Statistical techniques to determine of optimal and acceptable noise levels

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Abstract. The paper presents an approach for an application of QoS procedures, on noise impacts in communications, respectively Uniform White Noise (UWN), Gaussian White Noise (GWN), Bernoulli Noise (BN) and Poisson Noise (PN). The approach consists in experimental establishment of recommended optimal and acceptable limit levels of the noise indicator Root Mean Square based (RMS) on the processing of registered information sets for each specific noise. A set of methodological statistical procedures are applied to the experimental data with respect to the complete and individual input sets (RMS levels for each individual noise). Types of family characteristics are analyzed and evaluated about different quality indicators as “Mean Plot of multiple variables”, “Normal Probability Plots”, “Individual Plots”, “X-Bar and R chart variable”, “Capability Plots” and “Capability Histograms”. The approach is also associated with the detection of RMS samples with deviations outside the defined statistical levels, as well as their exclusion in order to improve the quality of the processed information sample.

1. Introduction

The sources of noise in communication systems can be external - atmospheric, galactic, synthetic noise, etc., or internal for the systems. The statistical description and modelling of noise impacts are based on concepts such as “random variable”, “Cumulative and Probability Density Functions” and “Statistical Averages” [1].

Algorithms for automatic detection of peak areas and interpolation process are often used in the practice of signal recovery at the appearance of pulse noise, in the basis of which is the principle of realization of an autoregressive process [2]. Other recovery approaches are associated with the use of statistical processing based on the inverse error functions, etc. [3].

The reduction of the effect of noise impacts is an important problem in a number of areas such as cellular mobile communications, speech recognition, image processing, medical, radar and other signals. That's why, is important to determine and maintain optimal noise levels in the communication channels, which would introduce minimal disturbances in the forms of signal and save the integrity of the transmitted information.

The paper proposes a statistical approach related to the assessment of experimental noise, establishment of recommended RMS optimal and permissible variance levels. The approach also involves the quality analysis and composition adjustment of the sample being processed for noise samples outside the statistically defined limits when such a procedure is required.
2. Exposition

Regarding the purpose of the study, four types of interference at fixed parameters were simulated for each specific noise, as follows: Uniform White Noise: Amplitude = 1; Gaussian White Noise: Standard deviation = 1; Bernoulli Noise: Ones probability = 0.5 and Poisson Noise: Mean = 1. The simulation of the signals was made through a virtual instrument developed on the basis of LabVIEW with included control elements for regulation of the experimental values and parameters of the noise, given in figure 1. The instrument also has digital and graphical indicator devices for complex and individual monitoring of the experimental signals. For each of them, a sub-virtual tool for statistical analysis and calculation of Root Mean Square parameter was used.
For each examined noise, a sample of 60 experimental observations was accumulated for the indicator, for subsequent processing and analysis with the tools of the STATISTICA software environment (figure 2) [4, 5]. A group analysis of the experimental data is applied, consisting in constructing a Histogram of the average values of RMS in a given confidence interval "0.95", shown in figure 3. No deviations from the defined confidence area have been identified.

![Mean Plot of multiple variables](image_url)

**Figure 3.** Mean plot about RMS in UWN, RMS in GWN, RMS in BN and RMS in PN.

![Normal Probability Plot](image_url)

**Figure 4.** Normal probability plots of (a) RMS in UWN, (b) RMS in GWN, (c) RMS in BN and (d) RMS in PN.

An individual quality analysis was conducted for the indicated information groups, the first step from which it is aimed at assessing the nature of the random change of the data by means of Normal probability graphs in figure 4. Examining the location of the test points in the direction of the 45° line, no discrepancies regarding normal distribution are detected visually. Based on individual graphs of the observations in figure 5 the following optimal RMS values of noises and their variation levels of change are found, in which they are subject to parametric control: UWN: RMS = 0.57860 compared to the levels from 0.53787 to 0.61933; GWN: RMS = 1.0029 in the range from 0.91317 to 1.0926, BN: RMS = 0.70145 according to the range from 0.65054 to 0.75235 and PN: RMS = 1.4101, limited from 1.2258 to 1.5945.
Figure 5. Individual plots for (a) RMS in UWN, (b) RMS in GWN, (c) RMS in BN and (d) RMS in PN.

Figure 6. Individual plots for (a) RMS in UWN, (b) RMS in GWN, (c) RMS in BN and (d) RMS in PN.

In each test group, individual points are observed, located relative to the respective boundaries, or outside them. In order to limit the number of RMS observations that are not characterized by a normal
distribution, it is necessary to group the data and establish a new information sample with a reduced dimension. In other words, each group of 60 observations is limited to a composition of 30 RMS samples. In this way, an increase of level of the data subject to regulation (falling into the established variation RMS levels) is achieved.

According to the presented X-Bar and R graphs in figure 6 only in the analysis regarding the RMS levels of Constant white noise a problematic sample was found below the lower optimal threshold (figure 6(a)). According to the diagrams, maximum permissible deviations of the RMS samples from the found optimal levels were determined, respectively for UWN: <0.10247; GWN: <0.22570; BN: <0.12808; PN: <0.46382. With regard to the registered object of non-parametric control, more complete detailed statistical information can be obtained and its constituent observations should be excluded from the sample for the specific signal (figure 6).

![Figure 7](image7.png)

**Figure 7.** Capability indicators of (a) RMS in UWN, (b) RMS in GWN, (c) RMS in BN and (d) RMS in PN.

![Figure 8](image8.png)

**Figure 8.** Capability plots for (a) RMS in UWN, (b) RMS in GWN, (c) RMS in BN and (d) RMS in PN.

Based on the processing and analysis of the experimental data, capability indicators are obtained. The entered indicators are presented in numerical and graphical form in figure 7 and figure 8. The Cr indicator can be accepted with the highest degree of significance, according to which the group "RMS at BN" is determined with the best quality, followed by "RMS at PN", "RMS at UWN" and "RMS at GWN".
In figure 9 a probability density functions are built. Total and Within, referring to the analyzed information observations and samples. The given dependences describe to a good extent the experimental data, confirming their normal nature of distribution.

3. Conclusion
The proposed methodology can be successfully applied for statistical analysis of different types of information arrays, concerning embarrassing impacts on electrical signals, traffic input and output flows in communication systems.

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