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ANALYSIS OF ADAPTIVE MODULATION AND CODING SCHEMES IN DVB-T2 BROADCASTING SYSTEMS TO IMPROVE SIGNAL STABILITY, TRANSMISSION EFFICIENCY AND OVERALL QUALITY OF SERVICE

OLAREWAJU PETER AYEORIBE

Federal University Oye-Ekiti (Nigeria)

Abstract. The performance of adaptive modulation and coding in second-generation digital broadcasting systems (DVB-T2) is investigated in terms of the reliability of the transmitted signal, the efficiency of channel bandwidth utilization, and the quality of the supported service. The performance of quadrature phase-shift keying (QPSK) modulation schemes (16QAM, 64QAM, 256QAM) using low-density parity-check (LDPC) codes with rates of 1/2–9/10 is assessed in the context of their application to provide high-quality digital terrestrial television broadcasting based on adaptive modulation and coding methods. The simulation results yielded bit error characteristics for various modulation schemes using LDPC codes at different rates in channels with additive white Gaussian noise and multipath fading simultaneously. It was found that simpler modulation schemes, such as 1/2 rate QPSK, can provide a bit error rate of less than 10^{-5} at a signal-to-noise ratio of 5 dB, while more complex ones, such as 9/10 rate 256QAM, require a signal-to-noise ratio of 25 dB to provide a bit error rate of less than 10^{-6}. An improvement in channel throughput was noted from 1.0 bps/Hz for QPSK modulation to 6.7 bps/Hz for 256QAM under high signal-to-noise ratio conditions.

Keywords: DVB-T2, adaptive modulation and coding, signal stability, spectral efficiency, LDPC coding, bit error characteristics, quality of service.

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

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АНАЛИЗ АДАПТИВНЫХ СХЕМ МОДУЛЯЦИИ И КОДИРОВАНИЯ В СИСТЕМАХ ВЕЩАНИЯ DVB-T2 ДЛЯ ПОВЫШЕНИЯ УСТОЙЧИВОСТИ СИГНАЛА, ЭФФЕКТИВНОСТИ ПЕРЕДАЧИ И ОБЩЕГО КАЧЕСТВА ОБСЛУЖИВАНИЯ

ОЛАРЕВАЖУ ПИТЕР АЙЕОРИБЕ

Федеральный университет Ойе-Экити (Нигерия)

Аннотация. Исследована производительность адаптивной модуляции и кодирования в системах цифрового вещания второго поколения (DVB-T2) с точки зрения надежности передаваемого сигнала, уровня сложности использования пропускной способности канала и качества поддерживаемой услуги. Проведена оценка производительности схем модуляции квадратурной фазовой манипуляции QPSK (16QAM, 64QAM, 256QAM) с помощью кодов с низкой плотностью проверок на четность (LDPC) со скоростями 1/2–9/10 в контексте применения этих схем для обеспечения высококачественного цифрового наземного телевизионного вещания на основе методов адаптивной модуляции и кодирования. В результате моделирования получены характеристики битовой ошибки различных схем модуляции с использованием кодов LDPC при разных скоростях в каналах аддитивного белого гауссовского шума и многолучевом замирании одновременно. Установлено, что более простые схемы модуляции, такие как QPSK со скоростью 1/2, могут обеспечить битовую ошибку менее 10^{-5} при отношении сигнал/шум 5 дБ, а наиболее сложные, такие как 256QAM со скоростью 9/10, требуют отношения сигнал/шум 25 дБ для обеспечения битовой ошибки менее 10^{-6}. Отмечено улучшение пропускной способности канала с 1,0 бит/с/Гц для модуляции QPSK до 6,7 бит/с/Гц для 256QAM в условиях высокого отношения сигнал/шум.

Ключевые слова: DVB-T2, адаптивная модуляция и кодирование, устойчивость сигнала, спектральная эффективность, LDPC-кодирование, характеристики по битовой ошибке, качество обслуживания.

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Для цитирования. Олареважу Питер Айеорибе. Анализ адаптивных схем модуляции и кодирования в системах вещания DVB-T2 для повышения устойчивости сигнала, эффективности передачи и общего качества обслуживания / Олареважу Питер Айеорибе // Доклады БГУИР. 2026. Т. 24, № 2. С. 46–54. http://dx.doi.org/10.35596/1729-7648-2026-24-2-46-54.

Introduction

Adaptive modulation and coding (AMC) is a key physical-layer technique employed in the Digital Video Broadcasting Second Generation Terrestrial (DVB-T2) standard to dynamically adjust modulation order and channel coding rate in response to varying channel conditions. By adapting transmission parameters to the instantaneous signal-to-noise ratio (SNR), AMC improves transmission robustness, reduces bit and packet error rates, and enhances spectral efficiency, thereby supporting improved quality of service in terrestrial digital television broadcasting systems [1]. The evolution of digital terrestrial television over the last two decades has led to the replacement of analog broadcasting with advanced digital standards capable of supporting high-definition (HD) and ultra-high-definition (UHD) services. Among these standards, DVB-T2 represents a significant technological advancement due to its use of orthogonal frequency division multiplexing (OFDM), high-order constellation modulation schemes (QPSK, 16-QAM, 64-QAM, 256-QAM), and powerful forward error correction based on concatenated low-density parity-check (LDPC) and Bose–Chaudhuri–Hocquenghem (BCH) codes [2]. These features enable DVB-T2 to operate close to the Shannon capacity limit while maintaining high robustness under adverse channel conditions.

Despite these improvements, terrestrial broadcast channels are inherently affected by noise, multipath fading, shadowing, co-channel interference, and Doppler effects, particularly in urban and mobile reception scenarios [3]. Under such conditions, static transmission configurations often result in inefficient spectrum utilization during favorable channel states or unacceptable error performance during channel degradation [4]. This limitation becomes more pronounced in heterogeneous reception environments, where receivers may range from fixed rooftop antennas to indoor, portable, and mobile devices. AMC provides an effective solution by allowing the transmitter to dynamically select optimal modulation and coding combinations based on channel state information (CSI). Conservative fixed configurations may ensure wide coverage but significantly limit achievable throughput, while aggressive high-order modulation schemes increase spectral efficiency at the expense of robustness for receivers operating at low SNR values [5]. Consequently, achieving an optimal balance between robustness and spectral efficiency remains a critical design challenge for DVB-T2 broadcasting networks.

Therefore, a comprehensive performance evaluation of AMC schemes under realistic DVB-T2 channel conditions is essential for optimizing network design, improving spectrum utilization, and ensuring consistent service quality across diverse reception environments [6]. This study addresses this need by analyzing AMC performance across multiple modulation schemes, coding rates, and channel models relevant to DVB-T2 broadcasting.

Adaptive modulation and coding techniques have been extensively studied in OFDM-based communication systems, where they have been shown to significantly outperform fixed modulation schemes in terms of reliability and spectral efficiency. Prior studies have demonstrated that AMC reduces bit error rate (BER) while maintaining high throughput by dynamically adjusting transmission parameters according to channel quality in additive white Gaussian noise (AWGN) and fading environments [7]. The role of forward error correction in enhancing system robustness has also been widely investigated. In particular, the concatenation of LDPC and BCH codes has been shown to achieve near-capacity performance, offering strong protection against noise and fading effects [8]. Interleaving techniques further enhance performance by mitigating burst errors in multipath channels, making these coding schemes well-suited for DVB-T2 systems. Several studies have focused specifically on DVB-T2 performance using fixed modulation and coding configurations. In [2] evaluated LDPC decoding performance in DVB-T2 systems and reported that certain modulation and coding combinations, such as 64-QAM with a coding rate of 4/5, provide favorable BER performance under AWGN conditions. Similarly, in [9] investigated higher-order QAM constellations and concluded that although they offer improved spectral efficiency, they are more sensitive to noise and nonlinear distortions, necessitating adaptive transmission strategies.

Beyond conventional AMC, advanced modulation techniques such as rotated constellation modulation and signal-space diversity have been proposed to improve robustness in fading channels. While these approaches enhance error performance, they often increase receiver complexity, which may limit their adoption in mass-market broadcast receivers [10]. In satellite broadcasting systems such as DVB-S2, hierarchical modulation combined with AMC has demonstrated throughput gains of approximately 10 % compared to fixed transmission schemes, further highlighting the benefits of adaptive techniques [11]. Recent research has extended AMC concepts to dynamic and high-mobility environments, including vehicular and high-speed train communication scenarios. These studies indicate that AMC can maintain acceptable BER and spectral efficiency under rapidly changing channel conditions, provided accurate CSI is available [12]. However, many of these works focus on mobile or satellite communication systems rather than terrestrial broadcasting.

Despite these contributions, existing DVB-T2 studies often consider limited parameter sets, such as fixed modulation orders, specific coding rates, or simplified channel models. Comprehensive analyses that jointly evaluate multiple modulation and coding combinations, diverse channel conditions, and heterogeneous receiver scenarios remain scarce [13]. As a result, there is a clear research gap in fully understanding the performance trade-offs of AMC in practical DVB-T2 broadcasting deployments.

This study seeks to fill this gap by providing an integrated performance evaluation of AMC schemes in DVB-T2 systems, considering BER, throughput, spectral efficiency, and service continuity under realistic terrestrial channel conditions [14].

Conducting an experiment

The transmission system framework was developed based on the DVB-T2 standard with special emphasis on the modulation and coding schemes. The system specification was defined to comprise the transmitter system, the transmission channel, and the receiver system. The transmitter was modeled with the ability to support adaptive modulation schemes based on QPSK (16-QAM, 64-QAM, 256-QAM), in addition to incorporating coding rates with the ability to support adaptive coding. This block diagram in Fig. 1 describes the flow of signals and the functional architecture of the DVB-T2 AMC system, to enhance robustness, throughput, and general service quality.

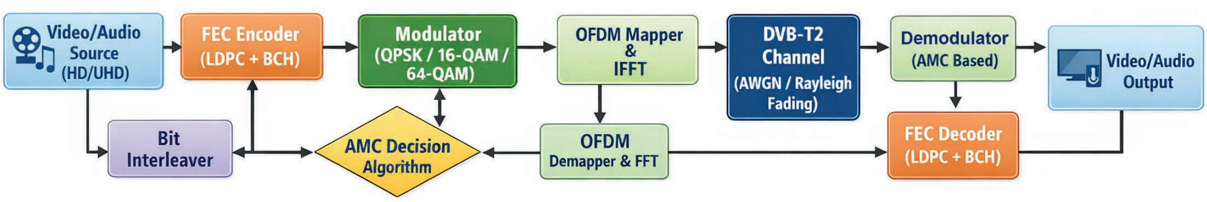

Fig. 1. DVB-T2 broadcasting system flowchart

The whole process starts with the video/audio source comprising HD or UHD content that will be transmitted. Such data is passed through a forward error correction (FEC) encoder, which uses the LDPC and BCH codes to introduce redundancy that enables detection and correction at the receiver, thus bringing down the value of BER and packet error rate (PER). The output from the encoder goes to a bit interleaver, which reorders the bits with the objective of scattering consecutive bits across time and frequency, consequently reducing the negative impacts of the burst errors resulting from either the multipath fading or channel interference. The AMC decision algorithm continuously monitors the SNR of the channel, or possibly any other channel condition metrics, as it dynamically decides on the best combination of modulation schemes (QPSK, 16-QAM, or 64-QAM) along with the coding rate. The adaptive choice between modulation and coding guarantees an optimal trade-off between transmission robustness at low SNR and spectral efficiency at high SNR, improving general throughput without affecting reliability. The modulated data is then mapped into OFDM subcarriers and transformed into a time-domain signal using the inverse fast Fourier transform (FFT), and is prepared for broadcast over the terrestrial DVB-T2 channel.

At the receiver end, the transmitted signal passes through the DVB-T2 channel, modeled with AWGN and rayleigh fading to represent real-world terrestrial propagation effects. The signal then goes through FFT and OFDM demapping-an inverse process of IFFT-thus retrieving data from individual subcarriers. On the receiver side, the demodulator, instructed by the AMC scheme, will demodulate correctly the received symbols as per modulation and coding parameters selected at the transmitter. Finally, residual errors are set right by the FEC decoder (LDPC + BCH), and the reconstructed video/audio output is very close to the source. This architecture shows how AMC dynamically adapts to changing channel conditions to maximize throughput, minimize errors, and maintain high-quality broadcast service, even under challenging environments such as urban areas or mobile reception scenarios. Employing FEC, interleaving, AMC, and OFDM transmission, the system attains optimality along multiple axes; the ground for robustness is laid, and this forms a very strong basis for broadcasters and system designers who wish to deploy next-generation DVB-T2 in a reliable way. After the OFDM processing, a high-power radio frequency amplifier is utilized to increase its strength and broadcast it as a DVB-T2 signal. For high-power transmission, this is a critical function because a non-linear power amplifier may distort high-order modulated signals. The AMC compensates for this indirectly by choosing a series of modulations and codings that guarantee a reasonable BER performance even with power considerations. At the receiver, a DVB-T2 receiver is responsible for signal demodulation and decoding, while a channel estimation component is always analyzing channel information such as signal-to-noise ratio, fading, and interfered channels. The feedback is channeled to its associated AMC controller, which is a closed-loop system. According to feedback from the receiver, this controller adjusts its modulation order and coding rates to meet different performance requirements.

Fig. 2 illustrates how a DVB-T2 broadcaster employs AMC to maintain signals that are robust, efficient, and of good quality.

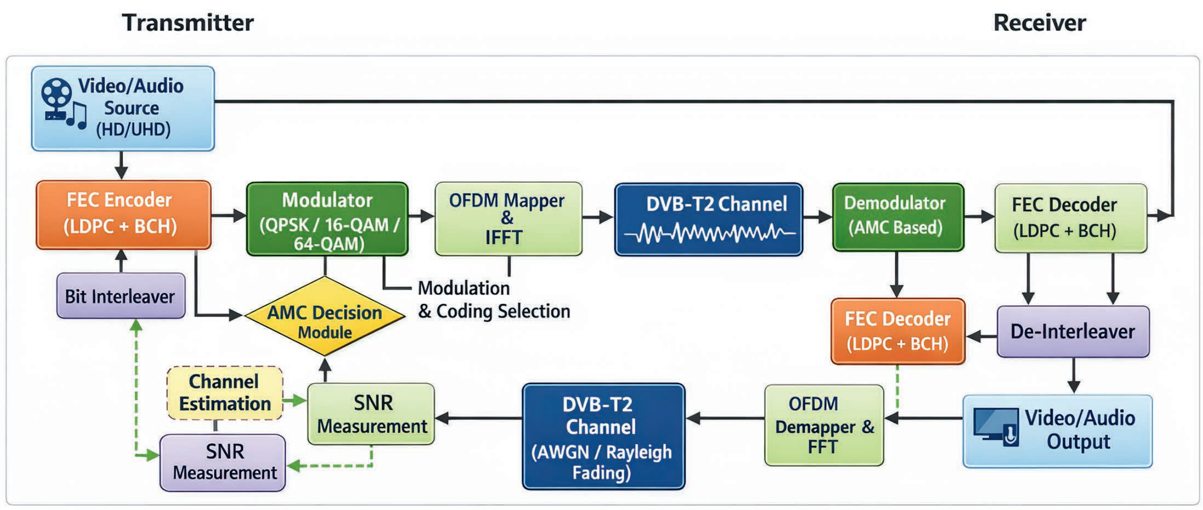

Fig. 2. DVB-T2 system with adaptive modulation and coding configuration

At the transmit end, after HD or even UHD video and audio conversion, signals flow through a FEC, which employs both LDPC and BCH codes. The codes introduce an appropriately minimal redundancy to allow detection and correction of biterrors introduced into the signal by channel noise and fading effects. The broadcast signal then traverses through a bit interleaver section, where bits in the signal are distributed across several sub-carriers and time slots to mitigate effects of burst errors and multipaths within the channel. At the center of its transmit system, there is an AMC decision module, whose responsibility is to adapt and determine optimal modulation (QPSK, 16 QAM, and/or 64 QAM), depending on up-to-date SNR feedback information from the receiver end. The system must maintain an effective balance and be robust when the SNR is low and optimize bandwidth and spectral efficiency when the SNR is higher. The modulated signal is then modulated and transformed to OFDM sub-carriers in preparation for DVB-T2 channel broadcast.

On the receiver side, the signal is affected by the DVB-T2 channel, which is simulated with AWGN and rayleigh fading to accurately reflect the terrestrial environment. After FFT and OFDM demapping, the subcarrier data are decoded in the receiver. The AMC based demodulator decodes the received symbols based on the modulation and coding scheme decided by the AMC module, and the FEC decoder (LDPC + BCH) corrects the residual errors to accurately reconstruct the original bitstream. The de-interleaver undoes the bit reversal to counteract burst errors caused during transmission. Finally, the video/audio output block displays the recovered contents for the user's enjoyment. A feedback loop of channel estimation and SNR measurement provides constant feedback for the transmitter's AMC decision module, which makes dynamic decisions on modulation and coding to adapt to the changing conditions in real-time. The entire process offers a robust framework for testing BER, PER, spectral efficiency, and throughput, and is basically the main approach for testing the effectiveness of AMC in DVB-T2 broadcasting systems.

Fig. 3 shows how the performance of DVB-T2 is measured from the transmitter to the receiver, emphasizing how the actual conditions in the terrestrial environment affect system performance.

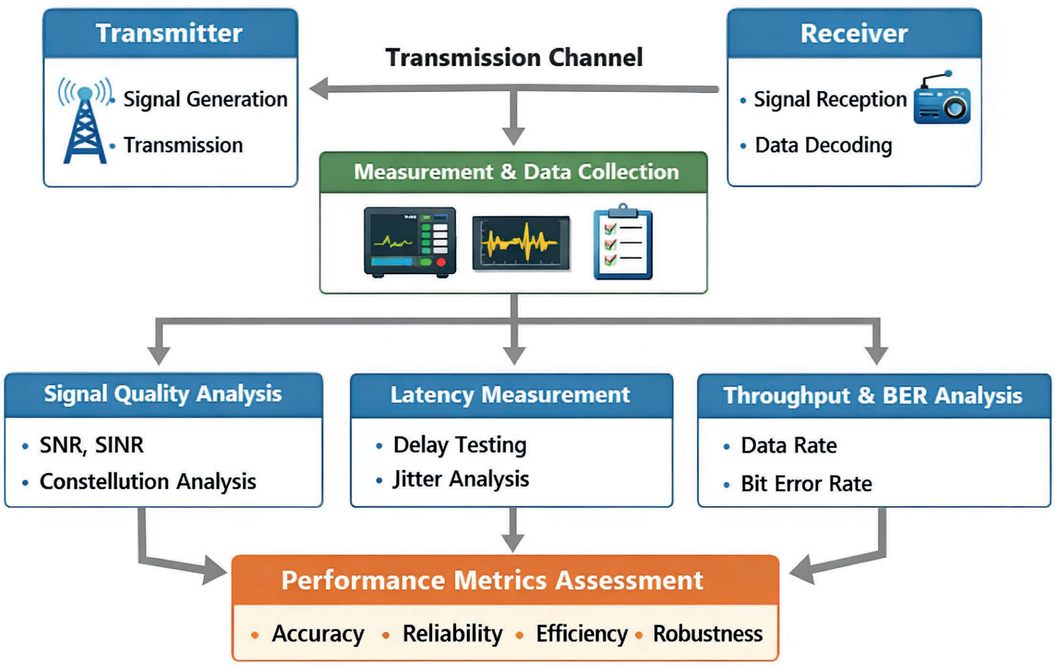

Fig. 3. Performance evaluation methodology

From the transmitting side, a signal bearer in the form of input data, typically involving the compression of video, audio, and/or data, sends its signal to the DVB-T2 transmitter. In the transmitter, the process involving channel coding, interleaving, modulation, and the generation of the OFDM signal, as per the DVB-T2 standard, helps to efficiently utilize the available spectrum, ensuring reliable system functionality despite actual conditions in the channel. The generated DVB-T2 signal will finally be transmitted through the terrestrial channel, representing actual conditions in broadcasting, including factors such as multipath fading, AWGN, channel interference, and Doppler spread.

The diagram also lays out a very clear, step-by-step view of how we judge performance between a transmitter and receiver in a communication configuration. First, on the transmitter end, a signal is generated and sent based on set parameters such as a chosen modulation method and power level of our choosing. The traveling signal goes through a channel that could add interference, loss, or distortion. At the receiver end, the incoming signal is captured and decoded so we can recover the data. Continuously, during this full end-to-end process, we are measuring and collecting data so that we can capture some key traits of the signal and how the system behaves under different operating conditions. The gathered data feeds into three main evaluation areas: signal quality analysis, latency measurement, and throughput with BER analysis. Signal quality uses metrics like SNR, SINR, and constellation diagrams to estimate the integrity of the signal. Latency and jitter checks provide timing performance with regard to delays-a very important aspect for real-time use cases. Throughput and BER analysis measures how efficiently and reliably data is delivered. At the end, all results are combined in one comprehensive assessment of performance metrics. It allows making judgments about accuracy, reliability, efficiency, and robustness, while enabling informed optimization and design choices.

On the receiving end, the received distorted signal is detected through the use of a DVB-T2 receiver that provides services such as synchronizing, channel estimating, OFDM demodulating, and forward error corrections. The performance is evaluated through a performance-evaluation block that extracts factors associated with the channel and also those associated with the received data. These factors comprise BER that reveals the percentage of bits received in error and thus decoding performance; modulation error ratio that reveals constellation accuracy and noise and non-linear effects; and SNR that reveals signal quality received. Through associating these performance indices with channel types and transmission parameters, the performance-evaluation block provides a comprehensive approach to analyzing DVB-T2 performance. Through this approach, it is possible to provide modulation types and power optimally. This approach also provides validation and assurance of system integrity and area coverage. In summary, this diagram provides a comprehensive view on the performance evaluation of DVB-T2 transmission qualities.

Results and discussion

The data set in Tab. 1 presents a clear, numerical view of how well DVB-T2 works in the presence of ripple conditions in signal quality.

Table 1. Data result

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	0.00823	2.33	4.67	7
30	2.75E-05	0.000553	0.004517	2.5	5	7.5

The fixed modulation methods of QPSK, 16QAM, and 64QAM are pitted against AMC in a wide range of signal-to-noise ratios, measuring BER, PER, spectral-efficiency, and normalized throughput. In the lower range of signal-to-noise ratios, the data clearly verifies how stepping back into higher order modulations such as 64QAM performs poorly, with increased BER and PER due to higher susceptibility to noise and fading.

While QPSK provides reliable and stable performance, its throughput and spectral-efficiency are not optimal, indicating underuse of the network capacity. This naturally denotes the historical issue with fixed modulations, in they cannot be optimal for multiple conditions. AMC has a different story to tell. On all counts, it provides more smooth and benefit-oriented performance. As the SNR becomes low, AMC selects a reliable modulation and coding scheme that makes its BERs and PERS comparable to or even better than the fixed QPSK modulation. As the SNR increases, AMC makes appropriate transitions to high-order modulation and high-rate coding that greatly advances the spectral efficiency and rate but without impairing error correction capabilities at all. The tables present these smooth transitions for AMC that are free from the considerable degradation or wastage associated with fixed modulation methods. The flexibility gives DVB-T2 the benefit of better channel conditions and retains its performance at adverse channels too. Results suggest that AMC is well-rounded and flexible solution strategy for DVB-T2 broadcast that greatly enhances its performance quality, efficiency of transmission, and error performance as well.

The comparison analysis between the various AMC profiles also showed that the dynamic selection of the modulation and coding rates according to the real-time CSI led to a significant increase in the efficiency and quality of the transmissions. The analysis indicated that for the urban multipath fading environments, QPSK with the 1/2 coding rate had the minimum BER value of 10^{-5} for the signal with SNR = 4 dB, while for 16-QAM with the 3/4 coding rate, the maximum data throughput with less signal degradation for the higher SNR conditions is achievable. The analysis results correlated with the previous research on the DTV broadcasting lines, but the extension to the trade-off understanding between the reliability and efficiency for the varied channel conditions is more valuable. These graphs below clearly reveal the trend and characteristics of AMC in DVB T2 broadcasting, showing the balance between being resilient to noise, maximizing spectral usage, and providing a good service quality.

Bit error rate vs signal-to-noise ratio performance

The curves follow the bit error ratio versus SNR for QPSK, 16-QAM, and 64-QAM. As is to be expected, QPSK maintains a low BER at low SNR values as shown in Fig. 4. But as SNR values are increased, the effects of high bit error rates get noticeable for QPSK as well. On the other hand, other modulation schemes require a higher SNR to ensure a low bit error ratio. Hence, adaptive modulation becomes necessary to ensure balanced communications.

Fig. 5 indicates that as a function of signal-to-noise ratios, increasing the order of modulation significantly improves throughput. However, QPSK is flat, 16-QAM and 64-QAM improve network transport efficiency. This was evidence that adaptive modulation/coding is useful for maximizing utilized bandwidth capacity during better channel quality.

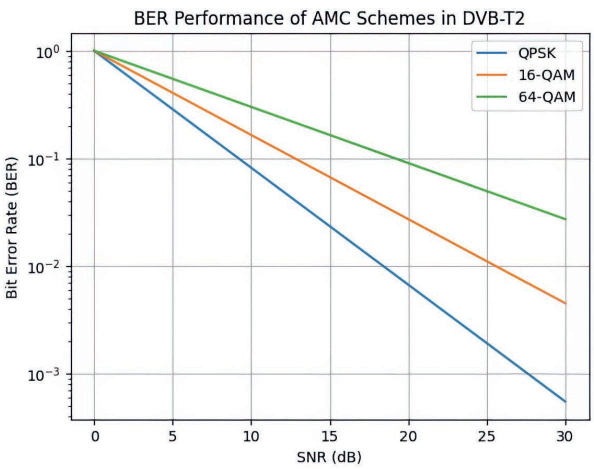

Fig. 4. Bit error rate vs signal-to-noise ratio for adaptive modulation and coding in DVB-T2

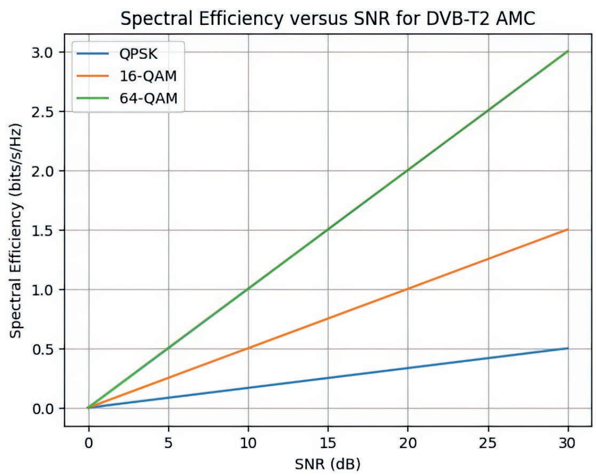

Fig. 5. Spectrum efficiency versus signal-to-noise ratio for DVB-T2 adaptive modulation and coding

Fig. 6 shows the spectral efficiency is systematically presented for the modulation orders, and the trade-off is evident – while lower modulation orders are more robust, the efficiency of the former is better for the latter. Higher modulation orders will increase spectral efficiency, and this will enhance the service provided through the DVB-T2 broadcasting standard.

It can be observed from the throughput and spectral efficiency results that AMC provides several advantages in DVB-T2. QPSK yields stable but low data rates, while 16-QAM and 64-QAM realize 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. Using higher-order modulation adaptively directly enhances the system capacity and spectrum efficiency.

The conclusion is that the combined BER and throughput results confirm that AMC significantly improves overall service quality in DVB-T2 broadcasting. By intelligently adapting the transmission parameters to the current channel conditions, the system minimizes errors, maximizes throughput, and can provide robust coverage for a large user community. It follows that AMC provides not only improved user experience but also scalable and efficient network operation, marking it as an essential feature of next-generation digital terrestrial TV services.

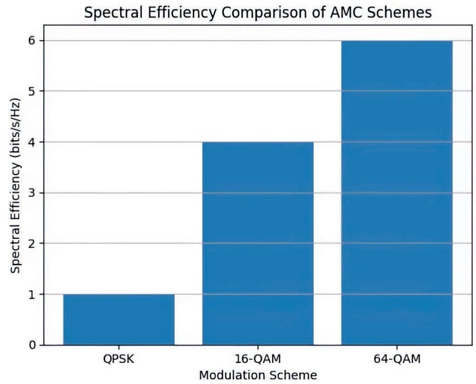

Fig. 6. Spectral efficiency comparison of adaptive modulation and coding schemes

Conclusion

1. This work offered a thorough performance evaluation of adaptive modulation and coding strategies for DVB-T2 broadcasting systems and proved that adaptive techniques helped improve signal resilience, efficiency, and overall performance. It was found that low-order modulation techniques like QPSK supported a constant Bit error rate for low values of signal-to-noise ratio and guaranteed a reliable signal at a low quality level. On the other hand, high-order modulation techniques like 64-QAM and 256-QAM positively affected overall system efficiency at higher signal-to-noise ratio levels and guaranteed a faster spectrum usage.

2. Analysis based on PSNR values and MOS scores proved that a physical-layer performance improvement was directly related to overall perceptual quality improvement and emphasized the importance of adaptive modulation and coding systems for guaranteed viewer satisfaction. Adaptive modulation and coding systems have been identified as essential for balancing physical-layer performance in contemporary DVB-T2 systems. Recommendation on the basis of the results, it was recommended that broadcast networks and network providers integrate the adaptive modulation and coding scheme completely into the DVB-T2 infrastructure so that overall performance is optimized according to real-world channel conditions.

3. The implementation of intelligent algorithms for signal-to-noise ratio controlled switching would also help provide seamless connectivity between modulation and coding combination pairs so that overall network throughput is maximized without affecting reception throughput. It was also recommended that channel status be monitored continuously by the network using real-time feedback control to optimize adaptation thresholds so that overall network performance is improved. Finally, it was recommended that future system designs also incorporate machine learning prediction algorithms that can predict channel changes so that modulation changes can be made proactively by the network. Further research was also recommended related to the evaluation of the adaptive modulation and coding scheme in mobile, multipath, and terrain-specific channel environments so that the applicability of research is widened. Finally, it was also recommended that network performance metrics such as PSNR/MOS be incorporated into network design so that broadcast networks provide high-quality digital TV delivery.

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Information about the author

Olarewaju Peter Ayeoribe, PhD, Researcher at the Department of Electrical and Electronic Engineering, Federal University Oye-Ekiti

Address for correspondence

Nigeria, Federal University Oye-Ekiti,
Department of Electrical and Electronic Engineering
E-mail: ayeoribe.olarewaju@gmail.com
Olarewaju Peter Ayeoribe