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A breadboard model of the measuring probe of a new type for the measurement of multiphase environments levels

The paper presents the results of experimental research of a measuring probe of a new type containing variable localized loads. The microwave diodes HSMS-8202 have been used as the variable loads. The reflectograms of responses for the different control voltages are presented. The obtained results show that microwave diodes can be used as variable loads for implementation of the proposed measuring probe.
Keywords: level measurement, TDR, method, measuring probe, variable load.
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One of the standard processes of modern industry is the measurement of contents in containers and tanks. Moreover, the content may be a combination including several environments with a layered structure and different properties. In the presence of a multilayer structure in a tank, an important task is to analyze this structure including determination of the number of layers and locations of layers' boundaries. An example is the task of monitoring layer-by-layer composition of liquids at the stage of oil-product clearing, which requires the determination of the oil, the bottom water and the emulsion layers.

The solution of such task is possible with the use of a limited number of methods. One of such methods is the time domain reflectometry (TDR) [1–5]. The article [5] contains a detailed overview and analysis of existing papers describing application of the method in the multiphase liquid measurement area.

In TDR the level location is determined based on the delay of the pulse signals reflected from the phase boundaries (responses). The response delay depends on the layer length and the signal propagation velocity, which, in turn, depends on the environment properties. The determination of the signal propagation velocity in each layer is quite a difficult task. In most existing technical solutions the determination of the signal propagation velocity is based on the use of: 1) the reference data about the measured environments; 2) the data received during a calibration procedure. However, the used data may not correspond to reality at the time of measurement, which can lead to a significant error [6].

Thus, a relevant task is to find an approach which can determine the multiphase liquid layers' properties in real time. It must allow us to determine the signal propagation velocities in the layers with high accuracy, thus increasing measurement reliability and precision.

Proposed solution

The task can be solved by the method proposed in the work [6], the base of which is the use of a special design of the measuring probe including so-called artificial discontinuities – the variable loads. It is worth mentioning that their localization along the probe is known in advance and their properties can be changed at the right time. In Fig. 1 the model of the proposed solution is shown.

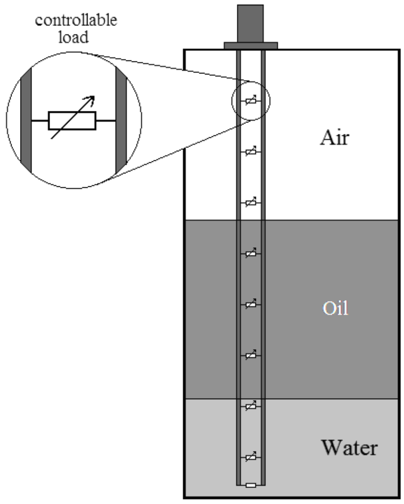

Fig. 1. Model of the measuring probe with variable loads

The advantage of the proposed design is that during the measurement it is possible to purposefully change the reflectogram of a researched object due to the change of the variable loads properties. It means that a reflectogram, in some way, is an extensional view of a measuring probe immersed in the researched environment, where the change of properties of an artificial discontinuity will allow us to localize the response from this discontinuity. As a result, the presence of such «reference» points on the reflectogram provides ample opportunities for research and analysis of the received data.

The procedure includes two operating modes:

1) *calibration mode,* where the condition of the variable loads is successively changed and the parameters of the investigated environments are determined;

2) *measurement mode,* where the multiphase liquid levels are determined based on the data received during the calibration mode.

The detailed description of the operation algorithm and its modeling are shown in [6]. It is worth mentioning that the article describes the ideal case, in which the properties of such variable load can be changed independently and within limits from the ideal matching with the transmission line to the full signal reflection mode.

In practice achievement of even approximate characteristics is quite a difficult task. Thus, it is expedient to designate the conditions that are instrumental to provide the described above functionality of a measuring probe:

1) in the measurement mode the influence of the variable loads on signal propagation should be minimal;

2) in the calibration mode it should be possible to identify responses from the variable loads, i.e. each response from the variable load on the reflectogram must be related to the variable load from which this response is reflected.

Experimental research

The purpose of this experimental research was to evaluate the possibility of using microwave diodes as the variable loads.

The control signal (the signal used to change the properties of the variable loads) in this case is a constant voltage (offset voltage), and its modification leads to a change in the state of the microwave diode. A clear advantage of this solution is the ability to control the parameters of the loads using the same line which is used for signal transmission, i.e. additional conductors are not used.

In Fig. 2 you can see the experimental setup layout including the following parts:

– pulse generator;

– sampling oscilloscope;

– z-matched pickoff tee;

– bias tee;

– variable TDR probe (VTDR Probe).

To obtain the test signal, the generator Geozondas GZ1105DLP2, the pulse shaper GZ1117DN-35 and attenuators were used. This set provided an amplitude of the output signal less than 1 V and duration about 40 ps. The generated signal was fed through the z-matched pickoff tee Picosecond 5372 to a sampling oscilloscope DSA 8300 and to the researched object connected through a bias tee Picosecond 5545, which was used to add the offset voltage.

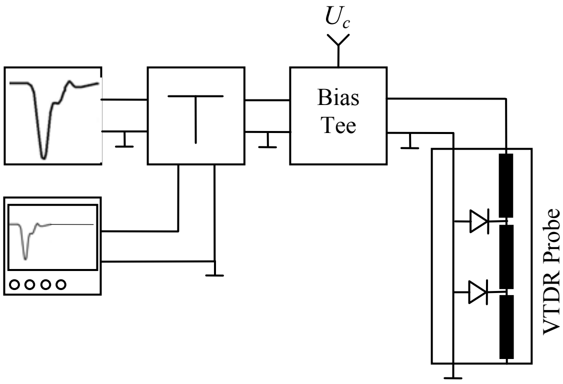

Fig. 2. Experimental setup layout

To analyze the control modes of pulse responses, a fragment of the measuring probe performed as a section of a coplanar waveguide including a microwave diode HSMS-8202 was made. The cathode of the diode was connected to the signal conductor, the anode – to the earth conductor. A negative pulse signal with different offset voltages (0, 1 and 2 V) was applied to the input of the probe.

In Fig. 3 the responses from the diode with different offset voltages are shown.

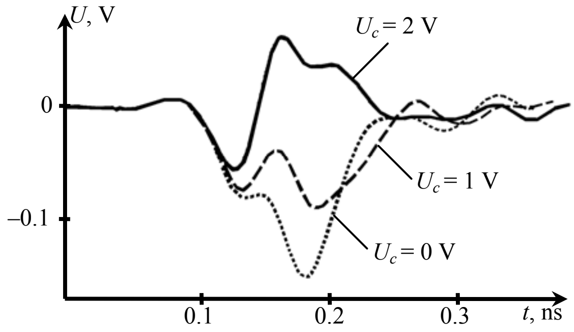

Fig. 3. Responses from the microwave diode with different offset voltages

In the case of the offset voltage absence (U_c = 0 V), the diode switches to the open state, that leads to a response with an amplitude of about 0.15 V. If there is a small positive offset voltage (U_c = 1 V), the diode switches to the open state only in part. With a further increase of the voltage (U_c = 2 V), the diode remains in the close state. The response in the close state is explained by the parasitic parameters of the microwave diode.

Figure 4 depicts the photo of the transmission line with the variable loads, placed at the distance 60 mm and 220 mm from the entrance of the line. The length of the line is 280 mm.

Fig. 4. Photo of the transmission line with two controllable loads

Figure 5 depicts the reflectogram of the described transmission line with the offset voltage $U_c = 0$ *V* (dashed curve) and $U_c = 2$ *V* (solid curve).

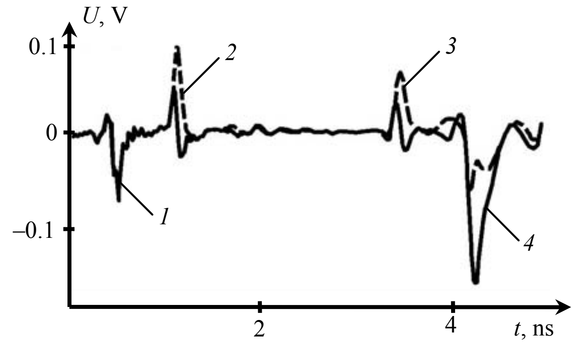

Fig. 5. Reflectogram of the transmission line with two variable loads

On the reflectogram (Fig. 5) the following signals can be defined: the response from the entrance of the line (pos. 1); the responses from the first (pos. 2) and the second (pos. 3) variable loads; the response from the end of the line (pos. 4).

Figure 6 shows the reflectogram of the VTDR breadboard model, which was partially immersed in a liquid. The distance from the transmission line entrance to the phase boundary air-liquid was about 180 mm. The dashed curve corresponds to the mode without offset, the solid curve – to 2 V offset voltage.

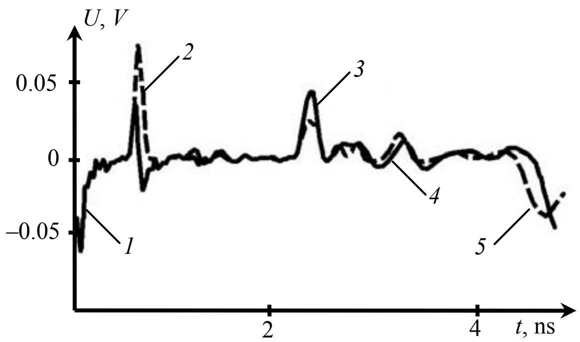

Fig. 6. Reflectogram of the partially immersed transmission line with two controllable loads, where *1* – response from the entrance of the line; *2, 4* – responses from the first and the second diodes; *3* – response from the phase boundary air-liquid; *5* – response from the end of the line

It is clearly seen that the offset voltage rise leads to a decrease of the response amplitude from the controllable loads, which results in an increase of the response amplitude from the air-water phase boundary and the end of the line. This fact may serve as a criterion for identification of the responses from the controllable loads. It should also be noted that the high reflection coefficient from the air-liquid boundary leads to a decrease of the amplitude of the response from the second diode.

Conclusion

The paper describes the results of prototyping the measuring probe containing variable loads, represented by microwave diodes. The reflectograms of responses from the diodes with the different control voltages are presented. The obtained results show that microwave diodes can be used as variable loads for implementation of the proposed measuring probe. The variable TDR probe with the discontinuities, which are made as microwave diodes, can be used for automatic determination of layers' parameters in the process of measurement. Advantages of this solution are the absence of additional lines for the transmission of the control signal and the simplicity and low cost of the implementation.

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Тренкаль Е.И., Лощилов А.Г.

Макет измерительного зонда нового типа для измерения уровней многослойных сред

Представлены результаты макетирования измерительного зонда нового типа, содержащего управляемые сосредоточенные включения. В качестве включений использовались СВЧ-диоды HSMS-8202. Приведены рефлектограммы откликов от включений при различных управляющих напряжениях. Полученные результаты показывают, что СВЧ-диоды могут использоваться в качестве управляемых включений для реализации предложенного измерительного зонда.

Ключевые слова: измерение уровня, TDR, метод, измерительный зонд, управляемое включение.

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