EXPRESS MONITORING OF DIELECTRIC LIQUIDS' PERMITTIVITY

Yu. N. Pchelnikov*, Senior Scientist, Raisa M. Dymshits, Executive Director, SloWaveS, Inc., 104 Drexelbrook CT, Cary, NC 27519,

Among many different methods of liquids' permittivity monitoring are two the most popular methods: capacitive, operating at low frequency, and microwave, using sections of transmission lines or waveguides as sensitive elements. A disadvantage of the first one, capacitive method, is its low accuracy caused by a very large value of the measured capacitive impedance $1/j2\pi fC$. At relatively low frequency this impedance can be comparable or can exceed the resistance of the monitored liquid. For example, while the specific impedance of an air gap is equal to *1.8 Mohm/M* at *10 kHz*, the specific resistance of river water is equal to *1 kohm/M*. This makes impossible to measure a water permittivity at this frequency.

The simplest way to convert a measured capacitance to an informative signal is connecting the sensitive element to an inductor and measuring a resonant frequency of the resonant circuit formed by the sensitive element an inductor. Due to the large impedance of the sensitive element, the resonant frequency of such circuit is very sensitive to the errors caused not only by finite resistance of a monitored liquid but also by other sources of errors such as parasitic capacitance of all elements forming a measuring circuit. It should be underlined that in many cases the measured capacitance can be of the same order that the mentioned above parasitic capacitances.

The second, microwave method, more often named as the radio-wave method of measurements, is widely used in Industry, including for different liquids' parameters monitoring [1]. This method is based on using transmission lines as sensitive elements and measuring resonant frequencies of such sensitive elements. Advantages of such measuring systems are: very low dependence of the resonant frequency upon a measuring circuit parameters, high resolution due to the high frequencies, and high absolute sensitivity. However, the Radio-Wave method has some disadvantages among which are: radiation, large electromagnetic losses in conductors and dielectrics, and expensive equipment.

The high accuracy and sensitivity of the radio-wave method and simplicity of the capacitive method can be realized by the third electromagnetic method of measurements, which is based on slow-wave structures (SWS) application [2]. Using transmission lines with slowed waves, SWS-based sensors operate at frequencies *10-100 MHz*, which are low enough to use simple electronics and high enough to obtain a good accuracy. Having advantages Occupying position between capacitive and radio-wave methods SWS-based method has some additional advantages provided by the specific of the SWS application. Among these advantages are:

- Possibility to choose a required field distribution at any reasonable frequency. It is provided by the field distribution dependence not only on frequency but also on deceleration and SWS configuration.
- Small resonant dimensions at relatively low frequencies.
- High absolute sensitivity due to the field concentration in the measuring volume. Though the relative sensitivity is the same for different methods, an increase in an absolute sensitivity is followed by a decrease in errors caused by different interference factors.
- A small radiation due to the field concentration.
- The possibility to use different configurations (patterns of SWS), each configuration providing a different pattern of an electromagnetic field.

In this paper, this novel method is demonstrated on the example of a SWS-based sensor, designed for an express monitoring of the permittivity of different liquids, including water. A section of SWS configured as an interdigital comb on both sides of a temperature stable PCB (Rogers material RO4003C) is connected in series to an inductor, both forming a delay line in the feedback circuit of the modified Pierce oscillator, which is assembled on the same board. The SWS takes part of a sensitive element and is submerged during a measurement into a monitored liquid. A change in the monitored liquid's permittivity causes a change in the SWS's equivalent capacitance that, in its turn, causes a change in the Pierce oscillator frequency. The inductor is formed by coupled arithmetic spirals, manufactured one opposite another on both sides of the same PCB. Using a temperature stable PCB for sensitive element as well as for the inductor provides a very small temperature dependence and allows to measure permittivity dependence on a liquid temperature. The circuit, PCB drawings and results of measurements are presented in the paper.

REFERENCES

1. V. A. Viktorov, B. V. Lunkin, and A. S. Sovlukov, Radio-Wave Measurements of Technology Processes' Parameters, M: Energoatomizdat. 1989.
2. Yu. N. Pchelnikov and D. S. Nyce, Slow-Wave Structures-Based Method of Measurements, IEEE Transaction on Instrumentation and Measurement, Vol. 51, # 5, October 2002, pp. 891-896.