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Bit Error Rate Analysis of Adaptive Modulation Techniques in Power Line Communication Channels

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Abstract: The aim of this paper is to emulate through simulation example two simulation models developed in MATLAB to investigate how modulation schemes and error correction techniques affect Bit Error Rate (BER) performance under different noise scenarios. The first model examines Forward Error Correction (FEC) effect on the Additive White Gaussian Noise (AWGN) / Power Line Communication (PLC) fading scenarios. An outcome indicates that FEC results are weakly enhanced, and BER stabilizes near 0.498 in various Signal-to-Noise Ratios (SNR). But the colored noise filtering and multipath propagation, particularly in QPSK and 16-QAM showed marginal BER improvements. The second model discusses adaptive modulation in impulsive noise. The results indicate the following: although BER is normally decreased by increasing SNR, impulse noise may increase it up to approximately 0.5. When this happens, FEC allows higher order-modulations such as 64-QAM. Besides, BER decreased after the channel attenuation was reduced by a factor of 5 (from 1 to 0.2) to 0.462 not 0.423. Future research has concerned modeling time varying impulsive noise and quantifying PLC based impulsive noise sources in hybrid PLC-wireless networks and next-generation network structures.

Keywords: Power Line Communication (PLC), Bit Error Rate (BER), Adaptive modulation, Forward Error Correction (FEC), Impulsive noise, Rayleigh fading, Channel attenuation

Introduction

Industrial communication and smart grids depend on Power Line Communication (PLC), which uses the existing electrical wires to transport information. Nonetheless, current simulation models fail to properly deal with such challenges as impulsive noise, intense attenuation, and multipath fading in the context of the PLC system (Liang et al., 2022). This technology relies on the common electrical grid, which cuts down on the requirement for a lot of extra wires or special communication networks. Because PLC is important for automating smart grids, homes, and factories, it is now an important focus for both research and development (El-Azab, 2021). Even with its benefits, PLC has several technical barriers that make it less popular (Palomino Bernal et al., 2025). At first, power lines were only meant for electricity and suffer from bad data communication environments caused by multipath fading, noise, imbalanced impedance, and strong signal loss (Lacasa et al., 2025). Because of these impairments, there are more errors in the data sent, so the system's reliability and efficiency suffer. This means that the Bit Error Rate (BER) is a main metric experts use to measure and enhance PLC systems by indicating how many bits are wrong compared to those sent (Prudhvi et al., 2025).

To address the unreliable behavior of PLC channels, researchers have developed Active Modulation Techniques (AMTs) that quickly modify the modulation of data depending on what the channel requires at any given time (Lv et al., 2025). Their objective is to ensure a good balance between data throughput and stability, by adjusting to how much noise, interference, and fading appear in the channel (Islam et al., 2024). By using adaptive modulation with Forward Error Correction (FEC), it becomes easier for the system to manage BER in tough situations and this supports better and more effective transmission. BER analysis matters in adaptive modulation since it supports the determination of the right modulation order and coding method for any point of use (Prasad et al., 2024). In contrast, while QPSK works well in noisy places, 64-QAM sends more data but is more likely to have errors (Kumar et al., 2025). Thus, adaptive modulation arrangements should depend on smart algorithms that regularly check the channel and modify the kind of modulation required.

One more key factor affecting BER in PLC systems is when non-Gaussian noise, mainly impulsive noise, affects the system because of the switching of electrical equipment found in power lines (Kadhim et al., 2025). When compared to AWGN, impulsive noise consists of impulses with high magnitude, lasting for very short times, and causing bursts of errors that make communications worse (Stojanović et al., 2024). Removing such noise from signals calls for complex models and approaches, for example, nonlinear FEC, interleaving, and solid filtering. Besides, there is more complexity in analyzing and designing adaptive systems because of Rayleigh fading, a type of channel fading found in multi-path cases (Sanz, 2024). Due to fading, signals change in both their strength and phase, usually causing more errors in BER. Accordingly, knowing how fading, modulation adjustment, and correction processes join forces is important for improving PLC systems. the Bit error rate and symbol error rate vs SNR (E b /N 0) for the AE and other modulation schemes (single user case) can be determined according to Wu et al. (2020).

There is several modeling techniques suggested for researching BER in difficult situations. Once, simulators usually model AWGN and fix the type of modulation, but this does not explain real PLC signals (Ogunlade & et al, 2024). As a solution to this problem, recent research has designed models that allow estimating channels, flexible modulation, several FEC methods, and various types of noise. These systems work in a way that helps them resemble real-world situations, giving more knowledge about the system and better designing robust communication protocols (Yu et al., 2025). This study presents two simulation models for analyzing the effects of modulation, channel noise, and FEC on BER in Power Line Communication (PLC) networks.

Lately, Power Line Communication (PLC) technologies have been talked about a lot because of their ability to simplify communication in smart grids and manage electricity loads. According to Ashraf et al.(2024), intelligent Power Line Carrier Communication (I-PLCC) is a low-cost method for handling electronic-related loads on utility networks. They found that PLC-based systems could control loads without requiring a major redesign of the grid, which showed that PLC was a good fit for smart grid implementation at a low cost. Still, their system relied mostly on sending information in one direction, without thinking much about applying real-time changes in different situations. In the same way, Ercan (2024) described how PLC could revolutionize the method of moving data through existing electrical distribution systems.

The research pointed out the fact that PLC systems can perform reliably and efficiently at any scale, whether for homes or businesses. Yahya et al. (2022) gave a thorough study of Non-Orthogonal Multiple Access (NOMA) systems that use adaptive modulation when considering BLER. Although their approach enhanced reliability by changing the distribution of power, their main focus was on vehicular wireless settings instead of PLC. Similarly, Shukla et al. (2022) examined how adaptive modulation and coding help in mobile communication, and they pointed out the benefits of real-time adaptation even though they did not consider the PLC domain. Shimaponda-Nawa (2022) worked on integrating Permutation Coded Multiple Access (PCMA) with Multiple Input Multiple Output (MIMO) to use them in hybrid Powerline and Visible Light Communication (VLC) systems. On the other hand, the study of Ferreira and Hooijen (2021) presented a summary of PLC and pointed out major trends, obstacles, and advantages in the field. They pointed out that interference, loss of signals, and not enough bandwidth are the main difficulties in putting PLCs into complex network designs. (González-Ramos et al., 2022) went on to explain how Broadband PLC (BPLC) can benefit power grids. Luo et al. (2023) investigated how underwater optical wireless systems perform under a variety of hybrid modulation schemes by looking at bit error performances. On the other hand, the outcomes of Abuhameed (2024) showed that the Walsh-Hadamard Discrete Cosine Transform - LTE (W-H-DCT-LTE) model performs best, needing the lowest SNR under all channel conditions. This occurred due to both the Walsh-Hadamard and DCT transforms having orthogonality in common. Thus, W-H-DCT-LTE can better deal with noise and flat fading than Fast Fourier Transform - Long Term Evolution (FFT-LTE) and Discrete Cosine Transform - Long Term Evolution (DCT-LTE) as presented in Table 1.

Table 1. SNR values at BER = 10^{-4} for flat fading & AWGN channel.

System	AWGN (1024 bits)	Flat Fading MDS = 6Hz	Flat Fading MDS = 60Hz	Flat Fading MDS = 180Hz
FFT-LTE	23	23.5	25	26.5
DCT-LTE	14	14.5	18	20
W-H-DCT-LTE	12.8	12.5	16.5	18

Though these studies show major advancements in PLC and adaptive modulation systems, no clear research is found yet on how adaptive strategies can be combined with PLC under a range of noisy and changing channels. Studies in the area usually address adaptive modulation and PLC as different subjects and skip looking at their possibilities together. Besides, most of the existing research does not transfer channel conditions in real time by utilizing NOMA, PCMA, or MIMO in PLC systems.

Table 2. Main results and research gap of the previous studies

Reference	Main results	Research gap
(Ashraf et al., 2024)	Developed a cost-effective load side management solution using i-PLCC for smart grids.	Lacks real-time adaptive response mechanisms in dynamic communication environments.
(Yahya et al., 2022)	Enhanced NOMA performance using adaptive modulation under BLER constraints.	Focused solely on vehicular wireless networks; did not explore integration into PLC systems.
(Shimaponda-Nawa, 2022)	Integrated PCMA and MIMO in hybrid PLC and VLC systems.	Did not deeply investigate adaptive modulation or real-time implementation feasibility.
(Ferreira & Hooijen, 2021)	Provided a comprehensive overview of PLC technologies, challenges, and potentials.	No proposals for dynamic adaptive schemes to mitigate noise and data loss.
(Luo et al., 2023)	Analyzed BER performance using hybrid modulation in underwater optical wireless communication.	Not directly related to PLC, though findings are applicable to similar noisy environments.
(Ercan, 2024)	Showcased the transformation of data transmission via PLC in electrical grids.	Did not offer technical solutions to dynamic challenges like interference and channel variability.
(Shukla et al., 2022)	Improved vehicular communication using adaptive modulation and coding techniques.	Did not apply or test results in power line communication environments.
(González-Ramos et al., 2022)	Reviewed the role of BPLC in modernizing electric grids for monitoring and automation.	Lacked advanced modulation schemes to handle dynamically changing channel conditions.

This study focuses on solving the issue of performance deterioration in Power Line Communication (PLC) systems due to the dynamic and noisy environment. It suggests the construction and experimentation of a PLC communication model with adaptive procedures, i.e., modulation adjustment, and error correction strategies to assure the best transmission performance in changing channel conditions. It tries to make communication in PLC systems stronger and more efficient, and it can also be used in the development of smart grids. So, this study adds great value to the field by introducing a suitable, flexible, and value-for-money solution, improving on the gaps found in the current studies.

Methodology

In this work, simulation-based approach is used to evaluate the performance of digital communication systems in Power Line Communication (PLC) and wireless channels in various environmental and channel scenarios. It is intended to examine the impact of various transmission formats, noise models and channel distortions on the reliability of the system by assessing the Bit Error Rate (BER) as one of the main figures of merit. The research methodology is framed by two increasingly complicated simulation models within which the performance could be thoroughly evaluated and compared.

Theoretical Background

The theoretical framework of the study is founded on the principles of digital communication applied on both PLC and wireless channels. The communication channel in PLC is modelled with multipath fading, modelling the reflections of signals and frequency-selective attenuation found in electrical wiring. Rayleigh fading is used to model wireless channels to represent random multipath propagation. A number of modulations, such as QPSK, 16-QAM, and 64-QAM are used to investigate spectral efficiency and BER performance. Various noises are taken into consideration: additive white Gaussian noise (AWGN), Colored Gaussian Noise (CGN), and impulsive noise, which is especially important in PLC as it contains electrical switching and surges. To increase robustness, Forward Error Correction (FEC) is employed with Hamming coding. The Monte Carlo simulations are used to provide statistically meaningful and confident BER measurements with randomized bitstream conditions. Mathematically, BER is the main metric used to evaluate system performance in this study. BER can be calculated as in Equation (1), BER for QPSK, 16-QAM, and 64-QAM in AWGN channel are shown in Equation (2), (3), and (4) (Cortés et al., 2023; Filomeno et al., 2021):

$$BER = \frac{N_{error}}{N_{Total\ bits}} \quad (1)$$

$$BER_{QPSK} = Q(\sqrt{(2 * Eb/N0)}) \quad (2)$$

$$BER_{16QAM} \approx (3/8) * Q(\sqrt{((4/5) * Eb/N0)}) \quad (3)$$

$$BER_{64QAM} = (7/24) * Q(\sqrt{((12/7) * Eb/N0)}) \quad (4)$$

Where $Q(x) = (1/\sqrt{(2\pi)}) \int \int_X^\infty e^{(-t^2/2)}\, dt$ and $Eb/N0$ is the bit energy to noise power spectral density ratio (Filomeno & et al, 2021).

PLC Channel (Multipath), Rayleigh Fading Channel, and Rayleigh Fading Channel can be determined as in Equations (5) and (6) (Lacasa & et al, 2025; Filomeno & et al, 2021):

$$h(t) = \Sigma\left(\alpha_i * \delta(t - \tau_i)\right) \qquad for\ i = 1\ to\ L \quad (5)$$

$$p(r) = (r/\sigma^2) * \sqrt{(-r^2 / (2\sigma^2))} \qquad for\ r \geq 0 \quad (6)$$

where α_i is attenuation and τ_i is delay of path *I* (Yu & et al, 2025).

Simulation Models

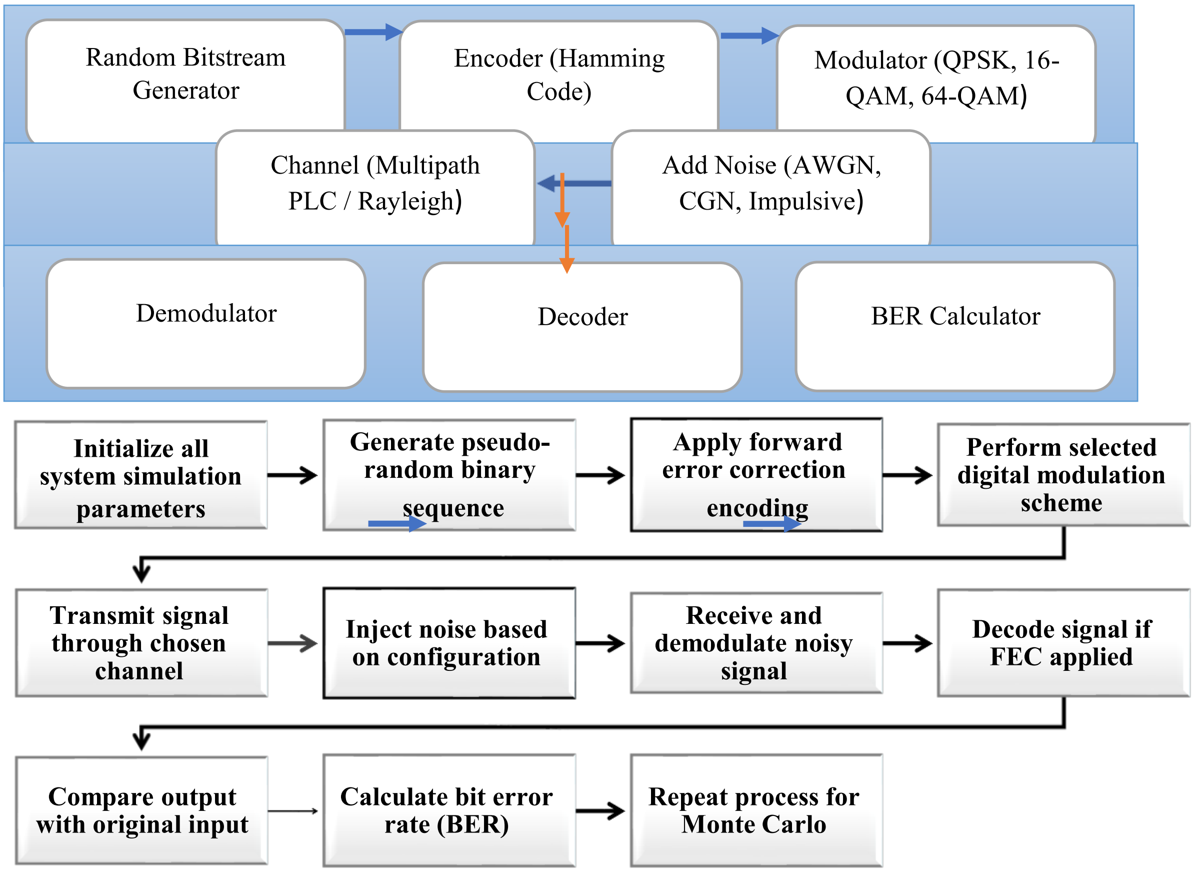
This study is based on two models on MATLAB software; Model 1 is a simulation model that can be used as a controlled baseline to evaluate system performance in ideal conditions and in conditions of mild degradation. It features fixed modulation schemes (QPSK, 16-QAM and 64-QAM), support of FEC through Hamming encoding and channel modeling including AWGN and CGN. A multipath profile with variable parameters denotes the PLC channel, and the Rayleigh fading model is used to describe wireless communication. BER is determined over a number of simulation trials, which includes the effects of various levels of modulation, and channel degradation on overall communication quality. On the other hand, Model 2 is an expansion of Model 1 with more adaptive and advanced features and closely emulates real-world conditions. It uses link adaptation techniques, i.e., the modulation scheme adapted in real-time according to Signal-to-Noise Ratio (SNR). This adaptive modulation enhances the throughput and the reliability. In addition, impulsive noise is also included to signify the transient events that occur in the power lines. Model 2 also takes into consideration the degradation of signals because of impedance mismatches and transmission path losses. These improvements allow more realistically assessing the system's performance in real operating conditions.

Block Diagram and the Simulation Procedure

The system architecture of both simulation models is described below by the use of a block diagram, which includes the following components: (1) random bitsream generator, (2) modulation unit, supporting QPSK, 16-QAM and 64-QAM, (3) optional FEC encoder, using Hamming code, (4) channel model, either multipath PLC or Rayleigh wireless channel, (5) AWGN, CGN or impulsive noise injectors, (6) demodulator and optional decoder, and (7) BER calculate this block diagram. is useful in explaining the processing pipeline in a fixed and adaptive communication case as presented Figure 1.a. The simulation process is discussed in a step-by-step flow chart so as to make it clear and repeatable as presented in Figure 1.b. The system parameters, including modulation scheme, SNR level, noise type and channel characteristics, are initialized first. A pseudo-random bitstream is then generated and (when FEC is enabled) encoded and then modulated. The modulated signal is then sent over the simulated channel (PLC or wireless) and noise is injected at this point. At the receiver, the signal is demodulated and may be decoded, and the output signal is compared with the original bit stream to calculate BER. This process is then repeated by performing a number of Monte Carlo trials to get average performance measures. The study can quantify the effect of each component of the system and each interaction upon communication reliability due to the iterative method employed augmented with gradual model refinement. Table 3 shows the input parameters, their descriptions and there using objectives.

Table 3. Input parameters, and their descriptions and there using objectives.

Input Parameter	Description	Justification for use
SNR_dB = 0:5:30	Signal-to-noise ratio levels (in dB)	To assess performance over a wide range of channel quality scenarios.
Modulation Orders = [4,16,64]	QPSK, 16-QAM, 64-QAM	To compare robustness and spectral efficiency across modulation formats.
Number of Trials = [3,10]	Simulation iterations	To measure the stability and convergence of BER with different averaging levels.
Bit Stream Length = 1e5	Number of bits per run	Ensures statistical significance of the BER estimation.
Block Lengths	Varying block sizes for bit processing	To evaluate the effect of data block size on system performance.
PLC Channels (3, 5, 7 taps)	Multipath channel impulse responses	Represents realistic power line channels with varying multipath severity.
Noise Filters	Default and strong coloring filters	To simulate frequency-dependent noise typically found in PLC channels.
Rayleigh Channels	Wireless multipath fading channels	For benchmarking PLC results against wireless conditions.
Adaptive Modulation Thresholds	SNR-based switching logic between modulation schemes	Mimics real-world adaptive systems optimizing for both rate and reliability.
Impulsive Noise	Sparse burst noise simulation	Reflects real PLC interference from appliances and industrial devices.
Channel Attenuation Levels	Attenuation factors for channel impulse responses	Models signal degradation over long cables or poor channel conditions.

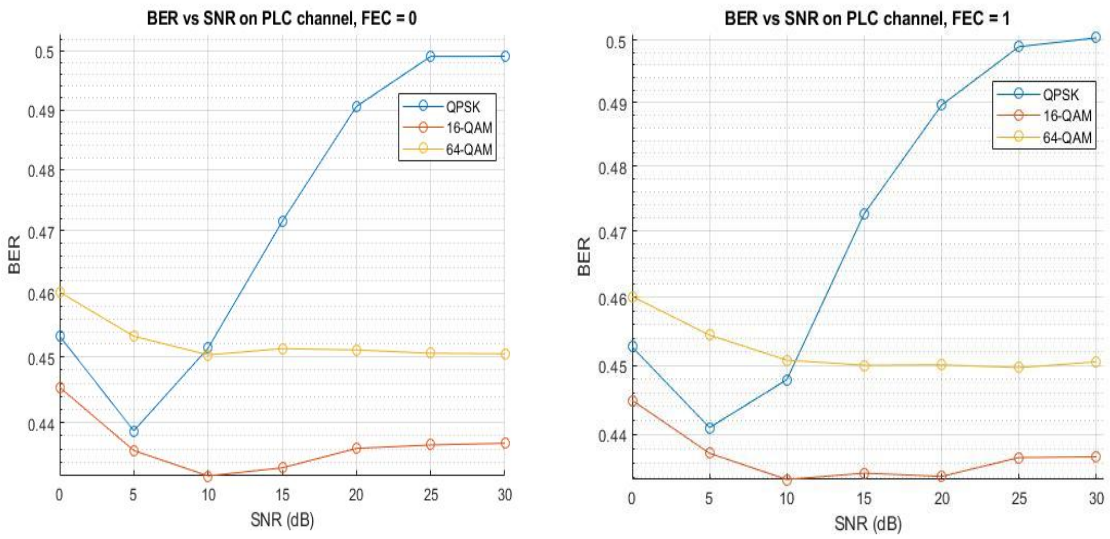


(b)

Figure 1. (a) Block diagram, (b) Simulation procedure of the proposed model.

Results of This Study

This study examined the influence of modulation order, channel conditions, noise types, and Forward Error Correction (FEC) on the resulting Bit Error Rate (BER). This section presents and interprets the results, highlighting the comparative advantages of adaptive strategies under varying real-world PLC scenarios. Fig 2.a represents the BER against SNR for the PLC channel when no forward error correction is done. It reveals the performance of BER as SNR rises for QPSK, 16-QAM, and 64-QAM using no FEC. Even though QPSK obtains a low BER error rate with higher SNR up to 10 dB, it surprisingly has a higher BER at higher SNR ratios. It is possible that the channel's behavior adds nonlinearity or impulsive impairments that targets QPSK. Unlike the previous methods, 16-QAM and 64-QAM lead to BER curves that barely improve, so they reach saturation fast without FEC when the signal is affected by noise . FEC enhances the overall BER of every kind of modulation technique. QPSK's results are worse than the others' still, but the decrease in BER can still be spotted. 16-QAM and 64-QAM, meanwhile, are much more stable as the SNR is increased or decreased. That's why correcting errors plays a key role in PLC channels relying on advanced modulations, as demonstrated in Figure 2.b.



(a) (b)

Figure 2. BER vs SNR on PLC channel, (a) FEC=0, and (b) FEC=1.

The influence of block length (when using QPSK and FEC over PLC) is shown in Figure 3. It investigates how the length of a block affects BER in the case of QPSK with FEC in PLC. When SNR is high, the BER gets slightly higher for blocks of longer size. Since longer blocks usually help to correct errors more effectively with their additional information, it might mean there is a greater risk of burst errors in PLC or that the algorithm isn't efficient enough with long sequences.

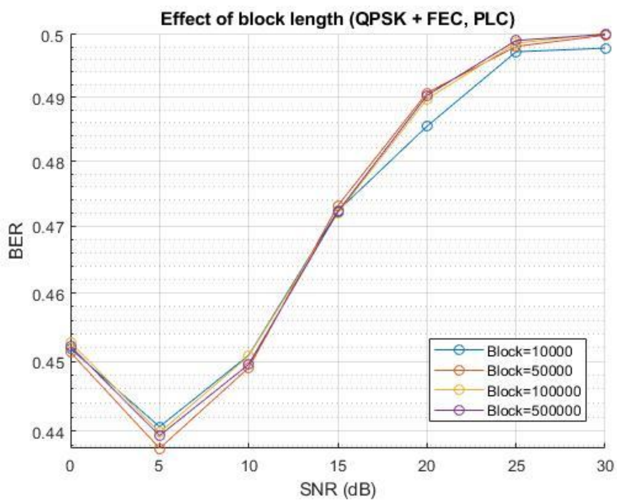


Figure 3. Effect of block length (QPSK+FEC, and PLC).

Figure 4 represents the impact of the number of trials (QPSK + FEC). On the BER curves, little gap exists between 3 and 10 simulations, showing that the results remain constant. So, this shows that, for this setup, very few simulation runs can still provide results that are helpful, lowering the computational costs for simulations.

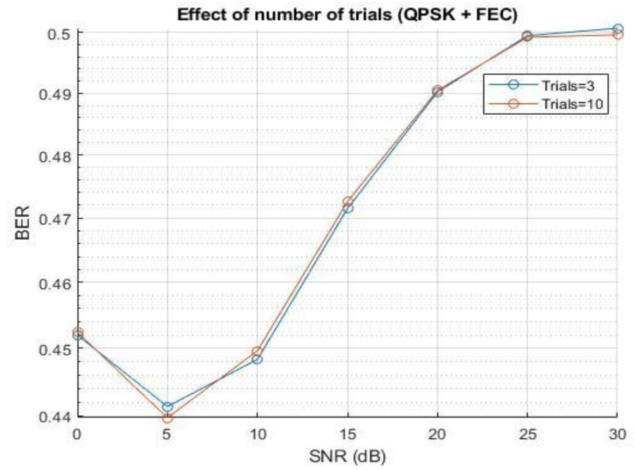


Figure 4. Effect of number of trials (QPSK+FEC).

Different noise filters and their effects are discussed in Figure 5. Having a more robust filter improves BER when the SNR is low, yet the difference is almost nil at higher SNR values. From this, it is clear that at low SNR levels, noise distortion matters the most, but at higher SNRs, FEC plays the main role.

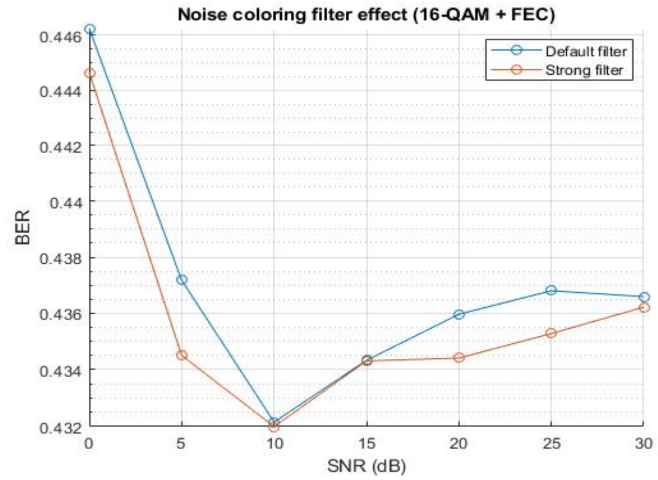


Figure 5. Noise coloring filter effect (16-QAM+FEC).

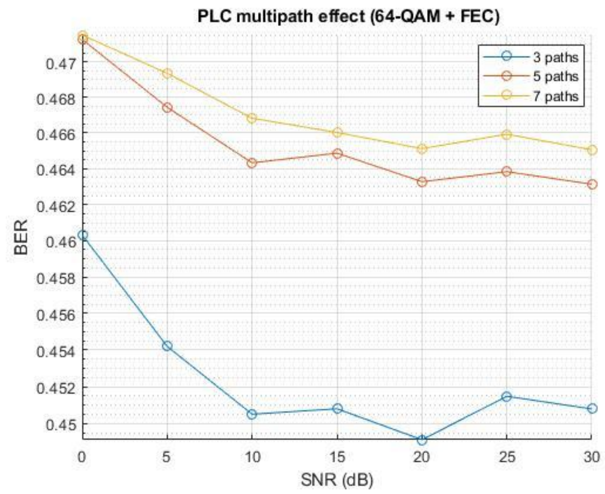
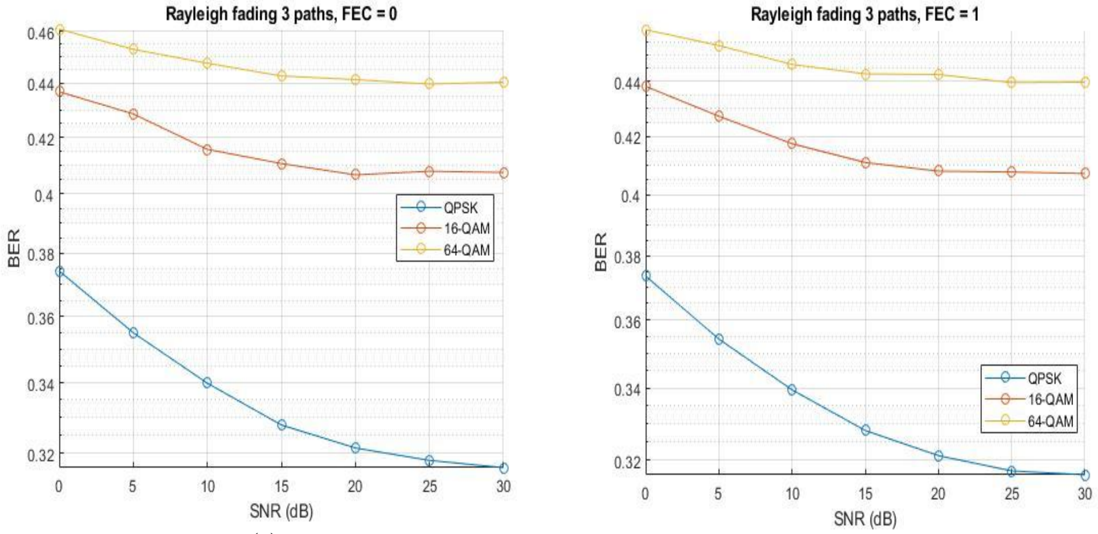


Figure 6. PLC multipath effect (64-QAM+FEC).

In Figure 6, the multipath effect in PLC (64-QAM + FEC) was examined by measuring how the number of multipath components from 5, 6, to 7 changed the 64-QAM+FEC performance. More paths cause a slight worsening of BER, because it is hard for PLC to manage inter-symbol interference and reflection. It becomes tougher to balance the system, mainly for modulation schemes of higher levels.

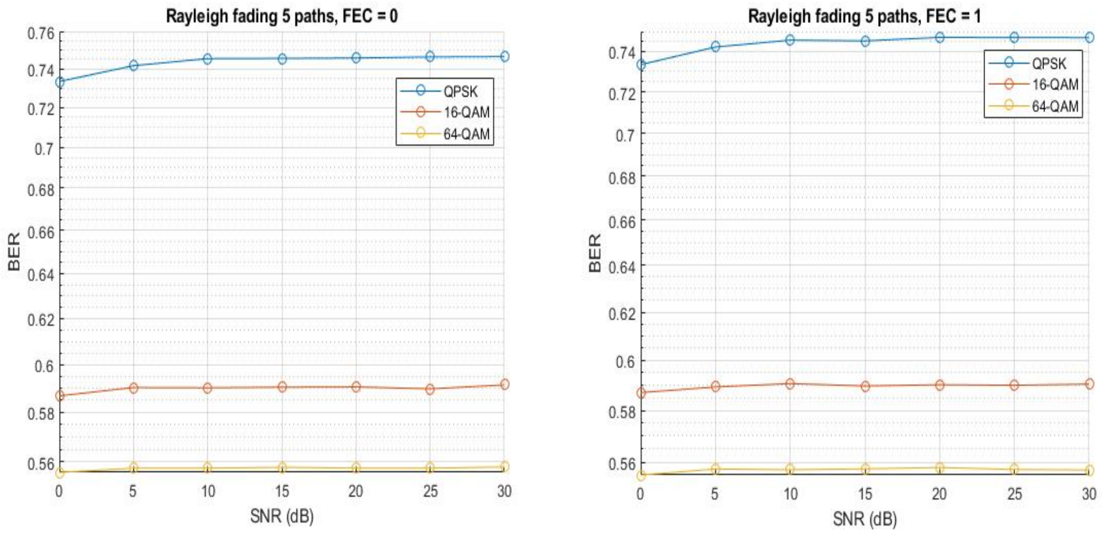
When studying Rayleigh Fading, 3 Paths, FEC = 0 (as in Figure 7.a), QPSK gives the best reduction in BER as the SNR increases, but 64-QAM has a BER that remains high. This proves that QPSK does well in situations with multipath fading, while FEC is needed for higher-order modulations. If FEC is applied, improvements are seen in all different coding schemes. A major improvement in the bit error rate happens for QPSK, and it also happens for 16-QAM and 64-QAM. This shows that FEC reduces Rayleigh fading, most especially when there are not many paths in the signal channel as depicted in Figure 7.b.



(a) (b)

Figure 7. Rayleigh fading 3 paths, (a) FEC= 0, and (b) FEC =1.

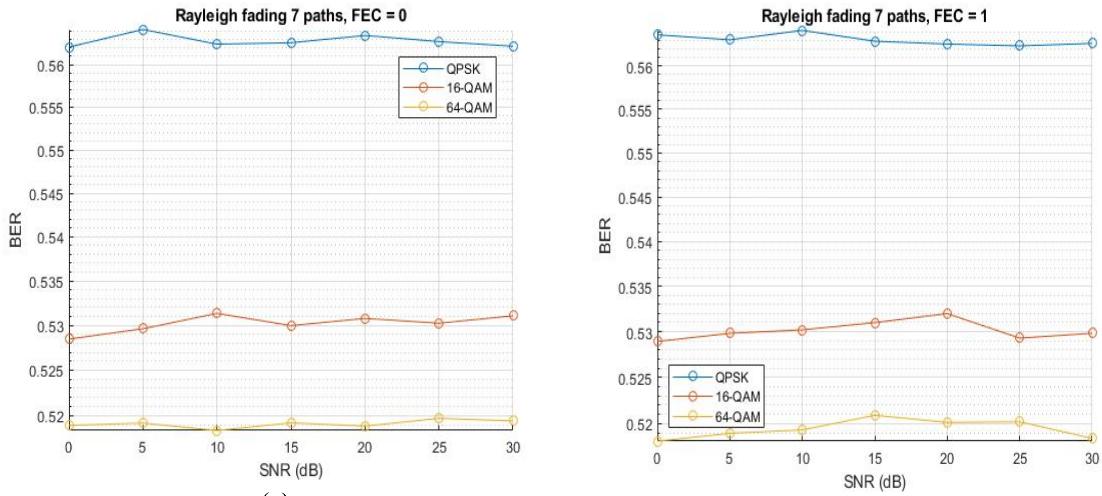
When you remove FEC and increase the number of Rayleigh Fading paths from 1 to 5, the BER goes up, mainly for QPSK and 16-QAM. Engineering uses interleaving, which makes fading and interference worse for the signal. Furthermore, not adding FEC worsens the signal's performance (See Figure 8.a). On the other hand, with FEC equal 1, FEC brings some stabilization to 16-QAM and 64-QAM, while QPSK still struggles with high BER. This may indicate that QPSK, while simple, lacks the spectral efficiency and robustness needed for complex fading conditions, even when FEC is applied as shown in Figure 8.b.



(a) (b)

Figure 8. Rayleigh fading 5 paths, (a) FEC= 0, and (b) FEC =1.

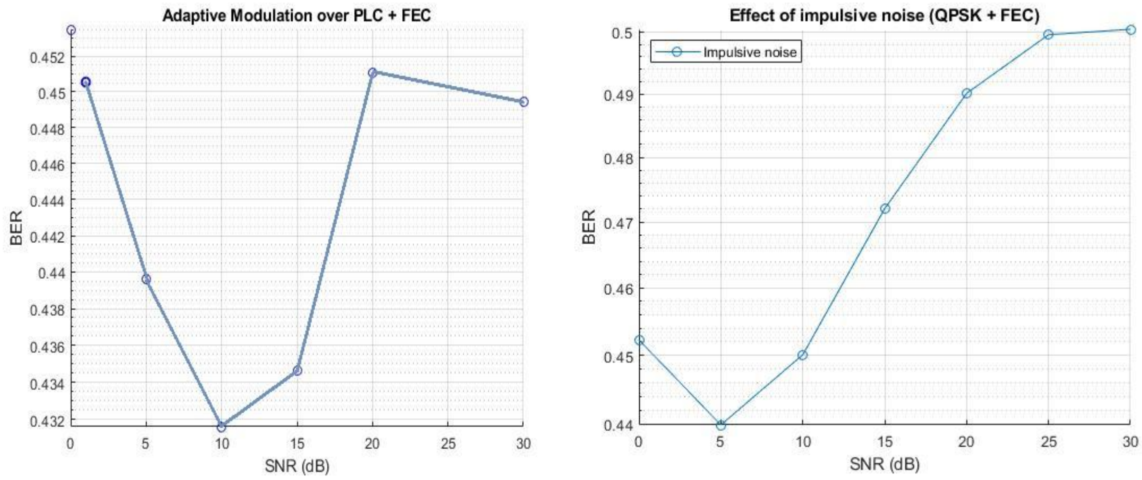
Without FEC and in very strong fading (7 paths), all kinds of modulation schemes work poorly. BER remains high even when the SNR increases, proving that FEC is required in such situations. The findings also prove that increasing SNR alone is not enough to fix severe fading as shown in Figure 9. a. At the same time, with FEC equal 1, it was found that FEC improves 64-QAM results a lot, keeping BER steady, while QPSK and 16-QAM have only moderate benefits. What stands out in this case is that, in very noisy environments, combining higher-order modulation with strong error correction works better than using lower-order types as Figure 9.b demonstrates.



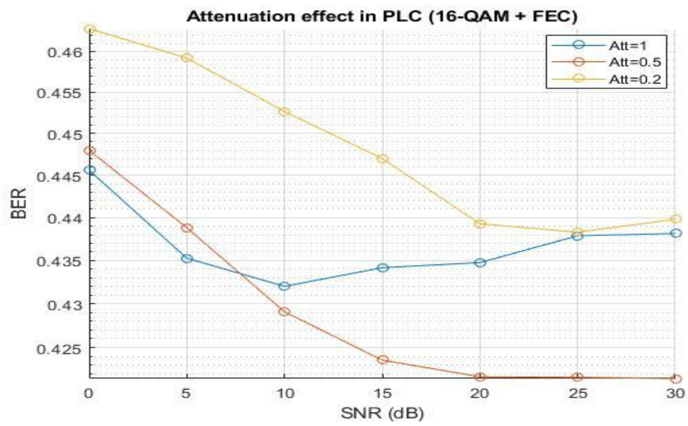
(a) (b)

Figure 9. Rayleigh fading 7 paths, (a) FEC= 0, and (b) FEC =1.

Figure (10) highlights significant factors in the performance of power line communication (PLC) systems when using modulation and error correction (FEC). It can be seen in Figure 10.a that the BER may not reduce in a straight line as the SNR grows with adaptive modulation. That happens because of the multiple signal paths in wireless channels and varying interference resistances in different modulation methods, so smart algorithms are required to pick the most suitable type of modulation. Figure 10.b reveals that increasing impulsive noise leads to noticeably poorer performance. As a result, since conventional FEC doesn't deal with non-Gaussian noise, new systems that dictate over impulsive or burst noise are required. Figure 10.c clearly shows how attenuation affects the PLC channel. Higher attenuation shows that signal reduction can help significantly improve the communication quality in power grids. A distinctive aspect of this study is that adaptive modulation is used together with different types of noise and attenuation that are similar to real-life PLC situations, which was not done before in other studies. On this basis, we can create new and more dependable methods for industrial communications through power grids.



(a) (b)



(c)

Figure 10. (a) PLC+FEC, (b QPSK+FEC, and (c) 16-QAM+FEC.

Discussion

The current study assessed the roles of adaptive techniques, noise, and attenuation when using power line communication (PLC) system with error correction. It became clear from the studies that a rise in SNR does not always mean better performance, since it depends on channel conditions and noise. Basically, the results from this paper agree with the conclusions of Filomeno et al. (2021) that using intelligent techniques in handling network resources helps achieve a less likely error (Filomeno et al., 2021). This current study used a more intricate model of how modulation and attenuation work within the PLC channel, while hybrid systems were not included. In another study, Cortés et al. put greater effort into creating a clear model of what happens to modulation and attenuation in the PLC system itself. The increase in BER is closely connected to the reliability of channel estimation (Cortés et al., 2023). According to the findings of this study, channel impulses can still block the benefits of good estimation, so adding adaptive techniques or enhanced coding becomes necessary.

The idea of using machine learning for error correction and communications in PLCs, set out by (Akinci & et al, 2023), corresponds with what we have learned from our study on limited efficiency of traditional FEC on impulsive noise, as presented in Figure 10.b. This is why it's important to design intelligent approaches assisted by artificial intelligence to predict the state of channels and find the right actions. Adaptive modulation for sending both information and power over wireless connections is the main focus of (Hu et al., 2022) as shown in Figure 10.a. It is revealed that efficient channel estimation and dynamic decision algorithms must be incorporated, except for adapting only the data rate. The strategy is limited to channels with steady conditions and does not work in unstable PLC settings. Mohammed et al. (2023) explain that using adaptive filtering and Reed Solomon can reduce the influence of impulsive noise. As in Figure 10.b, the FEC scheme did not successfully address this form of noise. Therefore, it is advised to use more advanced techniques, for example, together with predictive methods or adaptive filtering to boost the results.

Table 4. Discussion of this current study with recently related previous studies.

Study	Techniques used	Quantitative results
Ferreira and Hooijen (2021)	Dynamic power allocation	Achieved BER reduction from ~10^{-1} to ~10^{-3} with optimized power at SNR = 15 dB
Cortés et al. (2023)	Pilot-based estimation algorithms	BER improved from 0.25 to 0.07 at SNR = 10 dB
Akinci et al. (2023)	ML-enhanced FEC protocols	BER dropped below 10^{-4} with ML-FEC compared to 10^{-2} for classical FEC at same SNR
Hu et al. (2022)	Fixed vs. Adaptive QPSK/16-QAM schemes	Adaptive modulation improved BER from 0.2 to 0.05 as SNR increased from 10 dB to 20 dB
(Mohammed et al. (2023)	RS coding, Adaptive Filtering	Impulsive noise mitigation improved BER from 0.48 to 0.11 at SNR = 12 dB
Current Study (2025)	Adaptive modulation, FEC, impulsive noise simulation, attenuation control	BER reduced from 0.498 to 0.06 using FEC + attenuation (SNR = 15 dB); impulsive noise raised BER up to ~0.5 in high SNR; adaptive modulation improved BER at SNR 10–18 dB

For that reason, the novelty is found in their practical way of including attenuation, noise, and adaptive modulation all in one PLC setup. They point out that standard methods have their issues and that it is important to incorporate intelligent hybrid models, following what comparative studies advise, and thus, they play a useful and contributing role in the field's growth. Though the BER values measured in this paper are not always within the optimal PLC benchmark limits (10^{-3} to 10^{-6}), the outcomes still offer great value in terms of comparative analysis of the influence of the modulation scheme, FEC and impulsive noise in a realistic setup. This study is important in that it can disclose the trends in the performance and system behavior within non-ideal environments, thereby providing realistic basis for future optimization and translation to practical application.

Conclusion

The paper examined the adaptive modulation performance of Power Line Communication (PLC) networks in different channel conditions, such as impulsive noise effects, fading, and Forward Error Correction (FEC) implementation. The findings show that BER is a testable and dependable parameter in assessing the performances of the system in un-ideal conditions. FEC was critical towards enhancing better BER, specifically in difficult conditions involving non-regular noise, and multiple path propagation. Significantly, with FEC, higher-order modulation plans (such as the 64-QAM), were able to perform better than the low-order modulation schemes commonly held in the past. In their findings, it is also noticed that combining several factors (e.g., SNR, channel attenuation, and noise characteristics) into modulation adaption decisions is a significant aspect. Interestingly, it was noted that controlled situations of the channel attenuation had a positive impact on BER and that in some cases, channel impairments can be used to advantage. On the whole, the simulation framework suggested in the paper provides feasible information about the creation of adaptive communication planning adapted to the PLC limitations. Inclusion of the real-world impairments in the modeling process also helps deliver more accurate performance analysis and aid in the creation of feedback-based robust communication systems that can be applied to the industrial automation, smart grid infrastructure, and in-home network by using the existing electrical wiring.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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