# BASELINE CORRECTION TECHNIQUE FOR POLYMETRIC SIGNAL INTERPRETATION

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МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ
КОРАБЛЕБУДУВАННЯ
ІМЕНІ АДМІРАЛА МАКАРОВА
МИКОЛАЇВСЬКА ОБЛАСНА ДЕРЖАВНА АДМІНІСТРАЦІЯ
ДЕПАРТАМЕНТ ОСВІТИ І НАУКИ МИКОЛАЇВСЬКОЇ ОБЛАСНОЇ ДЕРЖАВНОЇ
АДМІНІСТРАЦІЇ

# ІННОВАЦІЇ В СУДНОБУДУВАННІ ТА ОКЕАНОТЕХНІЦІ

XIV Міжнародна науково-технічна конференція

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**ОРГАНІЗАТОРИ КОНФЕРЕНЦІЇ**
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**Abstract.** The uncertainty in the level measurement of polymetric systems was examined, with a focus on the impact of baseline estimation techniques. Using a polynomial baseline model, notable improvements in nonlinearity were observed compared to the conventional method. The findings highlight baseline stability evaluation, baseline robustness study, and algorithm optimization as key research areas, especially for efficient real-time processing on constrained hardware.

**Keywords:** baseline, correction, polymetric systems, signal processing.

***Introduction.*** It's common in signal processing to use a reference level of the signal for feature calculation (also called baseline, “zero-level” or “zero-line”). This baseline provides a reference point used to compare different signals and analyze changes in a signal over time. Establishing a common baseline makes it easier to identify patterns, trends, and anomalies. This is especially useful when trying to identify peaks or slow-shifting anomalies in signals that are exposed to noise or interference, as is the case with polymetric systems [1-3]. For these systems to be effective in industrial contexts, they need to address challenges posed by background noise and significant baseline drift.

There are various approaches to baseline definition and estimation that depend on signal type and particular goal (one level, or a complex curve) in the context of application. This review focuses on the techniques and definitions employed to estimate the "zero-level" models predominantly in the context of polymetric system signals used for accurate level and temperature measurements [3,4]. There are different possible interpretations of what exactly a “baseline” is. At [5-8] authors provide a review of the primary methods for defining and estimating baselines and baseline correction techniques for various signal types. If we assume the signal is entirely positive, rising from a theoretical zero baseline, then a smoothed running minimum can serve as a suitable baseline. On the other hand, if the noise is expected to vary around a baseline, as seen in cases with independent and identically distributed (iid) normal fluctuations, then a central measure like the median or mean would be more fitting.

***Objective.*** The work is focused mainly on the baseline estimation and correction technique aiming to reduce the influence of the zero-line drift and improve the overall accuracy of the polymetric system.

***Main material.*** The importance of baseline estimation can be explained using Figure 1 where the simplified approach of time delay estimation between 2 peaks is shown.

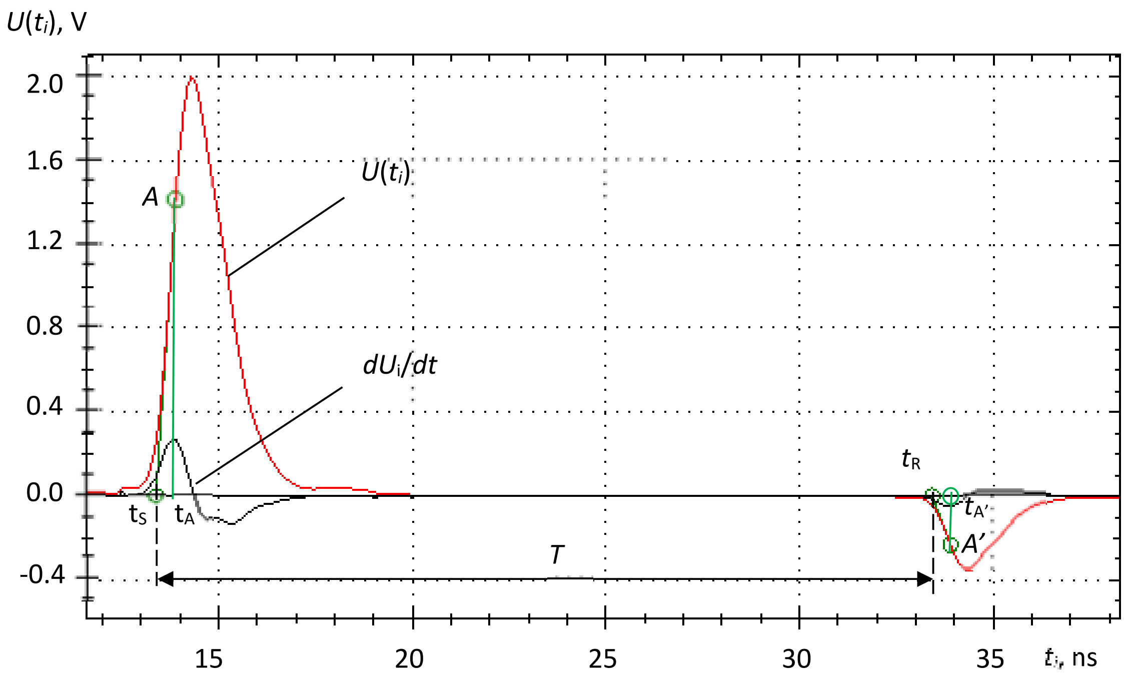


Figure 1 – Simplified explanation of time delay estimation and baseline influence

This signal $U(t)$ is a typical representation of a waveform used for distance estimation in level sensors using the measurement of time $T$ – the time between moments of the sounding and receiving of the characteristic pulses. Voltage $U$ is measured at the discrete moments of time $t_i$, where $i$ stands for sample number. The time discretization step $\Delta t_i$ is controlled by the hardware.

In early-generation polymetric systems, the threshold technique was used for peak detection and time-delay estimation (simply picking pulses above some level set). This simple approach gives acceptable results in applications with medium levels of precision because it's very sensitive to any signal drift. To overcome the issue with relatively small zero-line drifts derivative-based techniques were implemented (in the specified example the derivative technique is visualized). The derivative of a signal is calculated and the points with the maximum derivative values are selected as peaks-coordinates. When dealing with real-world applications several additional processing steps are made (like signal filtration to reduce the noise power, averaging to minimize the influence of random fluctuations, etc.). An important moment worth mentioning is signal distortion due to the propagation of the electromagnetic wave and the dissipation of energy in the liquid (energy loss). That causes the change of the waveform of the reflected pulse depending on the distance where reflection happens, which causes a problem in estimating the time delay T because the waveform was changed compared to the signal emitted. In this case model-based approach is used, where some approximation of a waveform is used for estimation of the specific pulse point position. In case of Gaussian-type sounding pulse the tangent to the graph of the function $U(t)$ at the point where the time derivative of this function has an extremum – $t_A$ (point $A$ for the sounding pulse and $A'$ for the reflected pulse). Those points are used for the approximation of a rising edge with some model, e.g. straight line or a spline. The coordinates of the start points for the sounding and reflected pulses (points $t_s$, $t_r$ on Fig. 1) are calculated as the intersection points of the baseline and approximated lines.

Simplified baseline calculation is performed using a selected portion of the initial waveform - a part of a signal before the sounding pulse. The manufacturer/user specifies a region based on parameters estimated during a production process or specific application. In this case, the baseline is assumed to be a constant value over the time-axis, while still recalculating each run as a simple mean/median value for the part of the signal. This approach works significantly better than simple thresholds for peak time delay measurement because it's less sensitive to the baseline drift. But, in case of signal distortions in the preselected area, baseline calculation is biased which leads to the error in pulse-start points estimation. To overcome this issue 2 approaches were tested: in the assumption of constant-value baseline model and in the assumption of polynomial baseline model (for 2 cases: both for all data given and for data with pulses regions excluded). The optimization technique was used to estimate the baseline parameters similarly to approaches in [5, 7]. The model used for the estimation of the baseline included the data on the voltage measurement uncertainty based on the data provided by the ADC manufacturer.

***Results and Discussion.*** The mean & maximum absolute values of nonlinearity of the level measurement channel were compared for all cases. It's crucial to emphasize that our research focuses solely on the nonlinearity component in the total channel measurement uncertainty(other uncertainty sources or interference were not accounted). For our analysis, we estimated a polynomial baseline model, excluding pulse regions from the data. When compared to the traditional method (which derives a constant baseline value based on a predefined signal region), the mean nonlinearity value dropped from 0.97 mm to 0.67 mm. Concurrently, the maximum nonlinearity value also declined from 5.6 mm to 3.01 mm. This was assessed over 14 sensor-length points, for a maximum uncertainty in distance estimation allowed of ±0.15 mm.

Looking forward, it's necessary to assess the resilience and robustness of this technique against varying interference levels. The baseline might fluctuate over time due to factors like temperature changes or material buildup on the sensor. Therefore, studying baseline stability and tracking is essential. Moreover, understanding the nature of baseline shifts and related signal changes could enhance accuracy or aid in detecting equipment malfunctions.

The applied method for baseline estimation and subsequent corrections notably enhanced the linearity of the level measurement channel. Future research should delve into baseline model evaluation in relation to sensor hardware specifics, like its probe profile, etc. Such insights could streamline and optimize baseline estimation, potentially reducing computational demands. This would pave the way for efficient real-time processing, even on constrained hardware with small resources to solve optimization tasks.

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## МЕТОД КОРЕКЦІЇ БАЗОВОЇ ЛІНІЇ ДЛЯ ІНТЕРПРЕТАЦІЇ ПОЛІМЕТРИЧНОГО СИГНАЛУ

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**Анотація.** Досліджено вплив базової лінії на невизначеність вимірювання рівня поліметричною системою. Використання поліноміальної моделі базової лінії дозволило значно поліпшити показники нелінійності вимірювального каналу порівняно з традиційним методом. Перспективним напрямком подальшого дослідження є вивчення стабільності та стійкості методу до завад та впливів, оптимізація алгоритмів оцінки/корекції базової лінії для ефективної обробки із використанням обмежених обчислювальних ресурсів.

**Ключові слова:** базова лінія, корекція, поліметричні системи, обробка сигналів.

УДК 681.1:681.5

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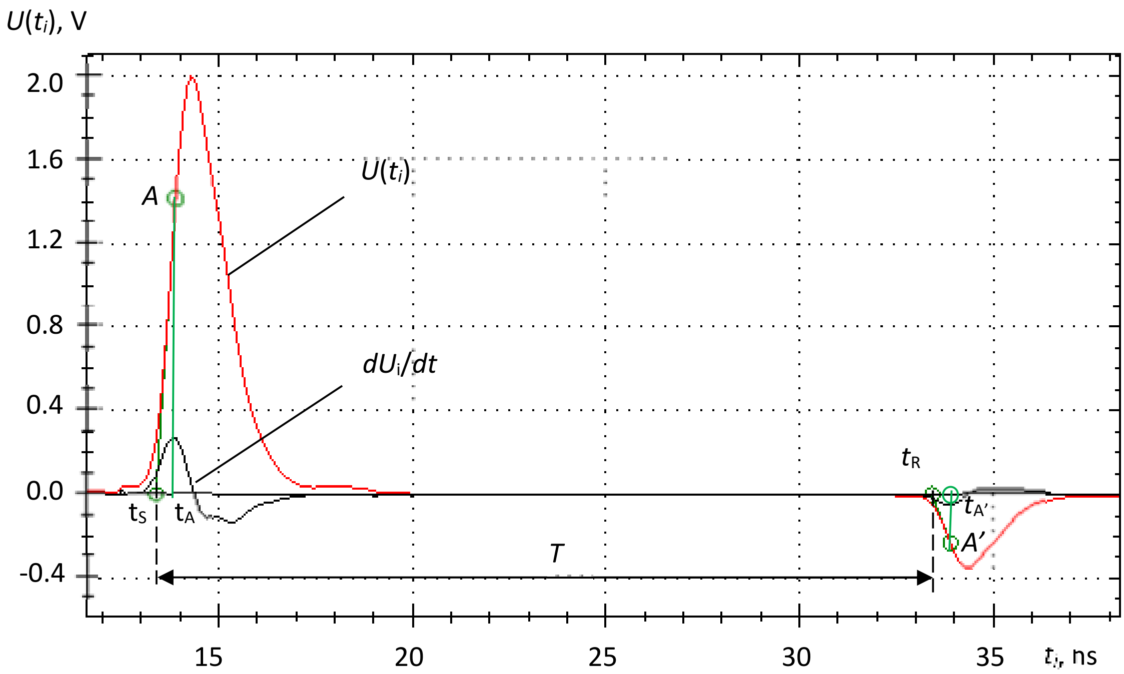


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The proposed method for baseline estimation and subsequent corrections notably enhanced the linearity of the level measurement channel. Future research should investigate baseline model evaluation concerning sensor hardware specifics, like its probe profile, etc. Such insights could speed up and optimize baseline estimation, potentially reducing computational demands. This would pave the way for efficient real-time scale processing, even on constrained hardware with small resources to solve optimization tasks.

## References


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**Анотація.** Досліджено вплив базової лінії на невизначеність вимірювання рівня поліметричною системою. Використання поліноміальної моделі базової лінії дозволило значно поліпшити показники нелінійності вимірювального каналу порівняно з традиційним методом. Перспективним напрямком подальшого дослідження є вивчення стабільності та стійкості методу до завад та впливів, оптимізація алгоритмів оцінки/корекції базової лінії для ефективної обробки із використанням обмежених обчислювальних ресурсів.

**Ключові слова:** базова лінія, корекція, поліметричні системи, обробка сигналів.