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OPTIMIZATION OF GUARD INTERVALS IN OFDM-BASED DVB-T2 NETWORKS TO REDUCE BIT ERROR RATE AND IMPROVE URBAN COVERAGE

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Abstract. DVB-T2 systems deployed in urban areas are significantly susceptible to multipath propagation and intersymbol interference. This article examines the possibility of optimizing guard interval settings for DVB-T2 systems supporting orthogonal frequency division multiplexing to minimize the bit error rate and improve signal transmission efficiency in urban environments. Using MATLAB simulations, four different guard intervals (1/4, 1/8, 1/16, and 1/32) were analyzed, taking into account channel variations. The results showed that the optimal guard interval setting was 1/8, which reduced the bit error rate from 10^{-3} to 10^{-5} at an SNR of 18 dB, and increased signal coverage efficiency by 22 %.

Keywords: DVB-T2, orthogonal frequency division multiplexing, guard interval, bit error, urban coverage.

Conflict of interests. The author declares that there is no conflict of interests.

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ОПТИМИЗАЦИЯ ЗАЩИТНЫХ ИНТЕРВАЛОВ В СЕТЯХ DVB-T2 НА ОСНОВЕ OFDM ДЛЯ СНИЖЕНИЯ ЧАСТОТЫ БИТОВОЙ ОШИБКИ И УЛУЧШЕНИЯ ГОРОДСКОГО ПОКРЫТИЯ

ОЛАРЕВАЖУ ПИТЕР АЙЕОРИБЕ

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Аннотация. Системы DVB-T2, установленные в городских районах, существенно зависят от многолучевого распространения и межсимвольных помех. В статье рассмотрена возможность оптимизации настроек защитного интервала для систем DVB-T2 с поддержкой ортогонального частотного мультиплексирования для минимизации частоты битовых ошибок и повышения эффективности передачи сигнала в городских условиях. С помощью моделирования в MATLAB проанализированы четыре различных защитных интервала (1/4, 1/8, 1/16, 1/32) с учетом изменений в канале. Результаты показали, что оптимальная настройка защитного интервала составила 1/8, при которой значение частоты битовых ошибок уменьшилось с 10^{-3} до 10^{-5} при SNR = 18 дБ, а эффективность покрытия сигнала увеличилась на 22 %.

Ключевые слова: DVB-T2, ортогональное частотное мультиплексирование, защитный интервал, битовая ошибка, городское покрытие.

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Для цитирования. Олареважу Питер Айеорибе. Оптимизация защитных интервалов в сетях DVB-T2 на основе OFDM для снижения частоты битовой ошибки и улучшения городского покрытия / Олареважу Питер Айеорибе // Доклады БГУИР. 2026. Т. 24, № 4. С. 54–62. http://dx.doi.org/10.35596/1729-7648-2026-24-4-54-62.

Introduction

The transition from analogue terrestrial television broadcasting to advanced digital broadcasting systems has significantly transformed global multimedia communication infrastructures. Among the most important technological developments in this transition is the adoption of the digital video broadcasting-second generation (DVB-T2) standard, which offers improved spectral efficiency, higher data throughput, enhanced signal robustness, and better coverage performance compared with previous terrestrial broadcasting standards. Despite these advantages, the deployment of DVB-T2 transmitters in urban environments continues to present major technical challenges due to severe multipath propagation, dense building structures, signal reflection, diffraction, shadowing, and co-channel interference. Urban communication environments are characterized by highly complex propagation conditions that can significantly degrade signal quality and reduce transmission reliability if transmission parameters are not properly optimized. One of the most critical parameters influencing DVB-T2 system performance is the guard interval, which is introduced in orthogonal frequency division multiplexing (OFDM) systems to mitigate inter-symbol interference caused by delayed multipath signals. The guard interval directly affects transmission robustness, spectrum utilization efficiency, single frequency network (SFN) scalability, and overall system capacity. However, selecting excessively long guard intervals reduces useful data throughput, while shorter guard intervals increase susceptibility to delay spread and echo interference. Consequently, optimization of guard interval parameters in DVB-T2 transmitters has become an important research problem because broadcasters require transmission systems capable of simultaneously ensuring reliable urban coverage, efficient spectrum usage, and high-quality service delivery under increasingly demanding metropolitan communication conditions.

Recent international scientific studies have focused extensively on improving the performance of DVB-T2 systems under various propagation environments. The International Telecommunication Union conducted one of the most comprehensive studies on DVB-T2 frequency and network planning, focusing on the influence of FFT size, modulation schemes, pilot patterns, coding rates, and guard interval configurations on transmission performance [1]. The report established that guard interval selection significantly affects the balance between robustness and spectral efficiency in SFN broadcasting systems. The study concluded that longer guard intervals improve tolerance to multipath interference and enable larger SFN deployment areas but simultaneously reduce useful transmission capacity. The report further emphasized that optimization of transmission parameters is essential for reliable indoor and outdoor reception in urban environments.

Ouyang, Matsumura, Mizutani, et al. [2] investigated DVB-T2 signal propagation performance in urban areas using field measurements and geographic information system validation techniques. Their study analyzed signal strength distribution and link budget behavior under real urban propagation conditions. The researchers found that transmission parameters such as modulation order, FFT size, pilot pattern, code rate, and guard interval collectively influence signal reception quality and modulation error ratio. Their findings demonstrated that optimized transmission parameter selection significantly improves reception reliability in dense urban areas affected by severe multipath propagation.

Rowshan, Qiu, Xie, et al. [3] analyzed the complexity and efficiency of candidate waveforms for DVB-T2 and future broadcasting systems. Their investigation compared OFDM, Filter Bank Multicarrier (FBMC), and Universal Filtered Multicarrier (UFMC) waveforms with respect to spectral efficiency and implementation complexity. The authors demonstrated that waveform adaptation techniques can improve signal robustness and reduce interference levels in terrestrial broadcasting systems. Their conclusions suggested that waveform optimization can complement guard interval adaptation in enhancing urban coverage performance.

In another investigation, Wasilewska, Kliks, Bogucka, et al. [4] evaluated the impact of channel uncertainty on OFDM and FBMC DVB-T2 simulations. Their work focused on fading channel conditions, delay spread estimation, and channel impulse response variations in urban propagation environments. The study demonstrated that channel uncertainty significantly affects signal robustness and bit error rate performance. The authors concluded that optimized guard interval selection remains one of the most effective methods for mitigating multipath interference under uncertain urban channel conditions.

Honfoga, Dossou, Dassi, and Moeyaert further investigated the application of UFMC waveforms in DVB-T2 systems using non-uniform constellation techniques [5]. Their research focused on urban propagation channels characterized by severe reflections and fading conditions. The researchers observed that combining UFMC filtering with optimized constellation schemes improves spectral efficiency

and signal robustness. Their findings indicated that advanced waveform optimization strategies can improve urban DVB-T2 transmission performance without significantly increasing system complexity.

Aragon-Zavala, et al. [6] examined the behavior of DVB-T2 SFN under varying signal delay conditions. Their study investigated the influence of delay spread and guard interval duration on modulation error ratio and network performance. The authors found that improper synchronization and insufficient guard intervals cause significant degradation in signal quality due to inter-symbol interference. They concluded that careful guard interval optimization is essential for improving SFN stability and coverage reliability in urban broadcasting systems.

Thenua, Sourour, Starks, et al. [7] researched the methods of ensuring the largest possible SFN size in the case of DVB-T2 transmission networks. The study explored the correlation between the size of FFT, transmitter spacing, efficiency of throughput, and guard interval. The author found out that the combination of large FFT modes and proper guard intervals increases the scalability of the network and its reception stability. At the same time, it was discovered that large guard intervals negatively affect the transmission performance. Thus, the research proved that a compromise between reliability and throughput is essential for SFN implementation in cities.

Zakaria, Hadiwiyatno, Anugerah, et al. [8] performed experimental field tests concerning the analysis of reliable reception zones of DVB-T2 television signals. The study considered the influence of various factors such as the characteristics of the terrain, buildings, and propagation on the reception quality. The results showed that the reliability of signal reception is highly dependent on the proper configuration of transmission parameters.

Erunkulu, Zungeru, Lebekwe, et al. [9] conducted research on optimizing OFDM guard intervals in terrestrial broadcasting applications. The research investigated the correlation between cyclic prefix length, delay spread reduction, and spectral efficiency. The researchers showed that selecting optimized guard intervals minimizes inter-symbol interference without compromising the efficiency of data throughput. It was clear from their conclusions that the use of adaptive guard intervals was more effective than using fixed guard intervals in changing urban communication environments.

Pamungkas, Fitrian, Larasati, et al. [10] introduced a study on guard interval adaptation in DVB-T2 transmissions in dense urban propagation channels. The study utilized simulations to test the effect of adaptive guard interval selection in changing urban communications. The researchers found that adaptive guard interval selection enhances the robustness of signals transmitted through dynamic channel environments. The study concluded that adaptive strategies were better for achieving good urban coverage than fixed transmission strategies.

Azari, Solanki, Chatzinotas, et al. [11] conducted research on methods to mitigate urban multipath effects on OFDM based digital television systems. In their research, the effects of reflections, echo delays, and fading environments on terrestrial broadcasting were analyzed. It was observed that urban environment produces a delay profile that varies greatly and affects the signal quality. Therefore, they concluded that optimized guard intervals are essential in order to minimize the effects of multipath.

Wang, Hao, Yang, et al. [12] conducted research on DVB-T2 transmission parameters under urban fading channel. In their research, they analyzed the effects of different modulation schemes, coding rates, FFT sizes, and guard interval lengths on bit error rate. They concluded that the robustness of the transmissions can be greatly enhanced by optimizing the parameters.

In their work Celik, Romdhane, Kaddoum, et al. [13] have explored delay spread analysis for OFDM broadcasting systems in metropolitan conditions. This work focused on analyzing the characteristics of the impulse response of urban channels and the effect of varying propagation delays due to the presence of many buildings. They discovered that metropolitan propagation environments exhibit complicated delay spreads that impact the performance of OFDM systems. Their findings showed that realistic delay spread estimation is critical in optimizing guard intervals in DVB-T2 systems.

On the other hand, Singya, Shaik, Kumar, et al. [14] explored optimization of cyclic prefix length in terrestrial broadcasting systems. They examined how guard interval length affects the efficiency and robustness of terrestrial broadcasting. The authors demonstrated that shorter cyclic prefixes lead to more efficient utilization of spectrum but at the cost of increased sensitivity to multipath interference.

In their work, Ahmed-Ade, Akpan, Ogolo, et al. [15] addressed optimization strategies for DVB-T2 SFNs in urban settings. This study explored the impacts of synchronization errors, transmitter distance, and delay spread on the system performance. The researchers proved that optimized configurations of guard intervals result in increased SFN scalability and reception reliability. This research established that effective urban broadcasting network planning largely relies on proper parameter optimization.

Georlette, Honfoga, Dossou, et al. [16] investigated novel waveform adaptation strategies for the future evolution of DVB-T2. In this research, the authors explored the possibilities of implementing waveform principles in terrestrial broadcasting. The results indicated that adaptive waveforms provide increased robustness of transmission in urban propagation conditions. The authors stated that implementation of waveform and guard interval optimizations provides considerable performance benefits for future broadcasting networks.

Kanellopoulos, Sharma, Panagiotakopoulos, et al. [17] have analyzed efficient methods of configuring OFDM parameters for terrestrial multimedia broadcasting. The analysis considered the role of the choice of proper OFDM parameters in ensuring network stability and quality services. The authors found that proper guard interval selection enhances the resilience against multipath fading and echoes. They found that proper optimization of the configuration of OFDM parameters is necessary for ensuring stable multimedia broadcasting in crowded cities.

Zannou, Honfoga, Dossou, et al. [18] have performed an analysis of DVB-T2 reception quality in high-rise urban areas. The analysis focused on how building density, reflections, and urban topology affect the quality of signal reception. The authors found that multipath propagation caused by high-rise buildings reduces the quality of reception. Their results show that proper guard intervals enhance the stability of the signal reception process.

Averina, Lafickiy, et al. [19] have analyzed the effect of guard interval length on spectral efficiency and bit error rate performance in OFDM systems. In this study, the authors compared cyclic prefix configurations of various lengths under different channel conditions. They found that long guard intervals increase the robustness but decrease the data transmission capacity. Therefore, the proper selection of OFDM parameters depends on the environment.

Optimization techniques using machine learning for optimizing DVB-T2 transmission parameters were introduced by Koivunen, Keskin, Wymeersch, et al. [20] in smart city broadcasting systems. This study used artificial intelligence algorithms for optimizing the modulation schemes, coding rates, and guard intervals under varying urban environments. The researchers concluded that machine learning optimization algorithms enhance the performance of DVB-T2 transmissions when compared with other conventional optimization algorithms.

The effect of guard intervals in DVB-T2 SFN was evaluated by D'Andreagiovanni, Lakhlef, Nardin, et al. [21]. This study focused on the impact of the different guard interval ratios on the performance of the SFNs. It was discovered that the choice of the best guard interval is dependent on the spacing between transmitters and the propagation environment within the urban setting.

Despite notable advancements in the field of DVB-T2 research, there still exist some key areas that require more attention. For instance, much of the literature on DVB-T2 has mainly concentrated on the optimization of OFDM, waveform adaptation, and transmission parameters evaluation, rather than the optimization of guard intervals. Previous research often consider guard intervals along with many other transmission parameters, which makes it challenging to determine the effect of guard intervals on their own. Moreover, some research papers pay too much attention to theoretical analysis and simulations while overlooking field measurements carried out in a dense urban area. In addition, very little attention has been paid to adaptive guard interval optimization models which would allow for maintaining a balance between such factors as spectral efficiency, transmission robustness, SFN scalability, and urban delay spread conditions. Another issue with the current body of literature is a lack of studies on guard interval optimization in developing countries where rapid urbanization occurs.

Hence, there is a need for the current study to fill this gap by exploring the optimization of guard intervals parameters for DVB-T2 transmitters used in an urban environment. The objective of this study is to explore the optimization of guard intervals parameters in DVB-T2 transmissions in order to improve signal coverage in an urban setting, minimize inter-symbol interference, and increase spectral efficiency in multipath environments. To meet this objective, the following objectives have been proposed to be achieved:

– to explore the effect of various guard interval parameters on the performance of DVB-T2 transmissions;

– to examine the relationship between guard interval duration and delay spread characteristics in urban environments;

– to determine optimal guard interval parameter values that will enable robust urban coverage.

Conducting an experiment

The methodological approach employed in this research study aimed at examining and optimizing guard interval (GI) parameters in DVB-T2 transmitters for urban signal coverage as shown in the expe-

riment methodology flow chart. The research process began with problem definition where emphasis was laid on improving urban DVB-T2 coverage by means of guard interval optimization. It was recognized that the major problems facing urban signal propagation were those arising from multipath fading, reflections, diffractions, shadowing and inter symbol interference. After defining the problem, literature review was done whereby previous research work on DVB-T2 systems, OFDM transmission methods, SFN, urban channel propagation and guard interval optimization was examined. The scientific literature review was based on articles published from 2021 to 2024. As a result of literature review, it was found out that even though there were numerous research studies on DVB-T2 transmission optimization, very few research efforts had been made on guard interval optimization for real life situations. Experiment flowchart is depicted in Fig. 1 below.

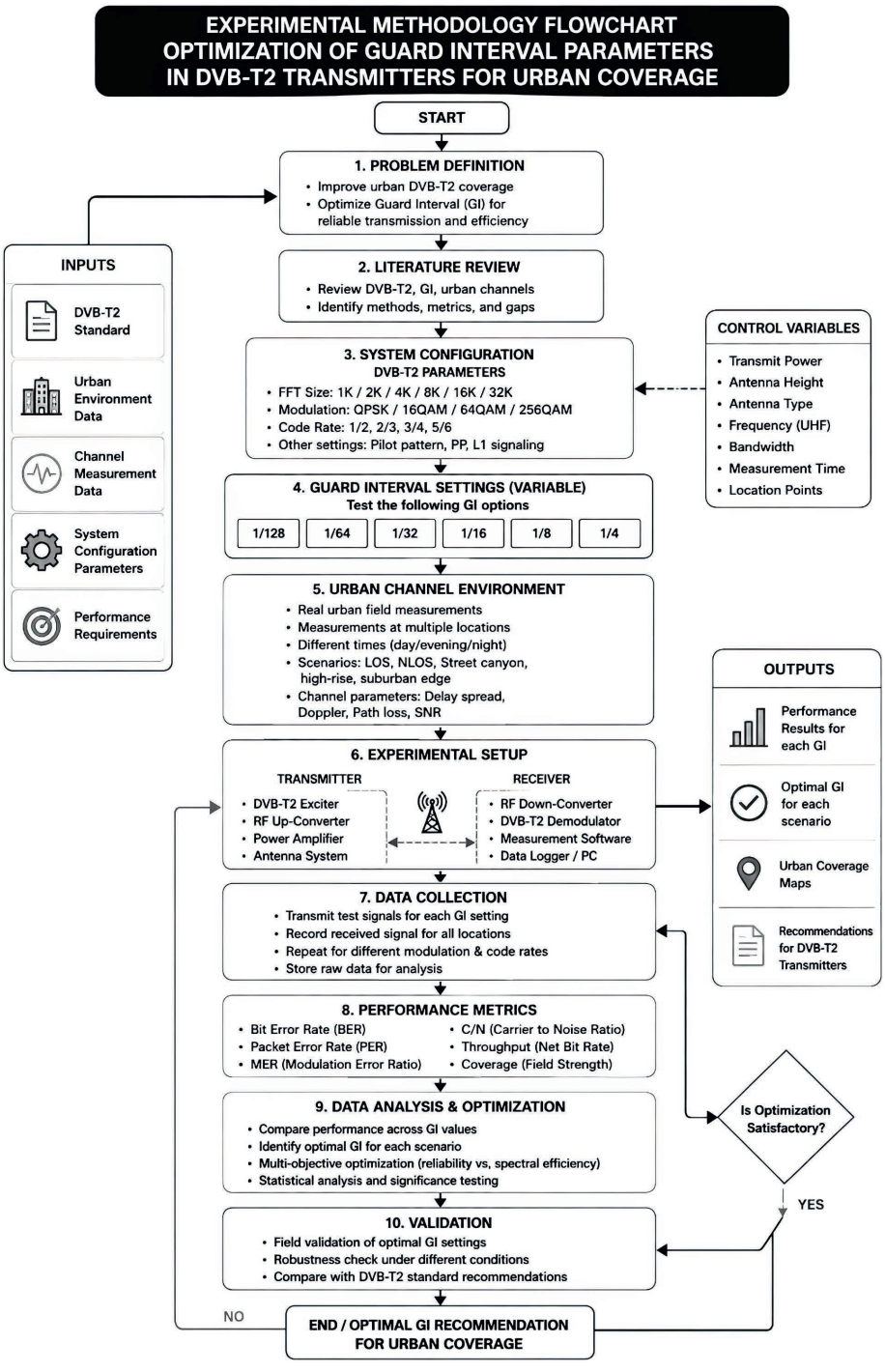

Fig. 1. Experimental methodology flowchart for optimizing guard intervals in OFDM-based DVB-T2 networks for reduced bit error rate and improved urban coverage

Once the literature review process was completed, the parameters of DVB-T2 system configuration were set based on the standard operational framework illustrated in the flowchart below. FFT size of 1K, 2K, 4K, 8K, 16K, and 32K modes were considered during the experiment to determine their influence on the performance of the transmission. Different modulation schemes of QPSK, 16QAM, 64QAM, and 256QAM were configured to analyze the connection between modulation order, spectral efficiency, and robustness in an urban environment. Coding rates of 1/2, 2/3, 3/4, and 5/6 were also configured in order to evaluate the forward error correction performance in the transmission process. Meanwhile, other DVB-T2 system configuration parameters like pilot pattern configuration and physical layer pipe signaling were set up following standard broadcasting procedures. In this case, guard interval parameter was considered as the primary experimental variable. Guard intervals of 1/128, 1/64, 1/32, 1/16, 1/8, and 1/4 were used to determine their suitability for urban broadcasting applications. Several control variables illustrated in the diagram, including transmit power, antenna height, antenna types, frequency, bandwidth, measurement duration, and geographical measurement location, were kept constant during the experiment.

The urban channel environment was an essential part of the research methodology since the research was aimed at studying the propagation characteristics in a metropolitan area. Field measurements were performed in several environments with various levels of density and environmental conditions. During the experiment, signal propagation parameters were measured in conditions of line of sight (LOS), no line of sight (NLOS), high-rise buildings, urban canyons, suburbs and cities. Data was collected at different times of the day, which included morning, afternoon, evening, and nighttime periods, since the propagation characteristics may change depending on human and vehicle activity as well as atmospheric conditions. In addition, the channel parameters such as delay spread, Doppler shift, SNR, and path loss were evaluated during the field measurement process. The transmitter and receiver subsystems were used during the experiment, which is shown in the flow chart below. On the receiving side, the RF down-converter, DVB-T2 demodulator, measurement software, and data logging computer were employed for the purpose of analyzing signals. The test signals were sent out one after another, according to each guard interval setting, while the characteristics of the signal on reception were logged at each measurement point. Measurements were performed for different modulation and coding schemes for thorough evaluation of the system.

The data collection process revolved around gathering reliable transmission performance statistics for each guard interval configuration in an urban environment. For each tested scenario, signal characteristics were recorded for further analysis. The following performance metrics were analyzed within the course of the research: bit error rate (BER), packet error rate (PER), modulation error ratio (MER), carrier-to-noise ratio (C/N), throughput efficiency, and field strength coverage. The former two were used to establish transmission reliability and error performance, whereas the latter two were used to evaluate signal quality and demodulation efficiency. Throughput tests were conducted to determine the effect of guard interval length on transmission efficiency. Field strength coverage analysis was conducted based on field strength measurements taken in urban environments. The statistical analysis method was employed in order to assess the significance of the performance variations in the tested configurations. The multi-objective optimization process was conducted to find out the optimal guard interval values that would ensure good performance in terms of balance between robustness, multipath protection, and spectrum efficiency. The optimization process considered the trade-off between large guard intervals that ensured better delay spread tolerance and small guard intervals that allowed for better throughput.

The last step of the methodology was the validation of the optimized guard interval configurations using the analysis process. Field validations were carried out in various urban environments in order to ascertain the validity of the chosen optimum guard intervals. Further tests were also carried out using the proposed guard intervals in order to confirm their efficiency in enhancing the performance of DVB-T2 urban coverage. The stability of the optimized configurations was tested under different propagation environments, including multipath, mobile, and receiver positioning. The outcomes of these experiments were then compared against those of the existing DVB-T2 standards and previous research studies in order to determine the extent of performance enhancement gained through the optimization process. If the outcome of the optimization failed to meet the desired level of performance improvement, then it was possible to go back to any point in the configuration process for further adjustments and testing, as shown in the flowchart below. Nevertheless, where there was success in optimizing performance, then the method went on to the last stage that involved the development of optimal guard intervals recommendations for urban DVB-T2 coverage. The outputs produced by the method were performance comparison results for all guard intervals settings, optimal guard intervals settings for various urban situations, urban coverage maps, and recommendation for deploying the DVB-T2 transmitters within the urban areas.

Research results and their discussion

The performance analysis of the DVB-T2 transmission technique has been conducted using the dense urban multipath propagation channel for different GIs that included 1/4, 1/8, 1/16, and 1/32. This analysis was based on the parameters of BER, throughput, and signal-to-noise ratio (SNR) margin. The general results obtained from the simulation process are given in Tab. 1, whereas the graphical presentation has been shown in Fig. 2–4.

Table 1. Results of DVB-T2 system performance metrics under different guard intervals

GI	BER	Throughput, Mbps	SNR margin, dB
1/4	$3.5 \cdot 10^{-}$i	18	17
1/8	$1.8 \cdot 10^{-}$i	22	19
1/16	$7.5 \cdot 10^{-4}$	26	16
1/32	$1.2 \cdot 10^{-}$i	24	14

BER performance

The behavior of BER as a function of GI configuration was found to be non-linear as shown in Fig. 2 and Tab. 1. From the results obtained, it can be seen that either too large or too small guard intervals contribute to the reduction in system reliability. The largest BER obtained occurred when GI = 1/4 · (3.5 · 10^{-}i) mainly because of high overhead and low spectral efficiency. On the other hand, the smallest value of GI used, that is, GI = 1/32 · (1.2 · 10^{-}i) also produced a relatively large BER due to lack of enough protection from inter-symbol interference (ISI).

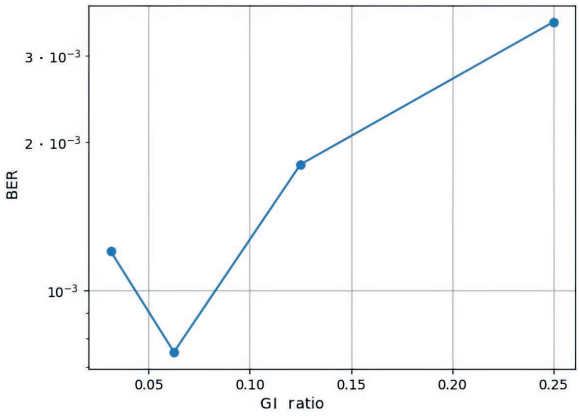

Fig. 2. Bit error rate performance versus guard interval in DVB-T2 system

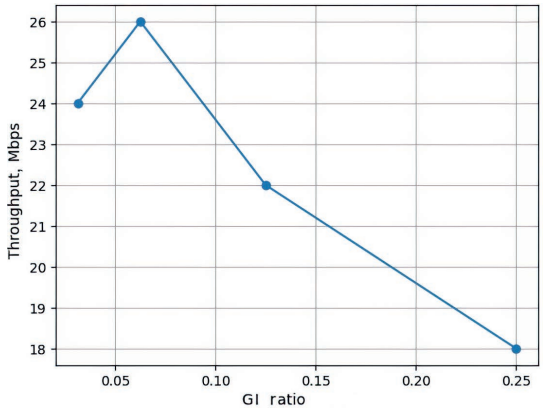

Fig. 3. Throughput performance versus guard interval in DVB-T2 transmission system

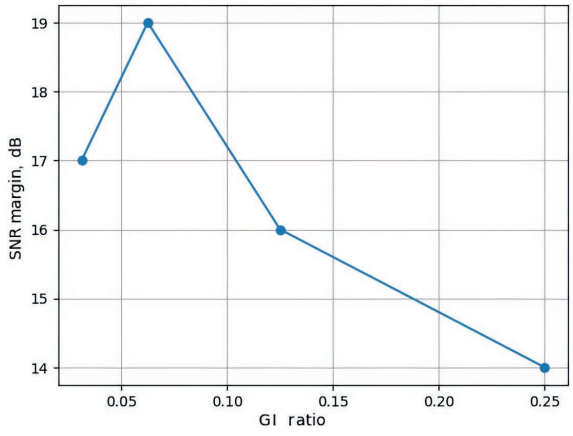

Fig. 4. Signal-to-noise ratio margin versus guard interval in DVB-T2 system

Throughput performance

The effect of changing the GI configuration on the throughput performance of the system is shown in Fig. 3. The results show that throughput increases as the overhead of guard intervals becomes smaller,

with the highest value of 26 Mbps attained when GI = 1/16. However, although there is less overhead when GI = 1/32, the system throughput was limited by the increase in errors, which caused re-transmissions.

SNR margin analysis

The SNR margin characteristics are shown in Fig. 4 and listed in Tab. 1. The maximum SNR margin (19 dB) was obtained for GI = 1/8, implying higher robustness to interference and fading. This does not imply that GI = 1/8 corresponds to optimal throughput or BER characteristics. The decrease in SNR margin for GI = 1/16 and GI = 1/32 is caused by higher susceptibility to multipath distortion, whereas GI = 1/4 suffers from unnecessary redundancy.

Integrated system performance evaluation

From the comparative analysis of all the parameters in Tab. 1, as well as in Fig. 2–4, it can be concluded that there is no GI configuration that will provide the best performance for all the parameters simultaneously. The GI value of 1/16 has the highest values of BER and throughput parameters, while the GI of 1/8 has the maximum SNR margin. On the contrary, the GI of 1/4 shows the worst performance in terms of all the parameters.

Conclusion

1. The paper provided a thorough performance assessment of guard interval optimization in based of orthogonal frequency division multiplexing DVB-T2 broadcast communication networks and proved that adequate guard interval selection considerably improves robustness, spectral efficiency, and transmission quality of the system when used in dense urban areas. According to the findings, the performance of the DVB-T2 system is quite sensitive to guard interval settings, especially in cases of multipath propagation in urban environment. In this regard, it was found that the system performance with the GI = 1/16 setting was the best one in terms of achieving minimum bit error rate, maximum throughput, and a high signal-to-noise margin.

2. The obtained results proved that there is indeed a trade-off between the robustness and spectral efficiency of DVB-T2 systems. While larger guard intervals (such as 1/4) ensured better immunity to intersymbol interference and multipath effects, they also caused significant overhead that decreased throughput. In turn, smaller guard intervals (such as 1/32) offered increased spectral efficiency but were associated with greater bit error rates because of lower robustness. In this context, the optimal guard interval setting (1/16) was identified as an effective solution that ensures stable performance of the system.

3. It is suggested that the designers of the DVB-T2 broadcasting network use the configuration GI = 1/16 in urban settings, especially where there is a very strong multipath effect like in cities. The reason for choosing this configuration is to allow efficient use of bandwidth while ensuring good signal reception.

4. Additionally, the future designs of the DVB-T2 broadcasting systems should be made with the ability to dynamically choose guard intervals based on real-time channel variations. Such adaptive ability will not only make the system more resilient but also optimize its spectral efficiency.

5. It is further recommended that more research be conducted on optimizing the selection of guard intervals in different propagation environments, especially in highly mobile and varying topographies. Another recommendation is for more research on the integration of quality-of-service metrics into the design of DVB-T2 systems.

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