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Noise in Telecommunications: Challenges and their Strategies- A Review Paper

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Abstract*: Noise in communication systems presents a significant barrier to reliable data transmission, often disrupting or breaking connections. Categorized into internal and external sources, noise impacts both wired and wireless systems, challenging the stability of modern multiservice telecommunication networks (MTNs). As the demand for data transmission grows, enhancing noise immunity has become crucial, with a focus on achieving high information, spectral, and energy efficiency to improve message reliability. Recent studies explore advanced mathematical modeling, optimal reception theories, and signal-code constructions (SCC) to bolster noise resistance, focusing on error-correcting receivers and efficient modulation schemes. However, optimization of SCC in line with energy efficiency remains complex due to varied system requirements and design constraints. This review discusses current methods for calculating noise immunity indicators, the limitations of existing models, and the need for a comprehensive framework to address noise immunity in next-generation networks (NGN) and future networks (FN). The proposed approach emphasizes optimizing signal processing and reception quality based on energy efficiency criteria, which is critical for improving the robustness of telecommunication systems in increasingly data-intensive environments.*

Keywords: Noise, Telecommunication, Performance, Bandwidth, Error Probability

I. INTRODUCTION

In the field of communication, both wired and wireless methods can face disturbances during transmission (Göbel et al., 2013). These disturbances are commonly referred to as noise. Noise is essentially an unwanted electrical signal that can disrupt data communication systems. When noise occurs, it can interfere with the communication process, potentially interrupting or even breaking the connection.

Noise can be categorized based on its source: (1) **Internal Noise** is generated by the components within the communication system. (2) **External Noise** comes from outside the system, which can be further divided into man-made noise and natural noise (like atmospheric disturbances). According to Xu et al. (2011), noise in communication systems can be grouped into four types.

As the number of users and the volume of transmitted data increase, enhancing the noise immunity of multiservice telecommunication networks (MTN) has become crucial (Ibrahimov et al., 2018). A key indicator of noise immunity in next-generation networks (NGN) and future networks (FN) is the system's information, spectral, and energy efficiency, which ensures reliable message transmission (Bianco et al., 2017). Energy efficiency is particularly important, as it reflects how effectively the system uses energy from transmitting devices and network terminals (Protopopov, 2013).

Energy efficiency depends on several factors, including the gain of the transmitting system, radio signal propagation characteristics, receiver properties, and the inherent noise of the receiver (Ibrahimov et al., 2022). It describes how power is utilized in the communication channel (Ibrahimov et al., 2020). To improve noise immunity in telecommunication systems, mathematical modeling methods are increasingly being used. Among these, optimal reception theory for discrete signals and effective modulation and coding schemes are particularly prominent (Ibrahimov et al., 2020).

Many studies (Ibrahimov et al., 2020; Burkov, 2023) focus on building error-correcting receivers and synthesizing demodulators. However, given the variety of potential solutions and initial requirements, selecting the best modem design with effective signal-code constructions (SCC) can be challenging (Yu et al., 2020). Furthermore, most research (Jin et al., 2023) tends to examine individual elements rather than the overall efficiency of systems that process and receive discrete signals (Chettri et al., 2020).

In this context, message processing systems using discrete signals can be viewed as SCC, consisting of a set of signals and an error-correcting code (Ibrahimov et al., 2020). An optimization problem arises when studying noise immunity, focusing on SCC and energy efficiency in telecommunications systems designed according to NGN and FN principles (Ibrahimov et al., 2020). Research (Zeng et al., 2017) indicates that a major obstacle in solving this issue is the absence of a new approach to calculating noise immunity indicators for signal reception and processing, which could help optimize communication quality (Ji et al., 2018). This work aims to develop a method for calculating the noise immunity characteristics of signal reception using SCC based on energy efficiency criteria in telecommunication systems.

As defined by Beritelli et al. (2002), there are two main types of noise:

(1) **Internal Noise** is produced by the internal components of a communication system and is categorized into four types: thermal noise, shot noise, transit time noise, and flicker noise.

(2) **External Noise** originates from outside the system and is not caused by its components. This type of noise includes atmospheric noise and industrial noise. According to Armada (2001), common terms like room noise, background noise, and noise criteria (NC) all refer to similar concepts, though they may be used differently depending on context. (1) "Room noise" typically refers to noise within an indoor space. (2) "Background noise" is a broader term that can apply to both indoor and outdoor settings, referring to sounds that are not part of the main sound source. (3) "Noise criteria" are technical terms used by experts to describe standard measurements of background noise in a room.

II. CONCLUSION

The performance of telecommunication systems is significantly impacted by noise, which can be broadly classified as internal and external. Internal noise, generated within the system's components, includes categories like thermal, shot, transit-time, and flicker noise, while external noise arises from external factors such as atmospheric conditions and man-made interferences (Journal La Multiapp, 2020). This study underlines the growing importance of noise immunity as data transmission demands increase, particularly within multiservice telecommunication networks (MTNs) and future communication systems.

The proposed approach in this review emphasizes a structured method for calculating noise immunity indicators, taking into account factors like energy efficiency, modulation schemes, coding coefficients, and bit rates. This approach yields practical formulas to estimate key performance metrics, including the minimum required signal-to-noise ratio and bandwidth considerations based on signal processing methods. Notably, findings suggest that optimal energy efficiency can be achieved through double phase shift keying (DPSK) with "soft" decision mechanisms and Low-Density Parity-Check (LDPC) codes, achieving energy efficiency around 0 dB. This configuration, while capable of high noise immunity, does involve a trade-off with bit rate reduction, highlighting a balance between energy efficiency and transmission speed.

The comparison of maximum achievable energy efficiency across different signal and coding types indicates that DPSK with soft decision and ideal coding yields the most favorable results, making it a promising approach for future telecommunication networks. However, differences observed between theoretical models and practical outcomes, particularly in systems with rigid decisions and LDPC coding, suggest that further research and analysis are necessary. Addressing these gaps could enhance our understanding of optimal system configurations, paving the way for more robust and efficient noise-resistant communication systems in next-generation networks (NGN) and beyond.

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