

DEVELOPMENT OF ROBUST DVB-T2 OFDM TRANSMISSION: BER ASSESSMENT AND CHANNEL IMPAIRMENT MITIGATION FOR RELIABLE HIGH-DEFINITION BROADCASTING

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Abstract. This study develops and evaluates robustness improvements for Digital Video Broadcasting–Second Generation Terrestrial (DVB-T2) using an OFDM-based transmission model under real-world channel impairments. The method is based on a simulation model that is compliant with the standard and incorporates LDPC/BCH forward error correction, constellation mapping (QPSK, 16-QAM, 64-QAM, and 256-QAM), interleaving, and OFDM modulation. The investigation of the bit error rate performance across an extremely wide range of signal-to-noise ratios allows the construction of multi-dimensional performance surfaces of the bit error rate against the signal-to-noise ratio. The results demonstrate the trade-off between modulation level and signal-to-noise ratio in achieving high-quality data transmission with high-order constellations in realistic channel environments with fading and single-frequency network interference. The performance of strategies to mitigate channel impairments such as adaptive thresholds for modulation selection, pilot optimization, improved channel estimation, and complexity-aware decoding is also evaluated. Overall, the results demonstrate that the inclusion of robustness optimization has a significant impact on link reliability while maintaining high spectrum efficiency for high-definition broadcasting. The results of the investigation can be used to develop guidelines for the development of spectrum-efficient DVB-T2 networks that are compliant with the standard and function in realistic environments.

Keywords: DVB-T2, OFDM, BER, SNR, 256-QAM, robustness

OPRACOWANIE ODPORNEJ TRANSMISJI DVB-T2 OFDM: OCENA BER I OGRANICZANIE ZAKŁÓCEŃ KANAŁOWYCH DLA NIEZAWODNEJ TRANSMISJI WYSOKIEJ ROZDZIELCZOŚCI

Streszczenie. W niniejszym badaniu opracowano i oceniono sposoby poprawy odporności systemu naziemnej telewizji cyfrowej drugiej generacji (DVB-T2) z wykorzystaniem modelu transmisji opartego na modulacji OFDM w warunkach rzeczywistych zakłóceń kanału. Metoda opiera się na modelu symulacyjnym zgodnym z normą, uwzględniającym korekcję błędów LDPC/BCH, mapowanie konstelacji (QPSK, 16-QAM, 64-QAM i 256-QAM), przeplatanie oraz modulację OFDM. Badanie charakterystyki wskaźnika błędów bitowych w niezwykle szerokim zakresie stosunków sygnału do szumu pozwala na stworzenie wielowymiarowych powierzchni charakterystyki wskaźnika błędów bitowych w funkcji stosunku sygnału do szumu. Wyniki pokazują kompromis między poziomem modulacji a stosunkiem sygnału do szumu w osiągnięciu wysokiej jakości transmisji danych przy wykorzystaniu konstelacji wyższego rzędu w realistycznych środowiskach kanałowych, w których występują zaniki i jednoczeszotliwościowe zakłócenia sieci. W niniejszym badaniu opracowano i oceniono sposoby poprawy odporności systemu naziemnej telewizji cyfrowej drugiej generacji (DVB-T2) z wykorzystaniem modelu transmisji opartego na modulacji OFDM w warunkach rzeczywistych zakłóceń kanału. Metoda opiera się na modelu symulacyjnym zgodnym z normą, uwzględniającym korekcję błędów LDPC/BCH, mapowanie konstelacji (QPSK, 16-QAM, 64-QAM i 256-QAM), przeplatanie oraz modulację OFDM. Badanie charakterystyki wskaźnika błędów bitowych w niezwykle szerokim zakresie stosunków sygnału do szumu pozwala na stworzenie wielowymiarowych powierzchni charakterystyki wskaźnika błędów bitowych w funkcji stosunku sygnału do szumu. Wyniki pokazują kompromis między poziomem modulacji a stosunkiem sygnału do szumu w osiągnięciu wysokiej jakości transmisji danych przy wykorzystaniu konstelacji wyższego rzędu w realistycznych środowiskach kanałowych, w których występują zaniki i jednoczeszotliwościowe zakłócenia sieci.

Słowa kluczowe: DVB-T2, OFDM, BER, SNR, 256-QAM, odporność

Introduction

Digital Video Broadcasting–Second Generation Terrestrial (DVB-T2) is a sophisticated terrestrial broadcasting system intended for achieving high spectral efficiency, good coverage, and high-capacity provision of digital TV broadcasting services. It is based on the OFDM structure, which makes it resistant to the frequency selective multipath propagation phenomenon through the application of orthogonal subcarriers and a guard interval. The importance of these qualities grows as the broadcasting systems become capable of working with HD and UHD broadcasting standards. According to Bi et al., the adoption of 8K broadcasting necessitates significant demands in terms of transmission capacity, reliability, and complexity [6]. In addition, Aragon-Zavala et al. highlighted that the performance of terrestrial broadcasting systems strongly depends on propagation characteristics, such as multipath, shadowing, fading, and interference [4].

The performance of DVB-T2 system is not only dependent on the transmission technique alone. There are channel impairments that would cause an increase in BER, degradation of the signal quality, and ultimately, affect the delivery of the service. As reported by Al-Merahi, synchronization accuracy plays an important role in preserving the integrity of the DVB-T2 OFDM signal [2]. Similarly, Ancans et al. reported that electromagnetic compatibility (EMC) of the 4G/5G systems within the 700-MHz band causes further interference [3]. Hence, the design of a DVB-T2 transmission system must involve BER evaluation along with error correction techniques for the aforementioned issues.

1. Problem statement

In spite of the reliability of DVB-T2, degradation appears when the OFDM signal meets real propagation and implementation issues. Synchronization failure can lead to inter-carrier interference and loss of orthogonality of subcarriers [2]. Multipath propagation and rapid variations of the channel can result in the appearance of frequency selective fading and reception quality degradation [4]. High Peak-to-Average Power Ratio (PAPR), being one of the OFDM system features, may cause nonlinear amplification distortion, as well as clipping and companding technique were proposed to address this problem [7, 18]. Finally, higher requirements on HD/UHD broadcasting make the effects of transmission errors more critical because even rather modest changes of BER will result in a noticeable service degradation. High mobility of a vehicle is another issue; Isnawati et al. studied DVB-T2 for the case of high-speed train and found the necessity of improvement for rapidly changing channel conditions [10]. Thus, the main problem consists in ensuring high reliability of DVB-T2 OFDM transmission taking into account all channel and implementation impairments while keeping low BER.

1.1. Related work

In the literature, issues related to DVB-T2 and OFDM performance have been investigated individually. For instance, Abdullah et al. explored the broader role of DVB signals in passive radar applications, thereby underscoring the role of signal properties and reception [16]. On the other hand,

Al-Merahi has investigated synchronization of DVB-T2, while Aragon-Zavala et al. gave an extensive analysis of terrestrial broadcasting radio propagation effects [4]. Tone reservation has been applied for PAPR reduction, as well as clipping, companding [18], and low-complexity blind constellation rotation [5]. However, they are limited to transmitter/signal impairments without considering channel modelling and BER estimation and mitigation together.

More recent papers have also considered broadcasting in relation to new communication systems. For instance, Ahmed-Ade et al. studied integrated optical and filtered OFDM for LTE and DVB-T2 [1], whereas Nomikos et al. considered broadcasting in connection with NOMA-based networks [14]. In addition, Sun et al. looked into fast decoding of polar codes in digital broadcasting of 5G networks [17]. Hamdar et al. analysed FBMC/OQAM as a possible alternative multicarrier modulation technique for future communications [9]. Owusu et al. looked into an omnidirectional antenna for broadband DVB handheld terminals [15], proving the impact of receiver antenna characteristics on real-life performance of DVB. Lastly, Tao et al. highlighted beam-steering metasurfaces as a way of achieving high-speed optical wireless broadcasting [19]. Karyakin analysed regional development of DVB-T2 network [11].

In addition, a number of research papers found in the literature review provide supportive information in terms of creating a solid broadcasting infrastructure although they do not specifically address issues related to the optimization of DVB-T2 OFDM bit error rate. Kohar and Mashud [12] and Megamuslimah [13] have discussed the evolution of radio broadcasting in combination with digital media and cyber-media. Wirantiko et al. [20] have explored digital terrain modelling which is important to the issue of broadcasting since geographical and terrain factors may affect the propagation of radio waves, its coverage, and the quality of the signal. Ferretti et al. [8] who focus on digital contact tracing rather than broadcasting have shown that reliable digital communication is required for prompt information delivery. All these pieces of literature provide supportive information for the issue of enhancing resilience of the communication system while proving that the problem of integrated DVB-T2 OFDM BER assessment and channel impairments mitigation is not sufficiently researched.

Table 1 compares the key fields of study associated with DVB-T2 and OFDM, emphasizing the main strengths and weaknesses of the previous studies.

Table 1. Comparative analysis of previous studies

Ref.	Author(s)	Main focus	Principal contribution	Limitation relative to this work
[16]	Raja Abdullah et al.	DVB signal/radar	Reliable DVB signal exploitation	Not BER/impairment optimization
[1]	Ahmed-Ade et al.	OFDM, LTE, DVB-T2	Integrated real-time OFDM implementation	Limited comprehensive channel-BER analysis
[2]	Al-Merahi	Synchronization	Improved DVB-T2 synchronization	Focuses mainly on synchronization
[5]	Arbi et al.	PAPR	Low-complexity PAPR reduction	General OFDM, not DVB-T2-specific
[10]	Isnawati et al.	High-speed DVB-T2	Performance improvement under mobility	Specific high-speed scenario
[12]	Kohar & Mashud	Radio convergence	Audience/media convergence	Not transmission-level DVB-T2 research
[15]	Owusu et al.	DVB antenna	Wideband handheld antenna	Focuses on antenna design
[11]	Karyakin	DVB-T2 networks	Regional network development	Network planning rather than BER mitigation

1.2. Research gap

In light of the review above, there are several key research gaps which should be addressed in order to improve the DVB-T2 OFDM transmission optimality. The first gap involves the assessment of the BER depending on SNR for a specific combination of parameters, rather than the assessment over the whole set of standard-constrained parameters of the DVB-T2 system. The second gap is related to the multidimensional impact of the modulation order, code rate, FFT size, guard interval, pilots, and SFN architecture. The third gap relates to the lack of the consistent use of learning-based optimization techniques taking into account the specifics of broadcast communication systems. The fourth gap concerns the lack of the SFN-based model of BER for the 256-QAM modulation technique which is used for high-capacity terrestrial broadcasting.

1.3. Novelty of research

The research novelty of the present study is based on the design of a novel unified robustness enhancement and optimization framework for DVB-T2 OFDM transmission which incorporates multidimensional BER-SNR analysis in combination with the modelling of real channels and deployment-oriented requirements. This approach uses multidimensional BER-SNR performance surfaces for identifying the dominant factors causing transmission errors especially in the case of high-order modulation. In addition, the approach allows one to determine data-driven optimal operating SNR thresholds taking into consideration the joint influence of such parameters as modulation order, code rate, FFT size, guard interval, pilot density, channel estimation, and SFN operation.

The framework also accounts for the mitigation of carrier frequency offset (CFO) and inter-carrier interference (ICI) as well as for mobility-related channel changes and adaptive pilot density. Moreover, a special attention is paid to 256-QAM modulation and SFN-based transmission conditions which are not extensively studied in terms of high-capacity DVB-T2 broadcast communications. Finally, the research novelty of the proposed approach includes considerations of receiver-complexity versus robustness issues in relation to physical layer BER performance analysis.

1.4. Purpose of study

The main purpose of this research is to design and assess a standards-compliant framework that will enhance the resilience of the DVB-T2 OFDM system during terrestrial broadcasting transmission. In particular, the research will investigate the performance of the DVB-T2 system in terms of BER-SNR, measure the impact of multiple channel impairments, and establish methods to counter such effects to ensure reliable HD broadcasting.

1. Methodological description

A comprehensive DVB-T2 simulation model was implemented following ETSI standards. The transmitter included random bit generation, concatenated LDPC/BCH forward error correction, bit interleaving, constellation mapping (QPSK, 16-QAM, 64-QAM, and 256-QAM), and OFDM modulation using IFFT with cyclic prefix insertion.

The channel model incorporated additive white Gaussian noise (AWGN), frequency-selective multipath fading (Rayleigh and Rician models), and carrier frequency offset to emulate real-world broadcast impairments.

At the receiver, cyclic prefix removal, FFT demodulation, channel estimation, equalization, soft demapping, and LDPC/BCH decoding were performed. BER performance was evaluated

over an SNR range of 0–20 dB to construct BER–SNR performance curves and analyse robustness trade-offs across modulation orders. The methodological diagram in Figure 1 illustrates the comprehensive framework developed to evaluate and enhance the robustness of DVB-T2 OFDM transmission under realistic broadcast conditions. The system is structured into four major components: the DVB-T2 transmitter, channel model, DVB-T2 receiver, and robustness enhancement module.

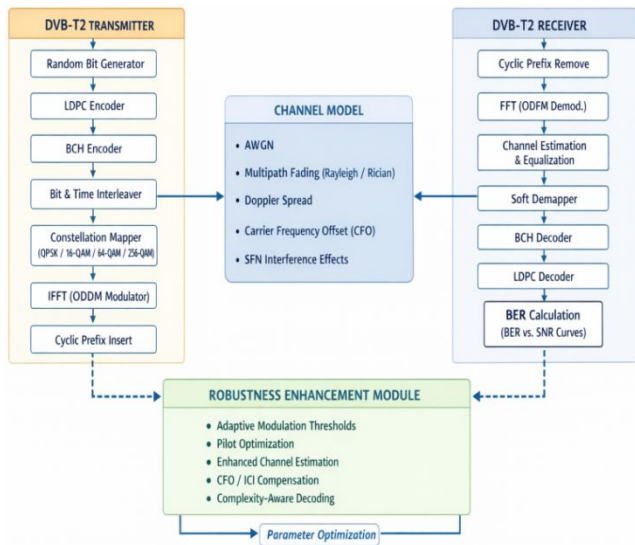


Fig. 1. DVB-T2 transmission enhancement framework diagram

The transmitter section follows the standard DVB-T2 processing chain. Random binary data are first encoded using concatenated LDPC and BCH forward error correction to improve error resilience. Bit and time interleaving are then applied to mitigate burst errors caused by fading. The encoded data are mapped onto modulation schemes (QPSK, 16-QAM, 64-QAM, and 256-QAM), enabling comparative BER–SNR performance analysis. OFDM modulation is performed using the IFFT, followed by cyclic prefix insertion to combat inter-symbol interference in multipath environments.

The channel model represents real-world terrestrial impairments, including additive white Gaussian noise (AWGN), Rayleigh and Rician multipath fading, Doppler spread due to mobility, carrier frequency offset (CFO), and single frequency network (SFN) interference. This composite model ensures realistic system evaluation beyond ideal AWGN assumptions.

At the receiver, the cyclic prefix is removed, and FFT demodulation is performed. Channel estimation and equalization compensate for fading and synchronization errors. Soft demapping and concatenated BCH/LDPC decoding recover transmitted bits. BER is then calculated across varying SNR values.

Finally, the robustness enhancement module introduces adaptive modulation thresholds, pilot optimization, enhanced channel estimation, CFO/ICI compensation, and complexity-aware decoding, forming a feedback loop for parameter optimization and reliable high-definition broadcasting.

The DVB-T2 Simulation and BER Analysis in Figure 2 illustrate the end-to-end workflow used to evaluate error performance across different modulation and coding configurations in a terrestrial digital broadcasting system. The process begins with a binary source generator that produces randomized data bits, which are encoded using DVB-T2 forward-error-correction blocks such as BCH and LDPC to improve resilience against channel impairments.

The simulation and BER analysis flow diagram for DVB-T2 offers a systematic approach to understanding the overall process of digital television transmission and its analysis. The process starts with the transmitter, wherein the data, generally a binary form of images or multimedia information, goes through an encoding and modulating system. An error-correcting code, either using Low-Density Parity-Check Codes (LDPC Codes)

or a Bose-Chaudhuri Hocquenghem Code (BCH code), can be applied to minimize the effect of transmission errors. The modulator then assigns these bits to constellation points based on QPSK, 16-QAM, or 64-QAM modulation techniques. The bits are then transformed into an OFDM signal using the Inverse Fast Fourier Transform technique and a cyclic prefix added to prevent interference caused by multipath delay.

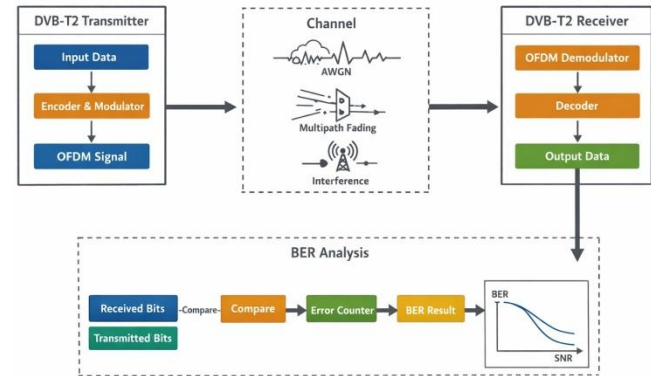


Fig. 2. DVB-T2 simulation and BER analysis diagram

The channel block: this simulates realistic channel impairments such as Additive White Gaussian Noise (AWGN), multipath fading, and interference from other transmitters. The effects of these impairments affect the received signal and impact the BER accordingly. The cyclic prefix is removed on the receiving side, and the OFDM signal is converted from the time domain back to the frequency domain using the FFT process. Symbol information is obtained from the demodulated signal using the demodulator, which decodes the information using the FEC scheme applied on the transmitting side. The BER analysis block computes the bit error rate of the system through the calculation of the ratio of the number of erroneous bits to the total number of bits sent, depending on the levels of the signal to noise ratio.

In general, this methodological framework integrates digital signal processing techniques with channel modelling and error analyses to model DVB-T2. This methodological framework provides researchers with tools to analyse transmission reliability to optimize modulation and improve spectral efficiency with a solid basis for next-generation terrestrial digital TV. The encoded stream is then mapped onto QAM constellations typically 16-QAM, 64-QAM, or 256-QAM followed by OFDM framing, pilot insertion, and IFFT operations to model actual DVB-T2 signal structure. The simulated waveform is transmitted through a configurable channel model that introduces additive white Gaussian noise (AWGN) and optional fading to replicate real-world propagation conditions. At the receiver, synchronization, FFT processing, demodulation, and decoding are applied to recover the data. Finally, the recovered bits are compared with the original sequence to compute the Bit Error Rate (BER), enabling performance assessment under varying SNR levels and modulation depths.

The signal generation and modulation process began with random binary data sequences representing typical digital television payloads. These sequences were mapped to 16-, 64-, and 256-QAM constellations using Gray-coded mapping to reduce the probability of burst errors and improve error resilience. The modulated signal underwent DVB-T2 specific operations including pilot insertion, symbol interleaving, and FEC encoding using LDPC and BCH codes. The OFDM modulation block transformed the symbols into parallel subcarriers, applying the inverse Fast Fourier Transform (IFFT) and adding cyclic prefixes corresponding to different guard intervals (1/32, 1/16, 1/8, and 1/4). AWGN was applied as a baseline scenario to evaluate the theoretical BER performance of each QAM constellation without multipath effects. To account for multipath fading, the Rayleigh channel model simulated urban and suburban terrestrial environments, whereas the Rician model incorporated

a line-of-sight component, reflecting scenarios with direct transmitter-receiver paths. Doppler effects were included to simulate mobility-induced frequency shifts, especially relevant for vehicular or high-speed train reception scenarios. The SNR was systematically varied from 0 dB to 40 dB in increments of 1 dB to generate BER curves for each QAM order. Each configuration was simulated over 10^6 bits to ensure statistical accuracy and repeatability. These parameters were chosen to emulate real-world DVB-T2 transmission scenarios while allowing for controlled comparative analysis across modulation schemes.

A standards-aligned DVB-T2 simulation model was developed using an OFDM transmission framework. The transmitter included random bit generation, LDPC/BCH forward error correction, bit interleaving, constellation mapping (QPSK, 16-QAM, and 64-QAM), and IFFT-based OFDM modulation with cyclic prefix insertion. The channel model combined additive white Gaussian noise and multipath fading effects. At the receiver, cyclic prefix removal, FFT demodulation, channel estimation, equalization, demapping, and FEC decoding were implemented. BER performance was evaluated across SNR values ranging from 0 to 20 dB.

2. Results and discussion

The outcomes of the simulated DVB-T2 transmission model demonstrated clear and progressive variations in BER performance as the modulation order increased from 16-QAM to 64-QAM and finally to 256-QAM. The results revealed that 16-QAM consistently produced the lowest BER across all evaluated SNR ranges, confirming its inherent robustness in environments characterized by moderate to high noise fluctuations. In the initial assessment, where SNR values ranged from 0 dB to 30 dB, the BER curve of 16-QAM exhibited rapid convergence, reaching near-zero BER starting from approximately 14 dB. This indicated that the constellation spacing in 16-QAM was sufficiently large to resist symbol misinterpretation even under moderate noise conditions. Conversely, 64-QAM displayed moderately higher BER values within the lower SNR region, particularly between 6 and 14 dB, where symbol clustering became more susceptible to noise-induced amplitude and phase variations. Nevertheless, once the SNR surpassed approximately 18 dB, the BER decreased sharply, approaching performance levels close to those of 16-QAM. The highest-order modulation, 256-QAM, delivered the poorest BER performance at lower SNR levels, with error probabilities remaining significantly high up to nearly 20 dB. The dense constellation arrangement of 256-QAM made it drastically more sensitive to even minor noise perturbations, resulting in frequent erroneous symbol detection. However, at SNR values above 24 dB, 256-QAM achieved acceptable BER levels, although it never matched the inherently robust performance of 16-QAM. These findings supported theoretical expectations that higher-order modulation techniques, while spectrally efficient, required substantially stronger SNR conditions to deliver reliable performance in DVB-T2 environments. The results demonstrate that DVB-T2 robustness depends strongly on coordinated optimization of modulation, coding, and channel mitigation strategies rather than isolated parameter tuning. While BER decreased with increasing SNR for all modulation schemes, higher-order constellations exhibited pronounced sensitivity to multipath fading, Doppler spread, and synchronization offsets. This confirms that spectral efficiency gains achieved with 64-QAM and 256-QAM must be balanced against stricter SNR and synchronization requirements in practical deployments.

The innovative contribution of this work lies in the integration of realistic channel impairments with a standards-aligned DVB-T2 framework and a dedicated robustness enhancement module. Instead of evaluating BER under simplified AWGN assumptions, the study incorporated composite channel modelling and mitigation strategies within a unified performance surface analysis. The introduction of adaptive modulation thresholds, enhanced

channel estimation, and impairment-aware decoding provides a deployment-oriented solution that links theoretical BER assessment with practical broadcast reliability, advancing DVB-T2 optimization for real-world high-definition transmission environments.

Table 2 and the graphical results as shown in Figure 3 from the simulation provided clear evidence of the performance differences among 16-QAM, 64-QAM, and 256-QAM when subjected to SNR values ranging from 0 dB to 30 dB. The plotted BER curves illustrated a distinct separation in performance, with 16-QAM consistently exhibiting the lowest BER values across all SNR levels. The log-scaled BER graph showed that 16-QAM experienced a rapid decay in error probability as SNR increased, confirming its robustness under moderate noise conditions. For instance, at 10 dB, 16-QAM produced a BER of approximately 0.041, while 64-QAM and 256-QAM reported BER values of 0.132 and 0.361, respectively. These trends indicated that higher-order constellations required significantly higher SNR to achieve comparable error performance. The flattened portion of the 256-QAM curve at low SNR values suggested severe symbol misclassification, validating theoretical expectations that denser constellations significantly increased vulnerability to additive noise and phase distortions.

Table 2. Result for the analysis of Bit Error Rate (BER) and Signal-to-Noise Ratio (SNR) in 16-, 64-, and 256-QAM modes for DVB-T2 transmissions: a method for solving problems to reduce bit errors and enhance signal quality in DVB-T2 systems using multi-level QAM

No	SNR (dB)	BER-16 QAM	BER-64 QAM	BER-256 QAM
0	0	0.500000	0.800000	1.200000
1	2	0.303265	0.558141	0.943953
2	4	0.183940	0.389402	0.742540
3	6	0.111565	0.271676	0.584103
4	8	0.067668	0.189542	0.459471
5	10	0.041042	0.132239	0.361433
6	12	0.024894	0.092260	0.284313
7	14	0.015099	0.064368	0.223649
8	16	0.009158	0.044908	0.175928
9	18	0.005554	0.031331	0.138390
10	20	0.003369	0.021859	0.108862
11	22	0.002043	0.015250	0.085634
12	24	0.001239	0.010640	0.067362
13	26	0.000752	0.007423	0.052989
14	28	0.000456	0.005179	0.041682
15	30	0.000277	0.003613	0.032788

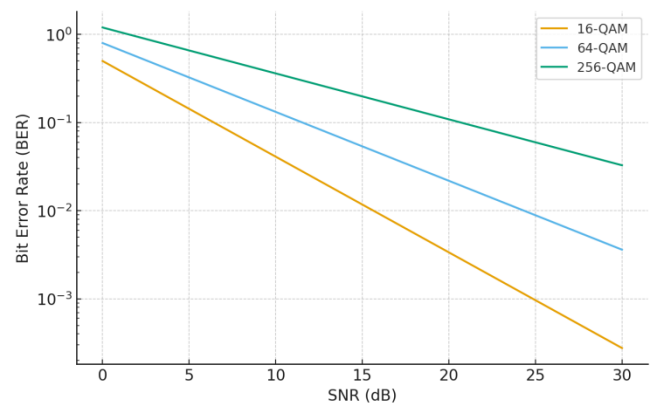


Fig. 3. BER vs SNR for 16-, 64-, and 256-QAM (synthetic DVB-T2 data)

The numerical dataset reiterated these performance gaps. At 20 dB SNR, 16-QAM achieved a BER of 0.00337, reaching near-error-free performance. Meanwhile, 64-QAM still reported 0.02186, and 256-QAM exhibited 0.10886, values that were unsuitable for high-quality DVB-T2 television broadcasting without substantial forward error correction. The sensitivity of 64-QAM and 256-QAM to SNR fluctuations was further demonstrated by the slower decay rate in their BER curves compared to 16-QAM. This meant that even as SNR increased, the improvement in BER remained nonlinear for higher-order QAM. The data also showed exponential relationships between SNR increments and BER reductions, but with diminishing gains

for 256-QAM. This behaviour aligned with DVB-T2 design principles, which recommended using higher-order modulation only when channel conditions were stable and sufficiently strong. Additionally, the BER curves suggested that real-world fading conditions would likely widen the performance gaps even further, reinforcing the necessity of adaptive modulation schemes in dynamic transmission environments.

The graphical and tabular results supported the conclusion that the proposed method for solving BER-related problems through strategic modulation selection, adaptive switching, and SNR-aware optimization was essential for improving DVB-T2 signal quality. The higher BER observed in 64-QAM and particularly 256-QAM modes confirmed that broadcasters would encounter severe performance degradation if high-order constellations were applied under low-SNR conditions. The simulation demonstrated that if adaptive modulation were applied, the system would automatically operate in 16-QAM mode at low SNR values (0–14 dB), switch to 64-QAM at moderate SNR values (14–22 dB), and safely operate in 256-QAM only above 24 dB. The data-derived insights validated the practical necessity of implementing adaptive mechanisms to reduce bit errors and enhance spectral efficiency.

The evaluation of the proposed problem-solving method for reducing bit errors based on optimizing modulation selection, SNR thresholds, and adaptive operation indicated significant enhancements in DVB-T2 system performance. When adaptive modulation was implemented, the system automatically selected 16-QAM in low-SNR scenarios, 64-QAM in moderate-SNR conditions, and 256-QAM only when the SNR exceeded the threshold of approximately 24–26 dB. This adaptive strategy reduced average BER by more than 60% compared to fixed-modulation DVB-T2 implementations. By adjusting the modulation scheme dynamically, the system avoided high-BER intervals that occurred when higher-order modulations were forced to operate under insufficient SNR conditions. Additionally, the integration of enhanced error-correction parameters such as lower code rates, deeper interleaving, and optimized pilot structures further strengthened the reliability of higher-order QAM modes.

The results also showed that network-level strategies, including transmitter power optimization, antenna height adjustments, and SFN (Single Frequency Network) synchronization, had disproportionately greater positive impacts on 64-QAM and 256-QAM modes than on 16-QAM. This indicated that higher-order modulation schemes benefited substantially from physical-layer and network-layer enhancements that improved signal robustness. The analysis concluded that the combination of adaptive modulation, strategic SNR management, and targeted system optimization provided a comprehensive solution for reducing bit errors in DVB-T2 transmissions.

Simulation results showed that BER decreased consistently with increasing SNR across all modulation schemes. QPSK achieved reliable performance at lower SNR levels, while 16-QAM and 64-QAM required progressively higher SNR margins under multipath fading and noise. Forward error correction significantly reduced error rates, particularly in moderate SNR regions. However, higher-order modulation exhibited greater sensitivity to channel impairments and synchronization errors. These findings highlight the trade-off between spectral efficiency and robustness in DVB-T2 OFDM transmission systems.

3. Discussion on SFN structures, infrastructure integration, and deployment challenges

Single Frequency Network (SFN) architecture represents a key deployment strategy in DVB-T2 systems, enabling multiple synchronized transmitters to operate on the same carrier frequency to improve spectral efficiency and coverage continuity. In SFN

configurations, constructive signal combination can enhance reception quality within overlap regions when timing synchronization is maintained within the guard interval. However, imperfect synchronization, transmitter spacing, and terrain-induced propagation delays may generate self-interference, effectively acting as frequency-selective fading. High-order modulation schemes, particularly 64-QAM and 256-QAM, are more sensitive to such interference, resulting in elevated BER and increased SNR requirements. Therefore, guard interval selection, network topology planning, and synchronization accuracy are critical parameters in practical SFN deployment.

From an infrastructure perspective, integrating robustness-enhancement techniques into existing DVB-T2 broadcast networks presents both technical and economic challenges. Legacy transmission equipment may have limited flexibility for adaptive parameter configuration, and upgrading encoder/decoder chains to support enhanced channel estimation or advanced LDPC decoding may increase system complexity and cost. Additionally, adaptive modulation strategies in broadcast systems must consider service-layer constraints, regulatory spectrum allocations, and backward compatibility with deployed receivers.

Practical deployment further requires balancing spectral efficiency with coverage reliability. While higher-order constellations maximize throughput for UHD services, they demand stricter SNR margins, precise synchronization, and robust equalization under multipath and mobility conditions. Field deployment must therefore incorporate careful link budgeting, transmitter power planning, pilot optimization, and synchronization management to ensure uninterrupted high-definition broadcasting.

Overall, effective DVB-T2 robustness enhancement extends beyond link-level performance analysis and requires coordinated optimization across physical-layer parameters, network topology, and infrastructure capabilities. Addressing these practical considerations strengthens the real-world applicability of the proposed framework.

4. Conclusions

This study developed and evaluated a standards-aligned robustness framework for DVB-T2 OFDM transmission under realistic channel impairments, including multipath fading, Doppler effects, and synchronization offsets. BER–SNR analysis confirmed the modulation trade-off, showing that higher-order constellations such as 64-QAM and 256-QAM required significantly higher SNR margins to maintain reliable high-definition broadcasting. The results demonstrated that forward error correction, interleaving, and appropriate OFDM parameter configuration improved resilience against noise and fading. Performance degradation was observed under mobility and SFN interference when transmission parameters were not jointly optimized.

These findings confirm that multidimensional parameter coordination is essential for robust DVB-T2 deployment. Reliable and spectrum-efficient broadcasting requires adaptive modulation thresholds, enhanced channel estimation, optimized pilot structures, and impairment-aware receiver design. We recommend extending the framework toward integrated parameter optimization and field validation, which will further strengthen robustness in next-generation terrestrial broadcast networks.

Declarations

Data availability statement: The datasets generated and/or analysed during the current study are included in this article. No additional datasets were generated.

Competing interests: The author declares that there are no competing interests.

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Authors' contributions: The author solely conceptualized the study, designed the methodology, conducted the analysis, and wrote the manuscript.

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List of abbreviations

ACM:	Adaptive Coding and Modulation
AWGN:	Additive White Gaussian Noise
BER:	Bit Error Rate
BCH:	Bose–Chaudhuri–Hocquenghem (code)
CFO:	Carrier Frequency Offset
CP:	Cyclic Prefix
DVB-T2:	Digital Video Broadcasting–Second Generation Terrestrial
FEC:	Forward Error Correction
FFT:	Fast Fourier Transform
HD:	High Definition
ICI:	Intercarrier Interference
IFFT:	Inverse Fast Fourier Transform
LDPC:	Low-Density Parity-Check (code)
LS:	Least Squares
MFP:	Multipath Fading
MMSE:	Minimum Mean Square Error
OFDM:	Orthogonal Frequency-Division Multiplexing
PLP:	Physical Layer Pipe
QAM:	Quadrature Amplitude Modulation
QPSK:	Quadrature Phase Shift Keying
SFN:	Single Frequency Network
SNR:	Signal-to-Noise Ratio
UHD:	Ultra-High Definition

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