that most affect the DVBT2 system is a complex process and requires many computations. The choice of these parameters has a significant impact on the results, especially the BER and throughput. Therefore, genetic algorithm was used to make the system adaptive to various conditions with the least calculations and the greatest possible accuracy. The results were achieved at the lowest possible SNR, with a range of (10-20). The genetic algorithm is greatly affected by the population size, which affects the number of iterations to reach the ideal solution. The results show that the algorithm reached to the best solution (optimal) with the lowest number of iterations when the population size is 200. When the population size is 100 or 150, the algorithm also reached the ideal solution, but it took a little more time than the scenario of population size 200. Poor results was obtained when the population size is 50.

References

[1] Astawa, I. G. P., & Santoso, T. B. (2016). Analysis Of performance DVB-T2 using MIMO system over MMSE channel estimation. *In IEEE Region 10 Symposium (TENSYMP)*, 299-304.

[2] EN302755, E. I. S. I. (2015). Digital video broadcasting (DVB); Frame structure channel coding and modulation for a second-generation digital terrestrial television broadcasting system. *European Telecommunications Standards*.

[3] Ghayyib, H. S., & Mohammed, S. J. (2021). Performance Enhancement of FEC Code For DVB-T2 System by Using Rotated Constellations. *In 1st Babylon International Conference on Information Technology and Science (BICITS)*, 234-238.

[4] Haffenden, O. (2011). DVB-T2: The common simulation platform, Research white paper. *British Broadcasting Corporation*, 25.

[5] Ingun, C. A. (2014). DVB-T2 field trial and optimized parameters in Thailand. *In International Electrical Engineering Congress (iEECON)*, 1-4.

[6] Kadhim, A. A., Mohammed, S. J., & Al-Gayem, Q. (2023). Digital Video Broadcasting T2 Lite Performance Evaluation Based on Rotated Constellation Rates. *Journal of Interner Services and Information Security (JISIS), 13*(4), 127-137.

[7] Kang, I., Ok, K. S., Kim, Y., Seo, J. H., Kim, H. M., & Kim, H. N. (2014). Design of a bit interleaver for the high-order constellation DVB-T2 system. *In IEEE International Symposium on Broadband Multimedia Systems and Broadcasting*, 1-4.

[8] Koumousis, V. K., & Katsaras, C. P. (2006). A saw-tooth genetic algorithm combining the effects of variable population size and reinitialization to enhance performance. *IEEE Transactions on Evolutionary Computation, 10*(1), 19-28.

[9] Lobo, F. G., & Goldberg, D. E. (2004). The parameter-less genetic algorithm in practice. *Information Sciences, 167*(1-4), 217-232.

[10] Lobo, F. G., & Lima, C. F. (2005). A review of adaptive population sizing schemes in genetic algorithms. *In Proceedings of the 7th annual workshop on Genetic and evolutionary computation*, 228-234.

[11] Malasri, S. (1999). Optimization Using Genetic Algorithms. *In MAESC Conf., Memphis, TN, USA*.

[12] Medium. (2022). Genetic Algorithm — An Optimization Approach. https://towardsdatascience.com/genetic-algorithm-an-optimization-approach-dd60e23261e6.

[13] Morgade, J., Ansorregui, D., Mouhouche, B., Jeong, H., & Lee, H. (2014). Improving the DVB-T2 BICM performance by newly optimized two-dimensional non-uniform constellations. *In IEEE Fourth International Conference on Consumer Electronics Berlin (ICCE-Berlin)*, 96-100.

[14] Nour, C. A., & Douillard, C. (2008). Rotated QAM constellations to improve BICM performance for DVB-T2. *In IEEE 10th International Symposium on Spread Spectrum Techniques and Applications*, 354-359.

[15] Pelikan, M., Goldberg, D. E., & Cantú-Paz, E. (2000). *Bayesian optimization algorithm, population sizing, and time to convergence* (No. UCRL-JC-137172). Lawrence Livermore National Lab. (LLNL), Livermore, CA (United States).

[16] Piszcz, A., & Soule, T. (2006). Genetic programming: Optimal population sizes for varying complexity problems. *In Proceedings of the 8th Annual Conference on Genetic and Evolutionary Computation*, 953-954.

[17] Polak, L., & Kratochvil, T. (2012). Performance of the rotated constellation in DVB-T2. *In Proc. 7th ICDT*, 84-87.

[18] Rajakumar, B. R., & George, A. (2013). APOGA: An adaptive population pool size based genetic algorithm. *AASRI Procedia, 4*, 288-296.

[19] Samo, D. A., Slimani, M., Baruffa, G., & Rugini, L. (2015). A performance study of DVB-T2 and DVB-T2-Lite for mobile reception. *Digital Signal Processing*, *37*, 35-42.

[20] Tsoukalas, L. H., & Uhrig, R. E. (1996). Fuzzy and neural approaches in engineering. John Wiley & Sons, Inc.

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