AUTOMATIZATION OF THE RESONANT FREQUENCIES AND PERMITTIVITY MEASURING IN THE CYLINDRICAL MICROWAVE CAVITIES

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Abstract - **The application of Hewlett-Packard Visual Engineering Environment (HP VEE) for automatic resonant frequencies measuring in loaded cylindrical metallic cavities as well as for the relative permittivity measuring is presented in this paper. The measurement setup is formed using HP 8757A scalar network analyser and an experimental cylindrical metallic cavity with circular cross-section. The computer program for automatic resonant frequencies measuring is developed. Also, the program for automatic measuring of the relative permittivity of lossless as well as of low loss dielectric material is developed.**

INTRODUCTION

Cylindrical metallic cavities loaded by homogeneous dielectric slabs are often used for modelling of real microwave applicators for thermal dielectric material processing. Understanding the dynamic behaviour of the heating process over a wide range of operating conditions, as well as the behaviour of various resonant mode oscillation in microwave cavities for various load conditions will help in designing and using these microwave applicators. Besides, using of proper numerical method for microwave applicator modelling and efficient resonant frequency determination, the experimental verification has important significance. In order to verify the numerical results the measurement setup should be formed. But, the procedure of resonant frequency measuring takes a lot of time as well as the procedure of resonant mode identification [1,2]. Also, the processing of the measured results takes a lot of time. Because of these, an idea about automatization of the resonant frequency measuring has been appeared.

Numerous methods for dielectric material permittivity measuring are available at microwave frequencies at this time. These methods can be differentiated according to the measurement technique used: the waveguides and/or transmission lines methods which necessitate the measurement of scattering parameters [3]; and the resonant methods which necessitate the measurement of the resonant frequency and the unloaded quality factor [4,5].

A new simple method for permittivity measuring of the lossless dielectric material as well of material with low losses using microwave cylindrical cavities is presented in [6]. This method demands measuring of the resonant frequencies in a loaded cavity with the sample under test as a load, which is placed on the bottom of the cavity (Fig.1), and the unknown load permittivity can be simple determined from measured results. When this measuring procedure is carried out manually, it takes a lot of time.

Using HP VEE software package [7] it could be possible to automate the resonant frequency measurements, the measured results processing, the oscillation mode identification and relative permittivity measuring very simple using the visual concept of programming. Creating the corresponding application using this package reduced to connecting of various object types, by which the measuring set up was managed, as well as the measured results were plotted and saved.

In the aim to automate the resonant frequency measurement the program in HP VEE sofware package is developed. This program has been applied for the resonant frequency measuring of the experimental cavity with circular cross-section.

Also, in the aim to automate the relative permittivity measuring of the lossless dielectric material as well as of material with low losses using a method presented in [6], the program in HP VEE sofware package is developed. This program has been applied for the real part of the complex permittivity of water measuring, which has more pronounced losses.

HP VEE ENVIRONMENT

HP VEE environment is made to develop the application for measurement and testing automatization priority using HP-IB interface. Besides the functions, which are characteristically for classical program language (for

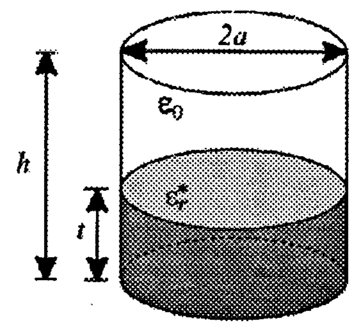

Fig.1. The cylindrical metallic cavity with circular cross-section, which height is h, is loaded by lossy dielectric slab of the thickness t, placed on the bottom of the cavity.

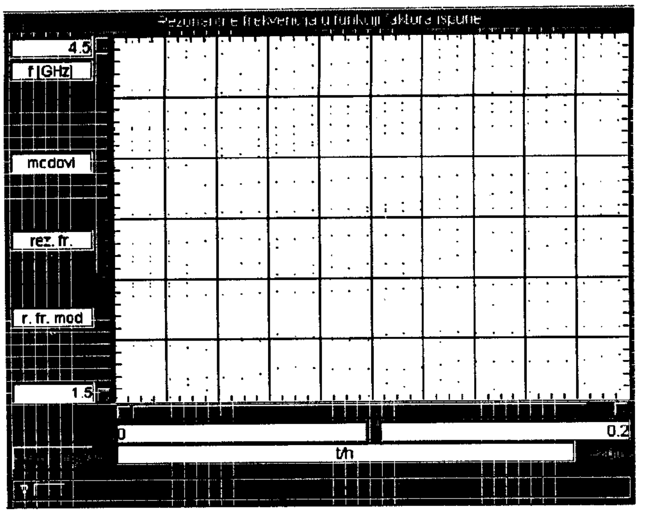

Fig.4. All measured resonant frequencies in the frequency range from 1.5 GHz to 4.5 GHz

data processing and data flow control), an area of mathematics and engineering functions is provided. Also, there are various data types adapted to nature of real measured data, various possibility of easy and simple manner of equipment controlling and management.

Using this development environment, program making reduced to the choice of object type from main menu, setting the choosing object to the corresponding position on the screen and connecting with other objects in the aim to form an functional connection. For measured equipment management this environment provides using of some object class, from which the simplest one is using of panel drivers objects. Panel drivers represent object with graphic viewing front side of equipment, and so one can manage to all equipment functions at the same manner as with the alone equipment.

The basic advantages of this environment look in a significant number of mathematics function for measured data processing (statistic function, function for data filtering, signal processing, numerical differentiation and integration), great number of various data types, as well as in various objects for measured results viewing (display objects).

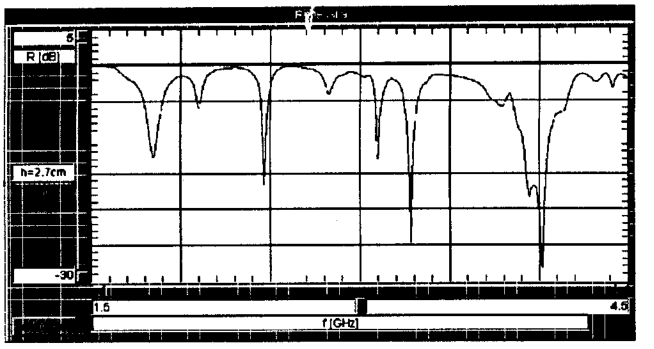

Fig.3. The reflection curve in the cylindrical metallic cavity for water load of thickness t=2.7 cm (Fig.1)

AUTOMATIZATION OF THE RESONANT FREQUENCY MEASURING

For resonant frequency measurement an experimental set up (Fig.2) is formed. A small probe is used to excite the microwave cavity. The resonance can be determined from the reflection characteristic or from the transmission characteristic by means of two probes placed on the opposite sides of the cavity. It is noticed that the reflection characteristic has the more distinct picks and the resonant frequency detection is easier.

To determine the resonant frequencies for given values of filling factor (t/h) it is necessary to note the minimum of the reflection curve (Fig.3). This procedure should repeat for all interesting values of filling factor. Also, it is necessary to identify the selected oscillation mode using approach presented in [8].

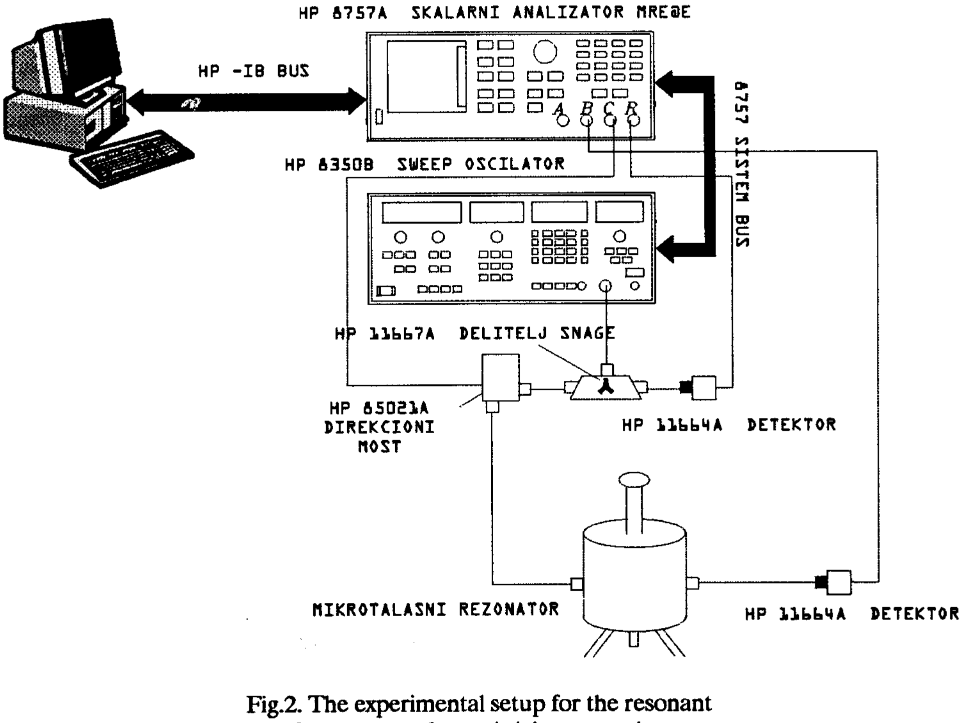

Fig.2. The experimental setup for the resonant frequency and permittivity measuring.

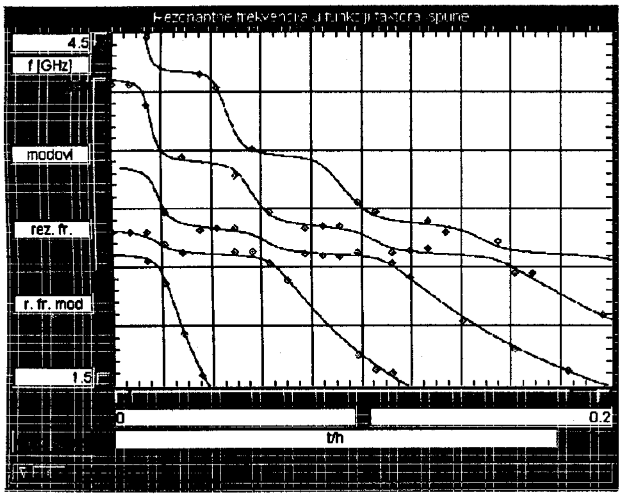

Fig.5. The results for TM_{11p} oscillation mode family

In order to automate the resonant frequency measurement using experimental set up shown in Fig.2, the program in HP VEE environment is developed, which provides the following:

- ☐ Automatic calibration of measuring equipment.
- ☐ Automatic measuring of reflection curve in given frequency range.
- ☐ Automatic frequency detection, which correspond to the minimum of the reflection curve.
- ☐ Automatic saving and plotting all detected resonant frequencies in considered frequency range.
- ☐ Automatic identification of selected oscillation mode.
- ☐ Automatic saving and plotting the measured results.

RESULTS OF AUTOMATIC MEASUREMENT

Automatic measurement of the resonant frequencies was done in the cylindrical metallic cavity with circular cross- section (Fig.1), with dimensions: a=7 cm and h=14.24 cm. The water is used as the lossy dielectric slab, which is placed on the bottom of the cavity. The water, which relative dielectric constant could be calculated from Debye's formula [9] (at a temperature of 20^{0}C and at 2.45 GHz relative dielectric constant is ε^*_{r1} = 78.5-j 11.1), is introduced on a convential manner. The thickness of the water layer is t.

The resonant frequencies are measured in the frequency range from 1.5 to 4.5 GHz, where range of filling factor (t/h) was from 0 to 0.21 ($0 \leq t \leq 3$ cm). All detected resonant frequencies in considered frequency range are shown in Fig.4. as dotes. After that, it is necessary to identify the corresponding oscillation modes. The results for TM_{11p} oscillation mode family are presented in Fig.5. The resonant frequencies numerically calculated [2] are plotted as solid, and the measured results after identification are marked by symbols. In identification process, it is considered that the difference between experimentally and numerically results are not grater than 50 MHz.

AUTOMATIZATION OF THE RELATIVE PERMITTIVITY MEASURING

For permittivity measuring the method presented in [6] was applied. This method demands only the resonant frequencies measurement. Also, the experimental set up shown in Fig.2 was used. In order to automate the permittivity measuring the program in HP VEE environment is developed, which provides the following:

- ☐ Selecting the oscillation mode family (TE_{mnp} modes or TM_{mnp} modes for fixed m and n) which can be excited in the cavity on the basis of the available resonant cavity, geometry and location of the probe.
- ☐ Automatic plotting the map [10,11] for the selected oscillation mode family for values of ε_r in expected range (for example ε_r (10,30,50,70 and 90)) for k=1, and several lowest values of l.

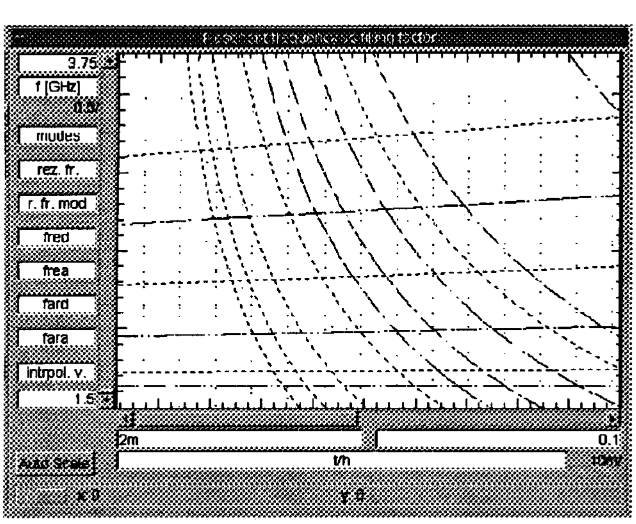

Fig.6. The map for selected TM_{01p} oscillation mode family and all measured resonant frequencies (• • •) in considered frequency range

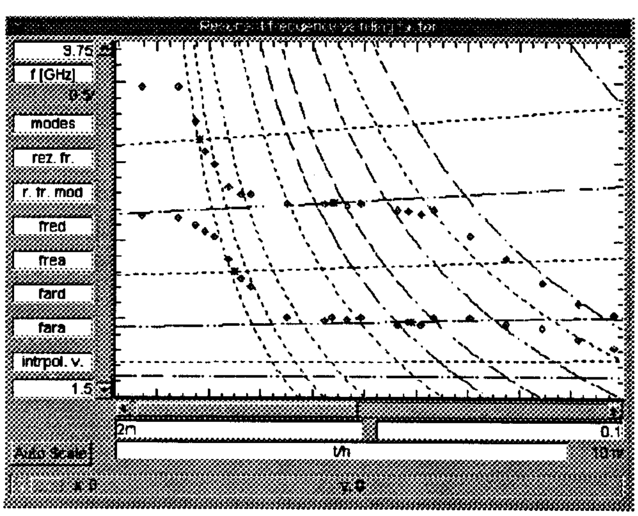

Fig.7. Determination of ε_r from measured results (♦) using the map for selected TM_{01p} oscillation mode family (* is interpolated value)

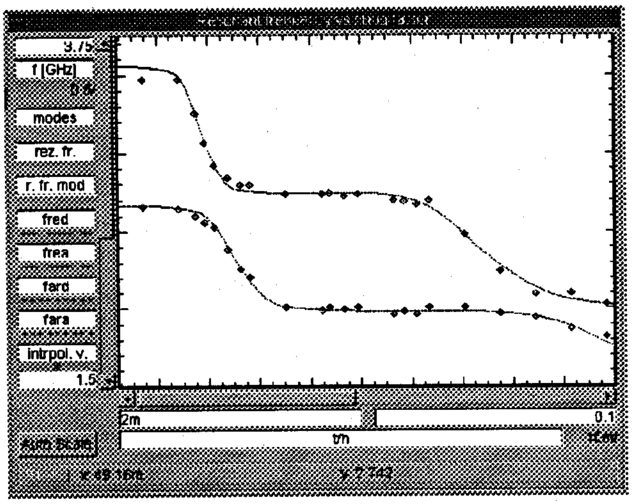

Fig.8. The measured results (symbols) and the resonant frequencies theoretically calculated with measured values of ε_r (solid line)

- ☐ Automatic calibration of measuring equipment.
- ☐ Automatic measuring of reflection curve in given frequency range.
- ☐ Automatic frequency detection, which correspond to the minimum of the reflection curve.
- ☐ Automatic saving and plotting all detected resonant frequencies in considered frequency range.
- ☐ Automatic identification of selected oscillation mode family.
- ☐ Automatic added resonant frequencies measurement near some characteristic points [11,6].
- ☐ Automatic determination of the values of f_{rez} and t/h for the characteristic points [6] using interpolation technique.
- ☐ Automatic calculation er from values of f_{rez} and t/h, which correspond to the characteristic points on the basics of expression given in [6].
- ☐ Automatic determination of the unknown permittivity as a mean value of ε_r for several modes (for $p=1, 2$ or 3)
- ☐ Automatic verifying of the measured results.

RESULTS OF AUTOMATIC MEASUREMENT

The developed program was applied to the real part of the complex permittivity measuring of the water, which has more pronounced losses, by using experimental cylindrical cavity (Fig.1).

At first the TM_{01p} oscillation mode family was selected, and the map for this family was plotted (Fig.6). Then, the resonant frequencies was measured and results (points) for considered frequency range are shown in Fig.6, also. After identification, the experimental results as well as the map for TM_{01p} family of modes are shown in Fig.7. In addition to, added resonant frequency measurements were done near selected characteristic points. The values of f_{rez} and t/h, which correspond to the characteristic points are determined by interpolation, and the unknown permittivity is determined by averaging the measured values of ε_r for four characteristic points (* in Fig.7) of two modes ($p=2$ and 3). In this manner, the real part of the complex permittivity of the water in the considered frequency range and at a room temperature is obtained to be 82.06.

In order to check the measuring accuracy, two resonant frequency curves (solid lines) obtained numerically for measured values of ε_r by using approach presented in [11] are shown in Fig.8. It can be seen that it is a good agreement between measured (symbols) and theoretically calculated resonant frequencies (solid lines).

CONCLUSION

The great possibility of data processing and viewing, as well as easy communication and management with measurement equipment makes that HP VEE represents a powerful developing environment intended to application development for automatic measurements and testing. In this paper, a program for automatic resonant frequency and relative permittivity measuring using cylindrical cavity with circular cross-section and HP8757A scalar network analyser is developed. The resonant frequencies are automatic measured in the cavity loaded with a water layer. Also, the real part of the complex permittivity of the water is automatic measured. The developed programs do not only accelerate the process of resonant frequency measuring and so relative permittivity measurement, but also provide automatic processing of measured data and mode identification, what represents a great advantage in relation to usual manual measurement [1,2].

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