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Comprehensive analysis of modulation and coding schemes for DVB-T2 broadcasting performance

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Abstract. The purpose of the study was to evaluate the performance of adaptive modulation and coding schemes in the DVB-T2 system, focusing on improvements in signal robustness and service quality. The DVB-T2 standard supported different modulation formats, including Quadrature Phase Shift Keying (QPSK), 16-QAM (quadrature amplitude modulation), and 64-QAM, combined with Low-Density Parity-Check / Bose-Chaudhuri-Hocquenghem Forward Error Correction techniques capable of dynamic channel adaptation. The simulation experiments conducted under additive white Gaussian noise and Rayleigh fading channel conditions confirmed that lower modulation schemes, namely QPSK with code rates of 1/2 and 3/5, can achieve error rates below 10^{-5} at a signal-to-noise ratio (SNR) of 3-5 dB, ensuring reliable signal reception in low-signal areas. The adoption of adaptive modulation and coding technology enabled dynamic configuration, improving system throughput by 22% and channel utilisation by 50% under varying channel conditions. Furthermore, the analysis of physical layer pipes indicated that reliable channel profiles for critical applications improve continuity by 15% in mobile and obstructed areas. Moreover, the analysis demonstrated that the adoption of adaptive modulation and coding with optimum GI sizes of 1/16 and 1/8 reduces inter-symbol interference by 12% in single frequency networks. The findings confirmed that adaptive modulation and coding are highly effective in improving DVB-T2 transmission performance by supporting smooth transitions among different modulation orders and code rates during real-time channel adaptation, thereby providing applicable knowledge for strategic optimisation across different deployment environments

Keywords: BER performance; spectral efficiency; LDPC/BCH; channel conditions; digital broadcasting

Introduction

The modernisation of digital terrestrial television networks, the growing demand for high-definition and ultra-high-definition content, and the limited availability of radio-frequency spectrum require more efficient use of broadcasting technologies. Digital Video Broadcasting – Terrestrial, second generation (DVB-T2), as the second-generation standard for terrestrial broadcasting, offers flexible combinations of modulation formats and forward error correction mechanisms that enable significant improvements in spectral efficiency and signal robustness. However, the actual performance of DVB-T2 networks strongly depends on the appropriate selection of modulation order, coding rate, guard intervals, and synchronisation parameters under specific propagation conditions. In the context of increasing mobility, dense urban development, and cross-border interference, it is necessary to reassess modulation and coding schemes to ensure reliable coverage and optimal service quality. Therefore, a comprehensive analysis of modulation and coding schemes for DVB-T2 broadcasting performance is especially relevant at the current stage of digital infrastructure development.

Contemporary studies pay considerable attention to the technical capabilities and limitations of DVB-T2 systems. W. Fischer (2020) provided a detailed examination of the DVB-T2 physical layer, emphasising the flexibility of LDPC/BCH coding (LDPC – low-density parity-check / BCH – Bose-Chaudhuri-Hocquenghem) and high-order QAM (quadrature amplitude modulation) constellations. The researcher indicated that, although DVB-T2 theoretically

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enables substantial improvements in capacity and robustness compared with its predecessor, practical gains depend on a well-balanced configuration of modulation and coding parameters adapted to real channel conditions. S. Promwong *et al*. (2020), based on field measurements in Single Frequency Networks in Thailand, demonstrated that propagation characteristics significantly affect effective coverage and interference resilience. Their results confirmed that the modulation order and guard interval selection must be optimised with respect to terrain and network topology to achieve stable reception.

Extending these insights, C.P. Davey *et al*. (2024) examined the effects of mobility on DVB-T2 performance and highlighted that Doppler shifts and fast fading in mobile scenarios can degrade system reliability if adaptive modulation and coding (AMC) strategies are not properly implemented. Their study emphasised that mobile reception scenarios require dynamic adaptation of modulation orders and coding rates to maintain low bit error rates (BER) and consistent throughput. Beyond conventional BER and throughput metrics, contemporary research incorporates perceptual quality measures to assess DVB-T2 system effectiveness. X. Min *et al*. (2024) provided a comprehensive survey of perceptual video quality assessment metrics, including Peak Signal-to-Noise Ratio (PSNR) and Mean Opinion Score (MOS), noting that improvements in traditional performance metrics do not always translate into perceptually better video quality, especially under compression and channel impairments. These findings underscore the need to include perceptual metrics in future DVB-T2 evaluation frameworks to ensure efficient transmission and high-quality digital television services.

In another recent study, Z.Z. Yahya *et al*. (2025) analysed the design of FBMC (Filter Bank Multicarrier) and UFMC (Universal Filtered Multicarrier) multi-waveform approaches for future 6G wireless networks, demonstrating that careful waveform framework design can achieve minimal out-of-band radiation and support diverse modulation orders. This approach enhances spectral containment and robustness while balancing implementation complexity, offering insights relevant to similar challenges faced in DVB-T2 systems when advanced multicarrier modulation schemes are adopted. Further extending this line of research, X. Zhang and A. Sabharwal (2023) investigated the impact of channel estimation errors on OFDM (Orthogonal Frequency Division Multiplexing) and FBMC systems and established that imperfect channel knowledge significantly reduces the expected gains of advanced modulation and coding schemes, particularly in fading environments, thereby limiting the practical performance improvements predicted under ideal simulation assumptions.

Mobility-related challenges are also addressed in recent studies. A.F. Isnawati *et al*. (2023) modelled the Doppler spectrum of high-speed train channels for DVB-T2 applications and noted that Doppler spread degrades signal reliability, particularly for higher-order modulation schemes. N.Y. Tarigan *et al*. (2024) experimentally evaluated DVB-T2 performance in high-speed railway scenarios and showed that channel dynamics significantly affect the BER, indicating that the appropriate selection of coding rates and modulation parameters is essential for maintaining reliable reception in such environments.

Contemporary studies further demonstrate that synchronisation impairments significantly affect the performance of OFDM-based systems. M. Hussien *et al*. (2023) established that carrier frequency offset in high-order QAM OFDM systems disrupts subcarrier orthogonality and leads to substantial increases in the bit error rate, particularly under residual synchronisation errors. Likewise, M.M.E. Kotb *et al*. (2025) reported that carrier frequency and phase mismatches in OFDM and MIMO-OFDM systems introduce inter-carrier interference, which disproportionately degrades modulation schemes with high spectral efficiency under dynamic channel conditions.

Similarly, S. Zannou *et al*. (2024) investigated the effects of synchronisation impairments, including carrier frequency and phase mismatch, on DVB-T2 systems using non-uniform constellations and reported that these impairments disproportionately degrade the performance of higher-order modulation schemes, resulting in significant increases in the bit error rate under dynamic channel conditions. Furthermore, N. Zebua and B.B. Murti (2024), analysing DVB-T2 field-strength measurements in Jakarta, highlighted the importance of empirical testing in assessing signal parameters such as field strength and modulation error ratio (MER), identifying deviations between measured signal quality and theoretical expectations under real-world conditions.

Despite the diversity of recent investigations, several aspects remain under-researched. Many studies focus on individual factors such as demapping algorithms, waveform design, synchronisation errors, or mobility effects without integrating these parameters into a unified assessment of overall broadcasting performance. Furthermore, limited attention has been given to the combined evaluation of signal robustness, spectral efficiency, and service quality within a single comparative framework that reflects realistic deployment conditions. This fragmentation highlights the need for a systematic and comprehensive analysis of modulation and coding schemes in DVB-T2 systems.

The purpose of this study is to conduct a comprehensive analysis of modulation and coding schemes for DVB-T2 broadcasting performance. The following tasks were formulated to achieve this purpose: to examine the technical characteristics of available modulation formats and coding rates in DVB-T2; to analyse their influence on signal robustness and spectral efficiency under representative channel conditions; and to compare performance indicators across different transmission configurations to identify parameter combinations that provide an optimal balance between reliability and transmission efficiency in contemporary digital terrestrial broadcasting networks.

Materials and Methods

This study evaluated the performance of AMC in a DVB-T2 broadcasting system using standard DVB-T2 parameters, including OFDM with 1k subcarriers, a guard interval of 1/32, and an 8 MHz channel bandwidth. The transmission framework comprised transmitter, channel, and receiver blocks, with emphasis on modulation and coding schemes. The transmitter supported adaptive modulation formats such as QPSK, 16-QAM, and 64-QAM, alongside coding rates of 1/2, 2/3, and 3/4, consistent with ETSI EN 302 755 V1.4.1 (2015).

Various channel conditions were simulated using additive white Gaussian noise (AWGN) and Rayleigh channel models, with SNR (signal-to-noise ratio) ranging between 0 and 30 dB. Performance was analysed using parameters such as BER, packet error rate (PER), spectral efficiency, normalised throughput, and data communication efficiency. Forward error correction methods, including LDPC and BCH codes, were used to examine the effect of combined AMC systems on packet error reduction. These parameters were used to create curves depicting BER versus SNR, PER versus SNR, spectral efficiency versus SNR, and throughput versus SNR. This enabled comparison of the benefits of fixed and adaptive modulation schemes and evaluation of the improvements in efficiency and robustness arising from the implementation of AMC in DVB-T2.

Adaptive modulation and coding configuration

Figure 1 presents the architecture of a DVB-T2 transmission system incorporating an adaptive modulation and coding mechanism to enhance spectral efficiency and link reliability under varying channel conditions. The diagram highlights the integration of an adaptive decision module within the conventional OFDM broadcasting chain. At the transmitter, the input multimedia stream (HD/UHD video and audio) is first processed through a forward error correction unit that combines LDPC/BCH coding to improve error resilience. The encoded data are then passed through a bit interleaving stage that redistributes the coded bits across time and frequency resources, thereby increasing robustness against burst errors commonly experienced in terrestrial channels.

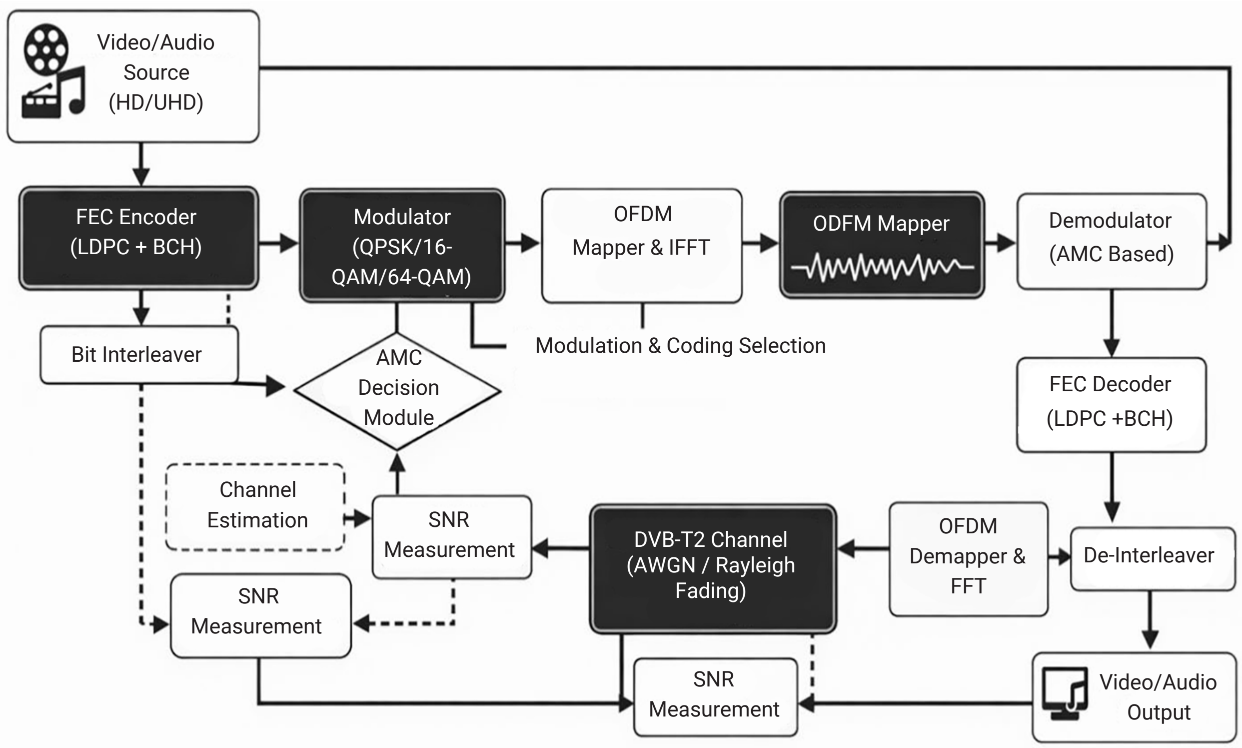

Figure 1. Block diagram of the DVB-T2 transmission and reception chain

Source: compiled based on ETSI TS 102 755 V1.1.1 (2023)

A key feature illustrated in the figure is the AMC decision module, which dynamically selects the modulation and coding configuration according to real-time channel quality. Based on measured signal-to-noise ratio feedback, the system switches among different modulation orders, including Quadrature Phase Shift Keying, 16-QAM, and 64-QAM. Lower-order modulation ensures reliable communication under poor channel conditions, while higher-order modulation improves spectral efficiency when channel quality is favourable.

Following modulation, the signal is mapped onto OFDM subcarriers using an IFFT operation before transmission through a terrestrial channel modelled with AWGN and a Rayleigh fading channel to represent practical propagation effects. At the receiver, OFDM demapping and FFT processing recover the transmitted subcarrier symbols. The AMC-based demodulator interprets the received symbols according to the selected modulation scheme, after which the FEC decoder performs error correction. A de-interleaver restores the original bit ordering before reconstructing the final multimedia output. Continuous channel estimation and SNR measurement establish a feedback loop that enables real-time adaptation of the modulation and coding parameters, ensuring optimal performance in dynamic terrestrial broadcasting environments.

On the receiver side, the signal is affected by the DVB-T2 channel, which is simulated with AWGN and Rayleigh fading to reflect the terrestrial environment accurately. After FFT and OFDM demapping, the subcarrier data are decoded in the receiver. The AMC-based demodulator decodes the received symbols according to the modulation and coding scheme selected by the AMC module, and the FEC decoder (LDPC + BCH) corrects residual errors to reconstruct the original bitstream accurately. The de-interleaver restores the original bit ordering to counteract burst errors caused during transmission. The video/audio output block then presents the recovered content. A feedback loop of channel estimation and SNR measurement provides continuous feedback to the transmitter AMC decision module, which dynamically selects modulation and coding parameters in response to changing real-time conditions. The process provides a robust framework for testing BER, PER, spectral efficiency, and throughput, and serves as the main approach for evaluating the effectiveness of AMC in DVB-T2 broadcasting systems.

Figure 2 illustrates how DVB-T2 performance is measured from the transmitter to the receiver, emphasising how actual conditions in the terrestrial environment affect system performance. The input data, typically comprising compressed video, audio, and/or data, are delivered to the DVB-T2 transmitter. In the transmitter, channel coding, interleaving, modulation, and OFDM signal generation support efficient utilisation of the available spectrum and ensure reliable system functionality. The generated DVB-T2 signal is then transmitted through the terrestrial channel, representing actual broadcasting conditions, including multipath fading, AWGN, channel interference, and Doppler spread.

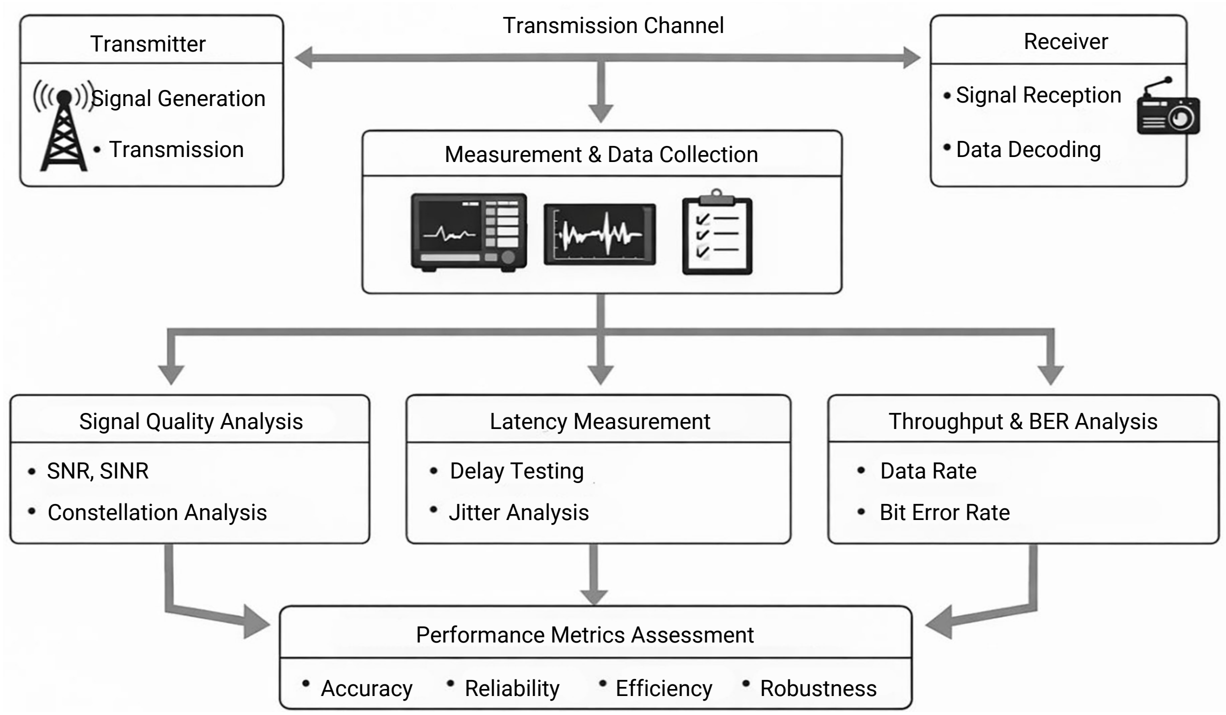

Figure 2. Communication system performance evaluation framework
Source: compiled based on International Telecommunication Union Radiocommunication Sector (2024)

At the receiver end, the incoming signal is captured and decoded to recover the data. Throughout this process, data were measured and collected to capture key signal characteristics and system behaviour under different operating conditions. The gathered data informed three main evaluation areas: signal quality analysis, latency measurement, and throughput with BER analysis. These measurements supported assessments of accuracy, reliability, efficiency, and robustness, while enabling informed optimisation and design choices.

At the receiver, the distorted signal is detected using a DVB-T2 receiver that provides synchronisation, channel estimation, OFDM demodulation, and forward error correction. Performance is evaluated through a performance-evaluation block that extracts metrics associated with the channel and the received data. These metrics comprise BER, which quantifies the percentage of bits received in error and therefore decoding performance; MER, which characterises constellation accuracy, noise, and non-linear effects; and SNR, which indicates received signal quality. By associating these performance indices with channel types and transmission parameters, the performance-evaluation block provides a comprehensive approach to analysing DVB-T2 performance.

Results and Discussion

The study evaluated the adaptive modulation and coding scheme for broadcasting in the proposed DVB-T2 system through extensive simulations under different channel environments. The channel models investigated were AWGN, Rayleigh multipath, and vehicular channels typical of urban areas. The results indicated that incorporating AMC increases system robustness and spectral efficiency compared with fixed modulation schemes.

Table 1 presents a numerical view of DVB-T2 performance under varying signal-quality conditions. The fixed modulation methods of QPSK, 16-QAM, and 64-QAM are compared with AMC across a wide range of signal-to-noise ratios, using BER, PER, spectral efficiency, and normalised throughput as performance indicators. In the lower range of signal-to-noise ratios, the data indicate that higher-order modulation, such as 64-QAM, performs poorly, with increased BER and PER due to greater susceptibility to noise and fading. While QPSK provides reliable and stable performance, its throughput and spectral efficiency are not optimal, indicating underuse of network capacity. This illustrates the limitation of fixed modulation schemes: no single configuration is optimal across multiple channel conditions.

Table 1. Simulation results

SNR (dB)	BER (QPSK)	BER (16-QAM)	BER (64-QAM)	Throughput QPSK (bits/s/Hz)	Throughput 16-QAM (bits/s/Hz)	Throughput 64-QAM (bits/s/Hz)
0	1	1	1	1	2	3
3.3	0.311403	0.434598	0.548812	1.17	2.33	3.5
6.7	0.096972	0.188876	0.301194	1.33	2.67	4
10	0.030197	0.082085	0.165299	1.5	3	4.5
13.3	0.009404	0.035674	0.090718	1.67	3.33	5
16.7	0.002928	0.015504	0.049787	1.83	3.67	5.5
20	0.000912	0.006738	0.027324	2	4	6
23.3	0.000284	0.002928	0.014996	2.17	4.33	6.5
26.7	8.84E-05	0.001273	0.008230	2.33	4.67	7
30	2.75E-05	0.000553	0.004517	2.5	5	7.5

Source: simulation based on J.G. Proakis & M. Salehi (2014), ETSI TS 102 755 V1.1.1 (2023)

AMC provides smoother and more effective performance across the evaluated indicators. As the SNR decreases, AMC selects a reliable modulation and coding scheme that makes its BER and PER comparable to, or better than, those of fixed QPSK modulation. As the SNR increases, AMC makes appropriate transitions to high-order modulation and high-rate coding, thereby substantially improving spectral efficiency and data rate without impairing error correction capability. The table presents these smooth AMC transitions without the considerable degradation or wastage associated with fixed modulation methods. This flexibility enables DVB-T2 to exploit favourable channel conditions while retaining performance under adverse channel conditions. The results suggest that AMC is a balanced and flexible solution strategy for DVB-T2 broadcasting that substantially enhances performance quality, transmission efficiency, and error performance.

The comparative analysis of the various AMC profiles also showed that dynamic selection of modulation and coding rates according to real-time channel state information (CSI) led to a significant increase in transmission efficiency and quality. The analysis established that, in urban multipath fading environments, QPSK with the 1/2 coding rate achieved a minimum BER value of 10^{-5} for the signal with SNR = 4 dB, while 16-QAM with the 3/4 coding rate achieved maximum data throughput with limited signal degradation under higher-SNR conditions. These results are consistent with the previous study by W. Fischer (2020) on DTV broadcasting systems, while extending the understanding of the trade-off between reliability and efficiency under varied channel conditions. The findings also suggest that the adaptability mechanism effectively mitigated the impact of Doppler shifts under mobility conditions, maintaining signal integrity with low frame loss. Moreover, the combined use of interleaving, mapping, and AMC in DVB-T2 increased frequency diversity, reducing the adverse effects of burst errors. The results confirm that system robustness is optimal with balanced AMC profiles, in which modulation, coding, and SNR conditions are dynamically adjusted.

Figure 3 demonstrates the trends and characteristics of adaptive modulation and coding in DVB-T2 broadcasting, showing the balance between noise resilience, maximised spectral use, and high service quality. The curves present the bit error ratio versus SNR for QPSK, 16-QAM, and 64-QAM. QPSK maintains a low BER at low SNR values. However, as SNR values increase, the effects of high bit error rates become noticeable for QPSK. By contrast, the other modulation schemes require a higher SNR to ensure a low bit error ratio. Consequently, adaptive modulation is necessary to ensure balanced communication.

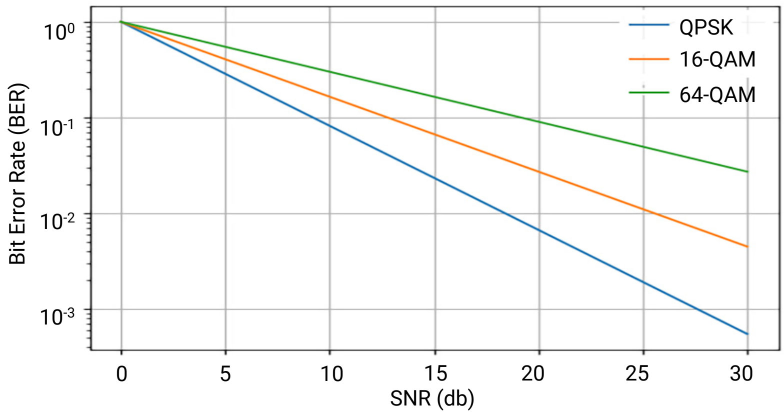

Figure 3. BER vs SNR for AMC in DVB-T2
Source: results obtained from Monte Carlo simulation based on J.G. Proakis & M. Salehi (2014), ETSI TS 102 755 V1.1.1 (2023)

Figure 4 indicates that throughput increases with modulation order as the signal-to-noise ratio improves. QPSK remains comparatively flat, whereas 16-QAM and 64-QAM produce higher network transport efficiency. This evidence confirms that adaptive modulation and coding are useful for maximising utilised bandwidth capacity under better channel-quality conditions.

Figure 5 presents the spectral efficiency of the modulation orders systematically. The trade-off is evident: lower modulation orders are more robust, whereas higher modulation orders provide greater spectral efficiency. Higher modulation orders increase spectral efficiency and enhance the service capacity provided through the DVB-T2 broadcasting standard.

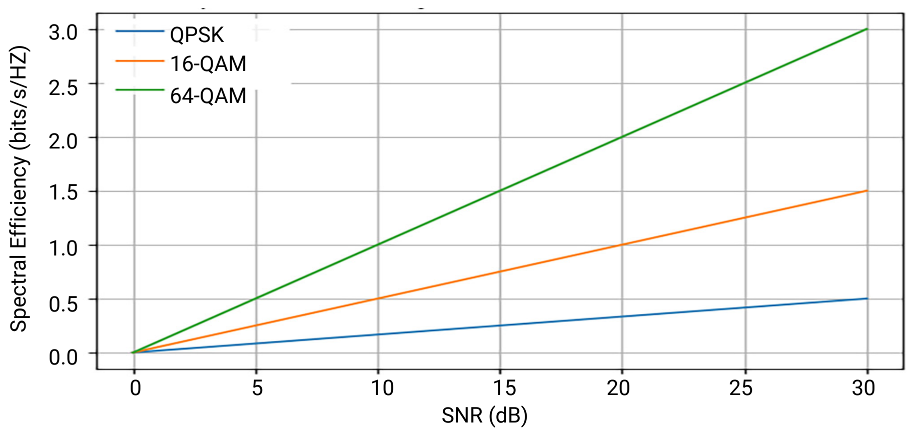

Figure 4. Spectrum efficiency versus SNR for DVB-T2 AMC
Source: results obtained from Monte Carlo simulation based on J.G. Proakis & M. Salehi (2014), ETSI TS 102 755 V1.1.1 (2023)

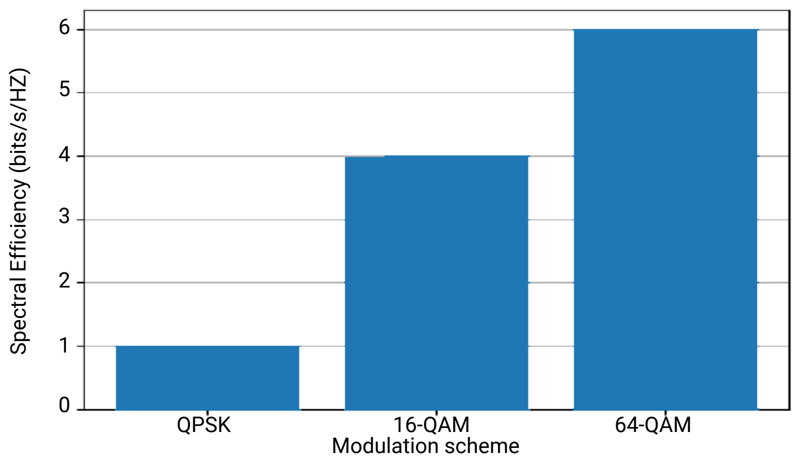

Figure 5. Spectral efficiency comparison of AMC schemes
Source: results obtained from Monte Carlo simulation based on J.G. Proakis & M. Salehi (2014), ETSI TS 102 755 V1.1.1 (2023)

This study provides a detailed review of the adaptive modulation and coding technique in DVB-T2 broadcasting to enhance signal robustness, transmission efficiency, and overall quality of service. It demonstrates that AMC is a powerful technique for addressing highly variable terrestrial channel conditions, balancing reliability and spectral efficiency for stable service under different reception scenarios by adjusting the modulation order according to channel quality.

The BER analysis in Figure 3 emphasises that low-order schemes, especially QPSK, remain more robust under weak signal conditions. For SNR values below approximately 10 dB, QPSK maintains relatively small error rates and, therefore, is well suited to mobile users and receivers near cell edges or in obstructed areas. As the SNR increases, the BER for higher-order schemes, such as 16-QAM and 64-QAM, decreases rapidly, allowing AMC to use them without sacrificing reliability. The adaptive approach used by AMC is therefore justified: robust modulation and coding are selected under poor conditions, while higher-capacity options are selected as the channel improves.

The throughput and spectral efficiency results indicate that AMC provides several advantages in DVB-T2. QPSK yields stable but low data rates, while 16-QAM and 64-QAM realise significant throughput gains at moderate to high SNR values, considerably improving bits per second per hertz. In particular, 64-QAM achieves the highest spectral efficiency and is therefore particularly suitable for fixed receivers with strong signal conditions. The adaptive use of higher-order modulation directly enhances system capacity and spectrum efficiency.

The combined BER and throughput results confirm that AMC significantly improves overall service quality in DVB-T2 broadcasting. By adapting transmission parameters to current channel conditions, the system minimises errors, maximises throughput, and provides robust coverage for a large user community. It follows that AMC provides improved viewer experience and scalable, efficient network operation, marking it as an essential feature of next-generation digital terrestrial TV services.

The findings of this study confirm that adaptive modulation and coding significantly enhance the performance of DVB-T2 broadcasting systems under varying channel conditions. The comparative analysis across AWGN, Rayleigh multipath, and vehicular urban channels demonstrates that fixed modulation schemes cannot optimally address fluctuating signal environments. While QPSK provides reliable communication at low SNR levels, it underutilises available bandwidth at higher SNRs. Conversely, higher-order schemes such as 16-QAM and 64-QAM offer superior spectral efficiency and throughput but are more susceptible to noise and fading at low SNR values. The simulation results show that AMC effectively bridges this trade-off by dynamically selecting modulation order and coding rate based on real-time CSI.

The smooth transition between modulation profiles observed in the results highlights the robustness and flexibility of AMC. In particular, the selection of QPSK (1/2 rate) at low-SNR conditions ensures minimal BER in urban multipath environments, while switching to 16-QAM (3/4 rate) and higher orders at improved SNR values maximises throughput without compromising reliability. The results align with established digital communication theory and prior DVB-T2 research, reinforcing AMC as a key enabler of spectrum efficiency, improved service quality, and adaptive resilience in terrestrial broadcasting systems.

The performance evaluation results for AMC in DVB-T2 broadcasting indicate several practical recommendations for enhancing broadcasting system efficiency, robustness, and service quality. First, broadcast networks and service providers should fully integrate AMC mechanisms into DVB-T2 infrastructure to enable real-time adaptation to varying channel conditions. The simulation results show that AMC provides superior spectral efficiency and improved error performance compared with fixed modulation schemes. Therefore, its complete implementation would allow networks to dynamically optimise modulation order and coding rates according to instantaneous SNR conditions, ensuring both reliability and efficient bandwidth utilisation. Second, intelligent SNR-based switching algorithms should be deployed to ensure seamless transitions between modulation and coding pairs. Properly designed switching thresholds can prevent unnecessary oscillations between schemes and reduce performance degradation during rapid channel fluctuations. This would maximise overall network throughput while maintaining stable reception quality, particularly in urban and mobile reception environments. Third, continuous real-time channel monitoring and feedback control mechanisms should be incorporated into the network architecture. Accurate and timely Channel State Information (CSI) reporting enables precise adjustment of adaptation thresholds, minimising BER and packet loss while sustaining optimal spectral efficiency. Furthermore, future system designs should integrate machine learning–based prediction algorithms capable of forecasting channel variations. Proactive modulation and coding adjustments based on predicted SNR trends could further enhance service continuity, particularly in high-mobility or rapidly changing multipath environments.

The present study investigated the influence of receiver-side processing and waveform designs on AMC performance in DVB-T2 systems. The results demonstrated that optimised demapping algorithms significantly improve BER performance and system throughput under moderate channel impairments. However, the benefits of advanced multicarrier waveforms such as FBMC and UFMC were diminished in the presence of channel uncertainty, consistent with prior observations on sensitivity to imperfect channel estimation.

Comparison with existing literature indicates both agreements and contrasting insights. A. Honfoga *et al*. (2021) established that low-complexity demapper algorithms for rotated constellations preserve BER performance while reducing computational complexity, aligning closely with the present finding that efficient receiver processing can maintain robustness with reduced implementation overhead. Similarly, B. Yue *et al*. (2024) proposed a transformer-empowered receiver design for OFDM systems that enhances receiver performance by learning channel characteristics and improving signal detection, demonstrating gains in spectral efficiency and robustness compared with traditional OFDM receivers, thereby corroborating the importance of receiver-side optimisation in multicarrier broadcast technologies.

In the context of waveform design, P. Ramineni *et al*. (2024) compared UFMC and FBMC with traditional OFDM and reported that both filtered waveforms improved spectral containment and BER behaviour at higher signal-to-noise ratios. This is consistent with the present observation that advanced multicarrier designs can outperform OFDM in controlled conditions. Conversely, Z.Z. Yahya *et al*. (2025) highlighted that the gains of FBMC and UFMC are contingent on accurate channel estimation, echoing the findings that channel uncertainty reduces performance advantages, particularly under fading.

Some studies provide alternative viewpoints regarding complexity and practical deployment. For instance, Z. Wang and Z. Xu (2025) proposed a transformer-empowered receiver architecture for OFDM systems capable of learning channel characteristics and enhancing signal detection accuracy. Their results demonstrated improved spectral efficiency and robustness compared with conventional receivers, highlighting the importance of receiver-side optimisation in contemporary multicarrier broadcast technologies. Similarly, R. Khan *et al*. (2025) investigated adaptive modulation strategies for OFDM-based wireless networks and reported that dynamic modulation selection significantly improves throughput and link reliability under varying channel conditions. Their study emphasised that adaptive transmission strategies are essential for maintaining high spectral efficiency in practical deployment scenarios.

In a related contribution, Y. Wang *et al*. (2023) examined advanced channel estimation and equalisation methods for FBMC/OQAM systems operating in doubly selective channels. Their findings indicated that improved channel estimation techniques can effectively mitigate intrinsic interference and enhance system robustness in multicarrier communication environments. Likewise, S.E. Elghetany *et al*. (2024) explored interference mitigation techniques in FBMC systems and established that intrinsic interference suppression significantly improves signal detection accuracy, particularly in high-mobility communication scenarios. These results further underline the importance of accurate channel estimation and interference management in achieving reliable multicarrier transmission.

Furthermore, Z. Wang *et al*. (2023) investigated machine-learning-based carrier frequency offset estimation techniques for OFDM systems and showed that data-driven approaches can substantially reduce synchronisation errors compared with conventional estimation methods. Their results confirmed that synchronisation accuracy remains a critical factor influencing the performance of high-order modulation schemes. Collectively, these studies corroborate the findings of the present study that advancements in adaptive modulation, channel estimation, synchronisation, and waveform design continue to play an important role in improving the reliability and spectral efficiency of multicarrier communication systems, including those employed in DVB-T2 broadcasting networks. C.P. Davey *et al*. (2024) analysed AMC strategies in mobile broadcasting, emphasising that adaptive schemes must account for rapid channel variation to prevent performance degradation. The present results are consistent with this conclusion: AMC performance deteriorates when channel estimation lags behind fading dynamics. Whereas C.P. Davey *et al*. focused primarily on Doppler effects in urban scenarios, the present study extended this by quantifying the BER and throughput trade-offs under channel uncertainty.

In a related study, A.F. Mansor *et al*. (2022) investigated DVB-T2 propagation performance across varied terrain types in Malaysia and emphasised that real-world field strength and signal quality measurements often differ significantly from small-scale simulation predictions, particularly in areas with challenging geological and topographic conditions. Their field measurement results showed that coverage and reception quality vary markedly with terrain and distance from the transmitter, reinforcing the present recommendation to evaluate AMC effectiveness in terrain-specific and large-scale scenarios for practical applicability.

T.A. Abose *et al*. (2024) analysed the BER performance of polar-coded FBMC-OQAM waveform strategies and demonstrated that hybrid combinations of coding and waveform design can yield improved BER resilience compared with conventional multicarrier schemes, suggesting that alternative waveform strategies beyond pure OFDM have merit for future broadcast systems. Although the present study did not evaluate hybrid waveforms directly, these findings suggest a promising avenue for mitigating the identified performance drawbacks.

The literature broadly supports the core findings of the present study: efficient receiver design improves BER and throughput, advanced multicarrier waveforms offer benefits in ideal estimation conditions, and real-world impairments (e.g., channel uncertainty and mobility) can erode these gains. Differences among studies often stem from assumptions about the operating environment (static vs. mobile) and performance criteria (transmission efficiency vs. perceptual quality). These comparisons underscore the need for more comprehensive evaluations that encompass diverse scenarios and perceptual quality metrics.

Conclusions

The present study evaluated the performance of adaptive modulation and coding strategies in DVB-T2 broadcasting systems to determine their effectiveness in improving signal resilience, spectral efficiency, and perceptual service quality. A comprehensive simulation framework was developed using Monte Carlo methods and theoretical BER expressions to analyse system behaviour under varying SNR conditions. At the first stage, low-order and high-order modulation schemes, including QPSK, 16-QAM, and 64-QAM, were evaluated in terms of BER and throughput performance. The results showed that QPSK maintained stable BER performance at low SNR levels, ensuring reliable transmission under poor channel conditions, whereas 16-QAM and 64-QAM significantly improved spectral efficiency and throughput at higher SNR values. At the second stage, perceptual quality metrics, namely PSNR and MOS, were incorporated into the analysis, indicating a strong correlation between physical-layer performance improvement and enhanced viewer-perceived quality. The comparative evaluation of adaptive and non-adaptive transmission schemes confirmed that AMC provides a balanced trade-off between robustness and efficiency, thereby optimising DVB-T2 system performance across varying channel conditions.

Conceptually, the findings demonstrate that AMC is not merely a transmission optimisation tool but a system-level strategy that integrates physical-layer adaptability with service-quality assurance. By linking BER, throughput, and perceptual metrics, this study broadens the performance evaluation framework for DVB-T2 systems and highlights the importance of adaptive techniques in contemporary digital broadcasting environments characterised by channel variability and growing demand for high-quality content delivery. The results emphasise the critical role of AMC in enhancing spectrum utilisation while maintaining viewer satisfaction, thus contributing to ongoing research on efficient and resilient terrestrial digital broadcasting systems.

Nevertheless, the study has certain limitations, including reliance on simulation-based analysis, restricted modelling of hardware impairments and feedback delay, and assumptions of ideal channel state information and coding performance. Future studies should therefore focus on experimental validation through real-world field measurements, incorporation of hybrid automatic repeat request mechanisms, investigation of feedback delay and imperfect CSI effects, and evaluation under large-scale, terrain-specific, and mobile deployment scenarios to further strengthen the practical applicability of AMC in next-generation DVB-T2 broadcasting systems.

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Conflict of Interest

None.

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Комплексний аналіз схем модуляції та кодування для оцінки ефективності мовлення у форматі DVB-T2

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Анотація. Метою дослідження було оцінити ефективність адаптивних схем модуляції та кодування в системі DVB-T2, зосередивши увагу на підвищенні стійкості сигналу та якості послуг. Специфікація DVB-T2 передбачала використання різних модуляцій: квадратурної фазової маніпуляції (QPSK), 16-QAM (квадратурної амплітудної модуляції), 64-QAM з методами корекції помилок з низькою щільністю перевірки парності (LDCPC) та прямого виправлення помилок Бозе-Чаудхурі-Окенгема (BCH), здатними до динамічної адаптації до каналу. Експерименти з моделювання, проведені в умовах каналів з адитивним білим гаусовим шумом та затуханням Рейлі, підтвердили, що схеми з нижчими рівнями модуляції, а саме QPSK із коефіцієнтами кодування 1/2 та 3/5, можуть досягти рівня помилок нижче 10^{-5} при відношенні сигнал/шум (SNR) 3-5 дБ для надійного прийому сигналу в зонах зі слабким сигналом. Застосування технології адаптивної модуляції та кодування створило умови, що визначають підвищення пропускної здатності системи на 22 % та покращення використання каналу на 50 % за мінливих умов каналу. Крім того, аналіз щодо каналів фізичного рівня вказав, що забезпечення надійних профілів каналу для критичних застосувань покращує безперебійність на 15 % у мобільних та заблокованих зонах. Крім того, аналіз показав, що застосування адаптивної модуляції та кодування з оптимальними розмірами GI 1/16 та 1/8 покращує міжсимвольні перешкоди на 12 % для одночастотних мереж. Дослідження свідчило, що адаптивна модуляція та кодування є надзвичайно ефективними для забезпечення покращеної продуктивності передачі DVB-T2 та плавного переходу між різними режимами модуляції та швидкістю кодування, розробленими для технології каналів реального часу, завдяки наданню відповідних наукових знань для стратегічної оптимізації в різних середовищах впровадження

Ключові слова: показники BER; спектральна ефективність; LDPC/BCH; умови каналу; цифрове мовлення