

Legal Metrology and System for Calibration and Verification of the Radar Level Sensors

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ABSTRACT

Purpose: The paper deals with the legal metrology that is principally responsible for assuring the uniformity and correctness of measurements and presents the results of the scientific and research work in the cross-disciplinary fields. The design of the new measuring system for the verification of the radar level gauges.

Methodology/Approach: The requirements on performing verification of the measuring instruments are changed significantly, especially the requirement for reducing the time necessary for putting the measuring instruments out of service. Slovak legal metrology (SLM) has developed a number of its own systems for verification of the legally controlled measuring instruments.

Findings: The paper presents the results of the research activities aimed to refine and improve metrological continuity and metrological control of selected types of measuring instruments.

Research Limitation/implication: This paper are based on the theoretical and practical knowledge from the field of metrology, the analysis of the legislative and normative requirements on the measuring instruments metrological assurance, and knowledge gathered during the practical performance of the measuring instruments metrological control.

Originality/Value of paper: In the paper, there are presented those results of solving the tasks in the research and development fields that lead to the higher measurement accuracy, and to the elimination of the undesired influences that may occur during a measurement.

Category: Technical paper

Keywords: legal metrology; measurement accuracy; radar level gauges; measuring instrument; uncertainty

1 INTRODUCTION

The legal metrology is the metrology applied in the practical life in order to assure the uniformity and correctness of measurements both on the national and international levels, creating thereby conditions for eliminating the technical barriers to trade and assuring the adequate protection of consumers. The legal metrology belongs to the technical regulations and requires for its operation a set of legislative and normative documents specifying the requirements on measurement procedures and measuring instruments. In the Slovak Republic, the basic terms for such a regulation are stipulated in the Act No. 142/2000 Coll. on metrology and in the implementing rule Decree No. 210/2000 Coll. on measuring instrument and metrological control. The Act on metrology specifies the legally controlled measuring instruments, that means the instruments used for measurements related with payments, health, security, property and environment protection that are liable to the mandatory metrological control before being put on the market, or in operation. Under the term the metrological control in operation (in use) the verification of the measuring instrument shall be understood that means the confirmation that its metrological characteristics are in compliance with the required metrological characteristics stipulated in the above mentioned Decree (Zgodavova and Slimak, 2008; Zgodavova, 2010). The radar level gauges also belong to the group of the legally controlled measuring instruments. They are used in the industry in relation with the storage of liquid and loose materials (Liberman, 2012). The verification and calibration of these level gauges are the subject matter of the present article, in which the current status of the measuring systems for the level gauges control is described, including the description of the new designed equipment that contributes to reduce the impact of the measuring system arrangement on the measurement result.

2 EQUIPMENT FOR THE CALIBRATION AND VERIFICATION OF THE RADAR LEVEL GAUGES

In case of the automatic level gauges, two principles of the level height measurement are used: the contact and the non-contact ones. In case of the contact method, the liquid level height sensor is usually the float being in contact with the measured medium, while the float is immersed into the medium completely or partially. The non-contact (electronic) way of measurement uses the principle of the electromagnetic waves radiation and their reflection from the measured medium. Thanks to the progress in the field of electronics, the non-contact method becomes even more currently used – nowadays, we may observe the increase in number of non-contact level gauges, especially the radar ones (Oréans and Heide, 2000). The radar level gauges not only prove the good metrological properties, but they show a number of practical advantages as well, such as safety, absence of any movable mechanical parts, and their capability to function under the adverse environmental conditions (fog, high temperature, high pressure, aggressive ambient conditions). The initiative to develop a measuring

system for the calibration and verification of the radar level gauges came from their manufacturers and suppliers themselves (Trebuňa, 2014; Pekarčíková, 2014; Popovič, 2015). The automatic level gauges are rather often used also for measurements related with payment purposes, as the legally controlled measuring instruments under the Act on metrology (Motzer, 2000).

2.1 Physical principle

The radar level sensors are based on two operating principles: the pulse radar sensor (TOF – Time of Flight) and the frequency modulated radar sensor (FMCW – Frequency Modulated Continuous Wave).

Pulse radar sensor

The basis for the distance determination is the measurement of the signal transition path time. The short clusters (so called packets) of the electromagnetic pulses of some milli or nanoseconds are sent by the transmitter, they bounce off the measured material, return back and are caught by the receiver. The number of waves and pulses times depend on the transmission frequency. The time delay of the transmitted packets is relatively long, enough for catching their reflection by the receiver. The time difference t_d between the transmitted and received pulse is equal to the time that the signal needs to pass the distance from the transmitter to the measured material and back, i.e. double of the measured distance. The measured distance L is continuously calculated using the formula:

$$L = \frac{c \cdot t_d}{2} \quad (1)$$

where c is the speed of the electromagnetic waves propagation (see Fig. 1) (Burenin, Pakov and Sizikov, 1998; Gu et al., 2014).

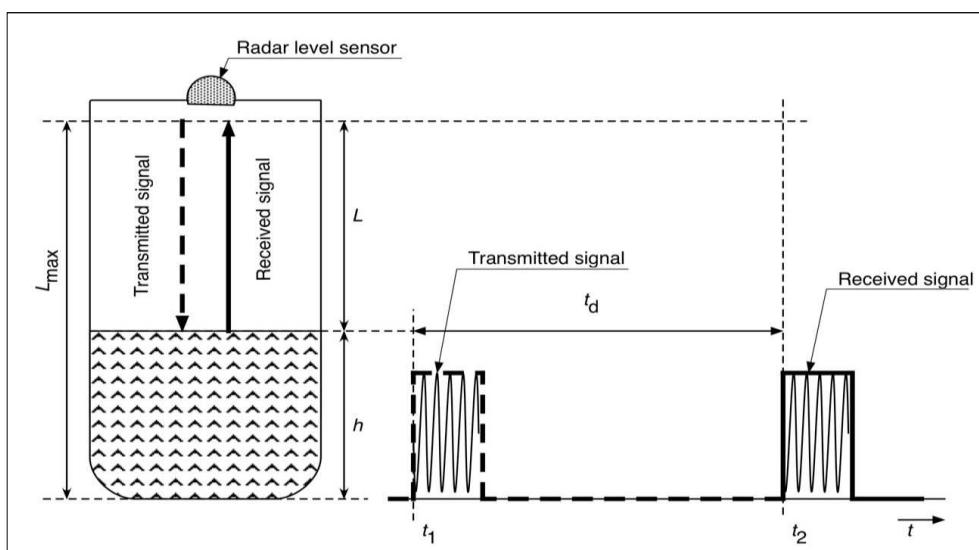


Figure 1 – Operating principle of TOF radar level sensor

Frequency (FMCW) radar sensor

The frequency modulated signal is transmitted continuously towards the measured object. The time slope of the transmitted frequency is linear and usually it has the saw-toothed shape. The reflected and received signal is compared with the transmitted signal, while the frequency difference f_d is measured corresponding to the time difference t_d for the calculation of the measured distance L . The frequency difference may be measured very precisely, and therefore also the measured distance may be determined with a high accuracy (see Fig. 2) (Kim and Lee, 2012; Wang et al., 2013; Mikuš and Hart'anský, 2013; Mikuš, Hart'anský and Čičáková, 2014).

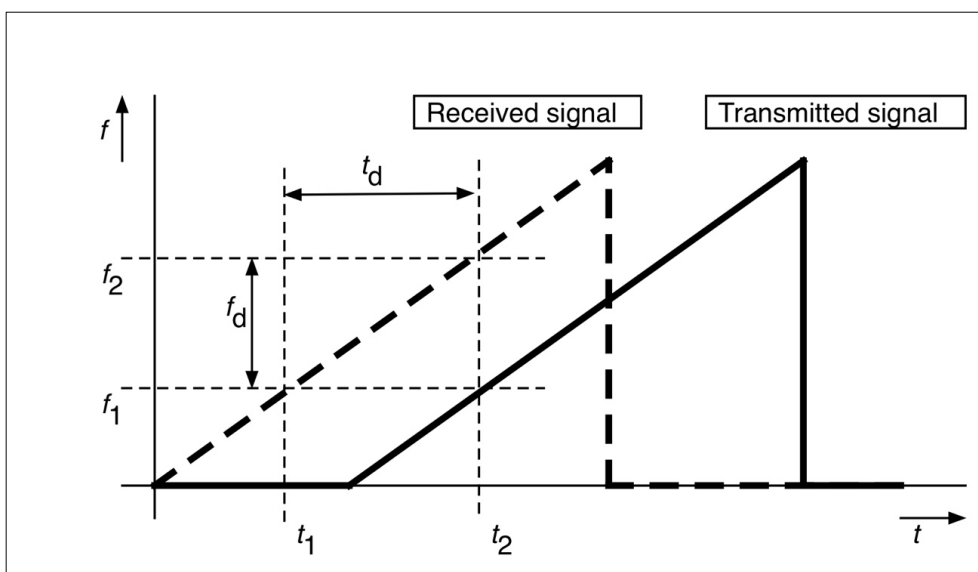


Figure 2 – Operating principle of FMCW radar level sensor

2.2 Legislative and normative requirements

When designing the above mentioned measuring system, the requirements of Decree No. 210/2000 Coll, Annex No. 68 "Automatic level gauges" on measuring instruments and metrological control were taken into consideration specifying both the requirements on maximum permissible error and methods of the level gauges verification. In addition, the design observes also the requirements of the International recommendation of OIML R 85 (Palenčár and Halaj, 1999; Palenčár, Kureková and Halaj, 2007).

2.3 Principle of operation and description of realized measurement systems

The operational principle of the original measuring system is based on the simulating the change of level using the reflection board - its distance from the calibrated/verified level gauge is measured by the laser interferometer

(Michalecki, 2001; Wei, Xu and Ma, 2013). For the scheme of the realized measuring system for the level gauges calibration see Fig. 3. The reflection board (2) is mounted on the linear guide runner (1) of the total length of 16 m. The angle of the reflection board may be set in two axes - vertical and horizontal - so it is set perpendicularly to the axis of the verified level gauge (4). The linear displacement of the reflection board is assured horizontally. The tested level gauge (4) is placed on the measurement table over which the standard - the laser interferometer is mounted (3) (Kim and Nguyen, 2003). The axes of the both devices shall be precisely aligned before the measurement, as any misalignment causes the cosine error of measurement. The precise appliances were prepared for fixing the measuring instruments (Mikuš, Hartánský and Smieško, 2016).

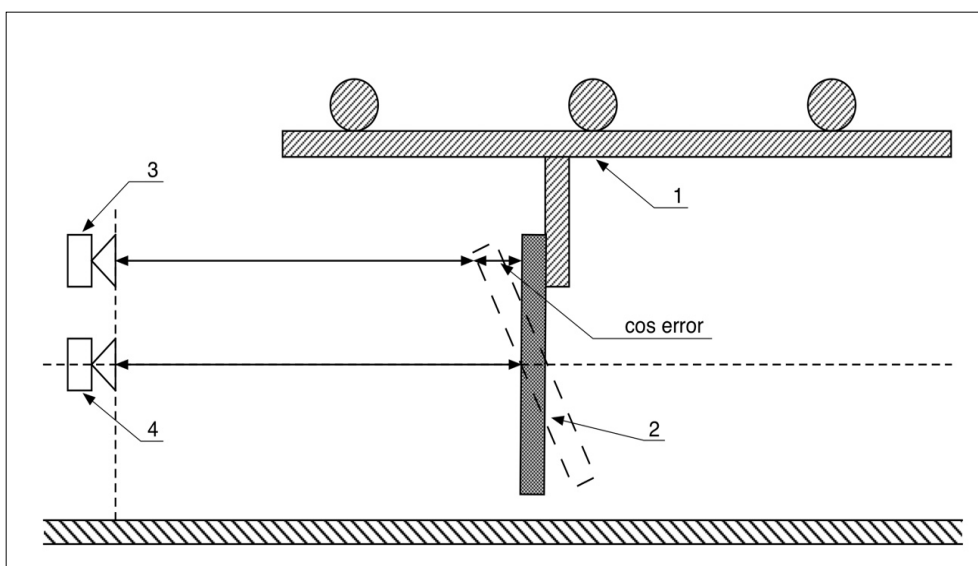


Figure 3 – Scheme of the original measurement system for calibration and verification of level gauges

In order to eliminate the cosine error, the new arrangement of the measuring system was designed. Therefore, in the new system, the interferometer is placed behind the reflection board; so its radiated beam is aligned with the radiated beam of the electromagnetic wave of the radar level gauge. This arrangement is shown in the Fig. 4.

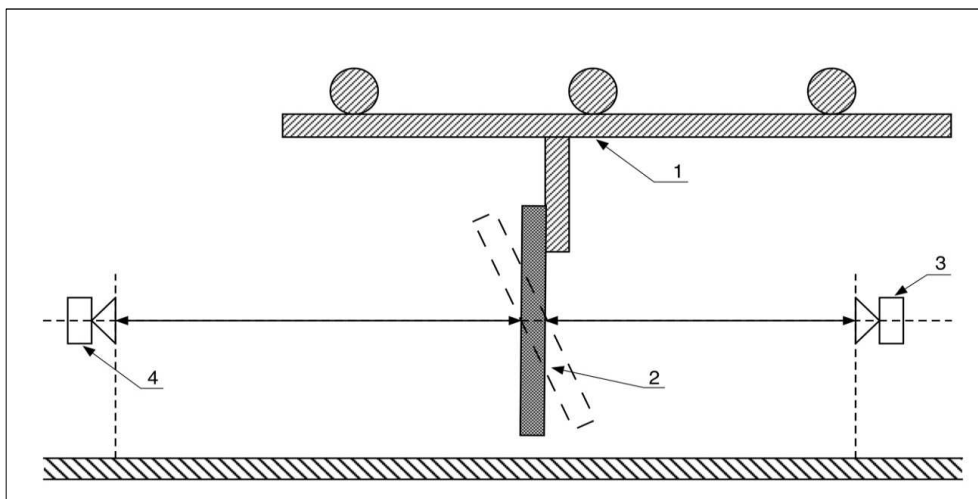


Figure 4 – Scheme of the new measurement system for calibration and verification of level gauges

Reviewing the benefits of the new arrangement of measuring system

In order to assess the new arrangement, the measurements before and after the adaptation of the measuring system were performed. The measurements were carried out within the length from 2 m up to 10.5 m in steps of 0.5 m so that the equal measurements conditions were assured. The measured results are recorded in the chart (see Fig. 5).

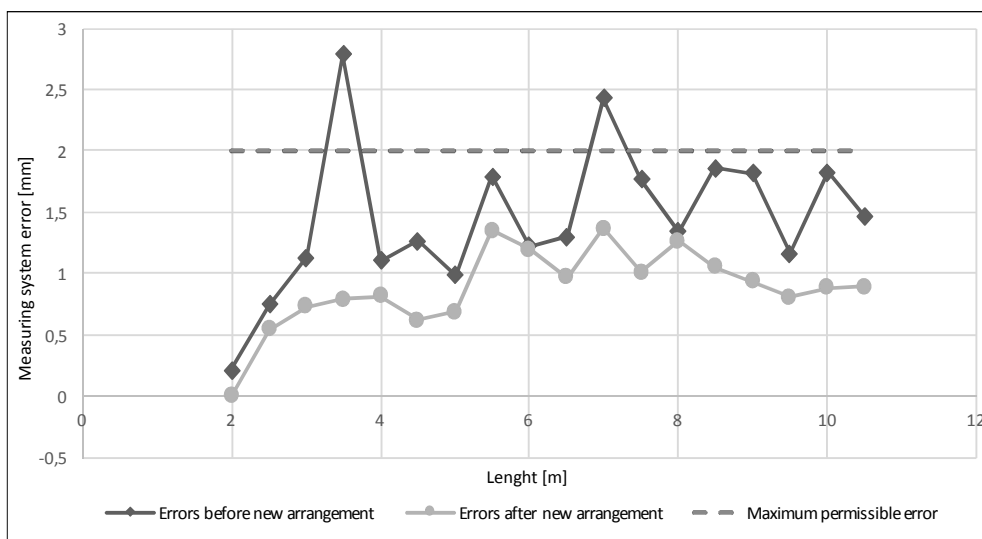


Figure 5 – Comparison of the measured values

The chart of the measured values shows clearly that the new arrangement of the measuring system resulted in the decreased influence of the cosine error on the measurement result.

3 CONCLUSION

The radar method of the level measurements is getting under the spotlight still more and more; nevertheless the main obstacle for putting the respective legally controlled measuring instruments on the market up to now was the insufficient metrological assurance of the radar level gauges. The necessity to solve this situation resulted in the development of the new measuring equipment construction. However, this equipment had some gaps due to the cosine error. The new arrangement of the measuring system eliminated this default so that the error contribution caused by the original arrangement was decreased.

The use of the developed equipment will not be limited only to the radar level gauges, but it will enable to calibrate and verify also the level gauges operating on different measurement principles.

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