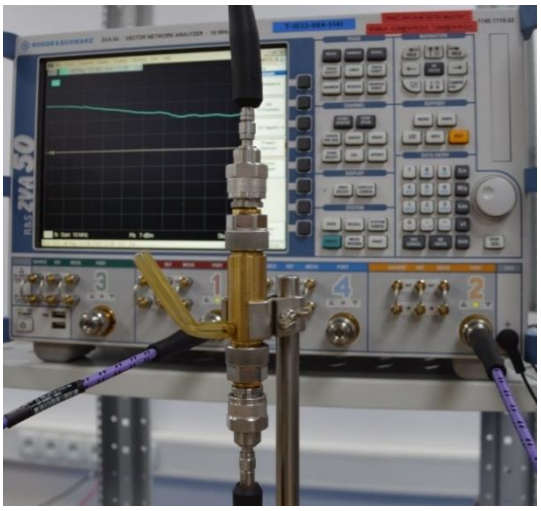
Development of a novel calibration-independent measurement technique for characterizing electrical properties of liquids at microwave frequencies

Probably everyone has ever poured a little too much drink into a glass, but the surface tension of liquid saved it from spilling. If the drink is valuable, this phenomenon is especially desirable. However, it turns out that the meniscus, resulting from surface tension forces, may disturb the results of measuring the electrical properties of liquids.

Although much has been achieved in the field of microwave material characterization, still, new, improved, more accurate measurement techniques are constantly emerging. Generally, measuring a liquid in the microwave band is difficult, because its response is disturbed also by the measuring instrument, which is most often a vector network analyzer (VNA). The key is to mathematically extract the quantities sought (e.g. permittivity). Appropriate processing of results is an art and field for creative work for an engineer.

In the course of our research to date, we have noticed, that taking **the meniscus** into account to the measurement model, it is possible to achieve an improvement in accuracy compared to the classical methods. The meniscus disturbs the symmetrical shape of the sample and changes the conditions of wave propagation. So far, we have conducted research in the so-called semi-open waveguiding structure. That means the liquid is blocked at the bottom with a plug and one can fill it with any volume (the fig. shows a measuring system with a coaxial line that allows measurements up to 18 GHz). Liquid dosing is possible thanks to the pipe attached to a small hole in the body of the cell. To change the level of the liquid column, there is no need to unscrew the system, which has a positive effect on the consistency of the results. The use of measurements of several liquid levels has made it possible to eliminate the effect of the meniscus and an increase in the measurement accuracy. We have performed the measurements using a calibrated VNA. Unfortunately, the accuracy of calibration strongly depends on the accuracy of the standards, and these are very expensive.



We have decided that it is worth investing in this measurement technique and go a step further. **The main goal of this project** is to develop a new method that will not only remove the impact of the meniscus but will also not require VNA calibration. The measurements will be cheaper and simultaneously more accurate. In addition, we want to increase the range of frequency bandwidth and use rectangular waveguides in these tests to be able to characterize liquids up to 50 GHz.

Why is the race for better accuracy still going on? Because the permittivity of liquids is used in many fields of science, technology and industry.

- ✓ In medicine and biology for diagnostics. Interesting research is currently underway on new devices for cell counting by impedance flow cytometry. The suspension of cells flows in a very narrow (so-called microfluid) channel forming a row of individual cells. By observing changes in permittivity, you can determine blood contend and even detect cancer cells.
- ✓ In measurements of the specific absorption coefficient (SAR), which determines a part of the power absorbed e.g. by human body tissue, which is very important in the case of mobile telephony.
- ✓ In the chemical industry to control the concentration of mixtures,
- ✓ in the food industry to control product quality.
- ✓ For designing radio links in unusual conditions (e.g. underwater) and many, many more.

We are convinced that thanks to the development of a new method we will be able to take the next step in a scientific pursuit for better and better measurement accuracy. As a result, it will be possible to create sets of accurate data characterizing the electrical properties of various types of liquids, e.g. used to calibrate the already mentioned microfluidic measuring systems.