The Errors in Radar Level Gauge Calibration

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Abstract. *This article deals with the verification of the radar sensors. These are very accurate devices but they are vulnerable to distortion of the measured value due to false reflections. This is an assigned measure, therefore it is necessary to ensure that the results are fixed and reproducible. It puts the request on geometry and optimalization of the environment to minimize the false reflections and in this way achieve the highest accuracy measurement.*

Keywords: *Radar Level Gauge, Verification, Reflections, High-Frequency Wave, Radiation Patterns.*

Introduction

The radar level gauge is a device which measures the distance by using indirect method in a contactless way. It consists of two basic parts: a transmitter and a reciever. The transmitter consists of a signal generator and a directional antenna. The receiver is composed of a directional antenna, an amplifier, a decoding device, a circuit with the volltage comparator and a powerline circuit. The transmitter and the receiver are integral. The latest sensors are not sensitive to the changes of temperature, pressure, density and the composition of the gas in the measuring environment. The radar sensor uses a continuous frequency modulation.

Continuous frequency modulated system

The most of the latest level sensors works through the continuous frequency modulated method. It uses a measurement of the distinction of the transmitter and receiver frequencies. The transmitted frequency is swept between two known values f_1 and f_2, and the distinction between the transmitted signal and the return signal is measured.

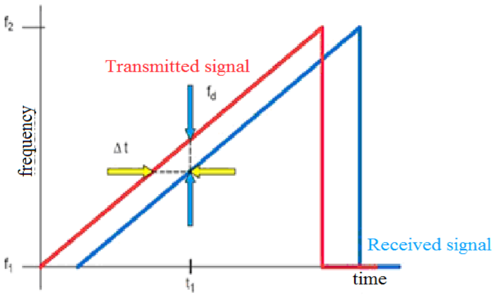

Fig. 1. The principle of the method "continuous frequency-modulated signal"

The principle of verification level gauges

Department for verification of radar sensors is located at the long corridor in the building SLM n.o. on the ground floor. Under the ceiling of the corridor (2.20 m high) are fixed beams which hold the metal guide rail. On the metal bar moves reflection board with the assistance of a toothed belt and a servo drive. This reflection board simulates water level in the tank. At one end of the hall is located a massive rack that holds the calibrated level gauge of 1.35 m above the floor and the etalon of the length - the laser interferometer XL 80. In this way of verification occur several disturbances. Unless unlimited space is available, there appears disturbing reflection. The radiation angle of level meter is 10 °, the width of the corridor is 1.93 m and the beams are 0.85 m distant. From these data we can calculate when there appear parasitic reflections. [1]

$$tg\alpha = \frac{d}{x} \Rightarrow x = \frac{d}{tg\alpha} = \frac{0{,}85}{tg6{,}5} = \frac{0{,}85}{0{,}11394} = 7{,}46\,\text{m} \qquad (1)$$

d – distance from the ceiling

There are reflections from the beam at a distance of about 7 m in our conditions. It means that there will occur distortion of measured values if the measuring distance is longer than 7 m . We can not change the environment so we must solve this problem in another way. It is necessary to focus a ray in a way to avoid reflection from the walls of the environment where the verification is carried out. One of the solutions is to build an anechoic wall which absorbs electromagnetic waves earlier than the parasitic reflection occurs. The next problem is to provide uprightness of the reflection board towards level gauge (If the uprightness is insufficient it can cause the distinction between the rays flating on the top and bottom part of the board and thus the distance measurement error). The shape, location and the edges of the board affect the extension of radar waves and therefore it also affect the process of verifing accuracy of the level gauges.

Minimizing the false reflections

In order to avoid or to minimize the formation of false reflections, it is important to send the sharpest ray without side lobes. This will ensure that the ray will turn out just to the reflection board and there will not form the false echoes. The figure (see Fig. 2) shows two types of radiation patterns and reflections which occurs in each type.

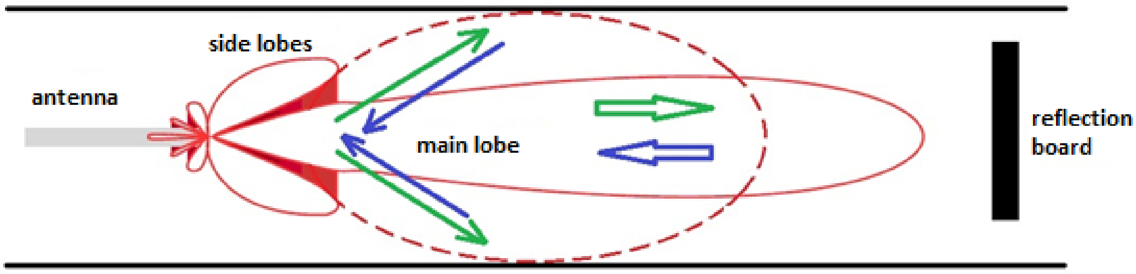

Fig. 2. Undesired reflections in the verification of level gauges

As we can see, if the ray is sharper there will occur only primary reflections on the reflection board which is desirable. If the ray is wider there will occur not only primary reflections but also false reflections of the radar signal. In this case interference of multiple signals appears which significantly change the final measured value. The borderline cases can be seen in the figure (see Fig. 3a). Another problem in the process of verification of level gauges is the formation of side lobes a directional patterns. It is caused by the reflection board itself. This phenomenon can be caused by diffraction on the edges of the reflection board. Diffraction or bending is a change of the spreading way of radiation because of the barrier. As it can be seen in the figure (see Fig. 3b) there can occur two cases. Only one side of the barrier is lightened or the both sides of the barrier are lightened. In the first case: in the area: 0 to $\pi-\varphi$ appear all the field components namely - incidental, reflected and bending fields. In the area: $\pi-\varphi$ to $\pi+\varphi$ occur reflected and bending fields. In the next area: $\pi+\varphi$ to α exists only bending field. In the second case, if the both sides are lightened we can see the following situation: In the area 0 to π−φ and 2α−π−φ to α appear all the fields. The area π−φ to 2α−π−φ includes incidental and bending fields. [2]

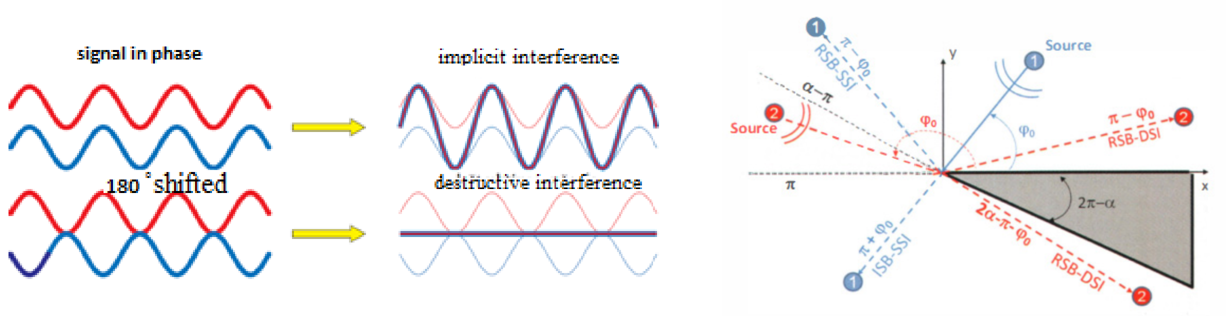

Fig. 3. a) Constructive and destructive interference, b) geometry of diffraction on the edge

In the formation of diffraction can be significantly changed the shape of the directional patterns of level gauge. This could negatively affect the results of verification.

Results

To be able to assess the effect of the environment (in this case – reflection board) in the process of verifing the radar level gauges we must simplify the situation in a way that the verification process affects only one factor. So we placed all the verification department in a fictitious, infinitely vast, homogeneous and linear space. In this space, using numerical methods, (Method of moments) we calculated radiation patterns of radar level gauge Fig. 4a. In the picture is microwave emitter, parabolic reflector (diameter: d= 441 mm) and the radiation patterns obtained at a freqency of 10 GHz and powering emitter voltage of 1 V. The width of the sheaf of the radiation patterns can be read from Fig. 5a – more thickness curve.

Fig. 4. a) Antenna of the level gauge and its radiation patterns, b) irregularly shaped absorber

In the next step, we add to the environment perfectly conducting board of finite dimensions *a* x *a* = 60 x 60 cm. On board occurred a reflection of electromagnetic wave on the face side and diffraction of waves at the edges of the board. These two physical mechanisms affect the shape of the radiation patterns. Width of the main lobe sheaf was increased to 40 ° in Fig. 6 - blue curve. This will increase the probability of parasitic reflections of electromagnetic ray and the degradation of the verification, see Fig. 2. It is important to minimize such components of the reflected waves which cause the extension of the main lobe of radiation patterns. Such components are primarily diffraction fields. In order to suppress diffraction at the edges we covered edges of the reflection board with the absorbing material [3], which followed the edges of the board. Simulation results are shown in Fig. 5b – more thickness curve. As can be seen from the figure, the main lobe of radiation patterns was not changed, and the results were not satisfactory. In the next step, we modified the outer edges of the absorber into the irregular shape (see Fig. 4b).

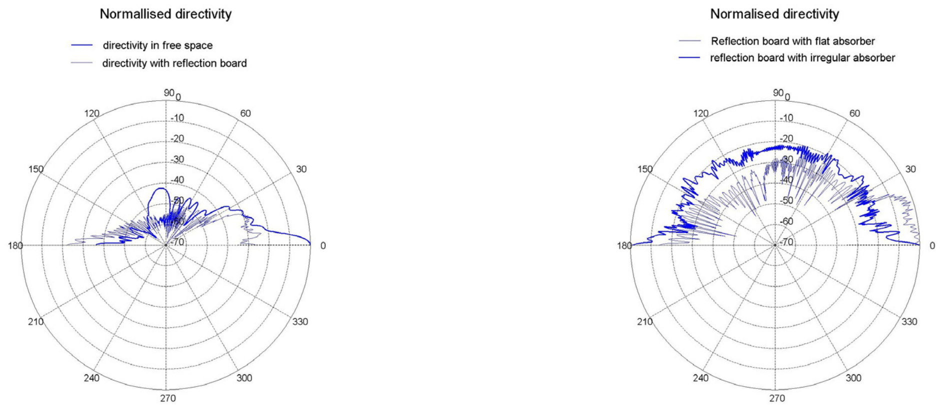

Fig. 5. a) Comparison of emitted ray with and wihtout reflection board, b) comparison of absorbers with straight and curved edge

The results can be seen in the picture (see Fig. 5b) - blue curve. Originally, the HPBW of the main lobe of the radiation patterns was 40 ° and after modification of the shape of the absorbers was this HPBW reduced to about 2 °, which is extremely satisfactory result. This means that adding of the reflection board will only reflect the electromagnetic ray, and not to change the HPBW of the sheaf. This result is for the verification of the accuracy and reproducibility of microwave level gauges very important.

Conclusions

To ensure the accuracy and reproducibility of measurements in the process of verifying microwave level gauges we need to make a number of mechanical and electrical requirements. This article focused on ensuring the narrow HPBW of the sheaf of the radiation patterns. The narrow sheaf will minimize occurrence of the parasitic reflections from the walls or the construction of the verification department. Suitable shape of the radiation patterns, in the presence of the reflection board, was provided by placing irregularly shaped absorbers are secure location on the edge of the reflection board. The type and the shape of the absorbers ensure the sheaf reduction from 40° to 2°.

Acknowledgements

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-0333-11 and by the project VEGA VG 1/0963/12.

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