ELECTRO-ULTRASONIC SPECTROSCOPY FOR TESTING QUALITY OF RESISTIVES MATERIALS

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ABSTRACT

The ultrasonic signal is widely used in non-destructive spectroscopy. The paper presents the new method of the non-destructive testing of resistives materials. The non-linear electro-ultrasonic spectroscopy is new method which has higher sensitivity and range of using than common ultrasonic testing method which has many problems. This non-destructive method consists of two signals. The electric ac signal with frequency f_E and the ultrasonic signal with frequency f_U. The ultrasonic signal changes the resistance ΔR of the measured sample by frequency of ultrasonic excitation f_U. Defects in the material are causer larger changes resistance ΔR then in the material without defects for the same amplitude of ultrasonic signal.

1. INTRODUCTION

The ultrasonic is used for prediction of lifetime for any products in the non-destructive spectroscopy. This non-destructive testing method is not fit in case a sample has complicated form or a sample is made of non-homogenous materials. This is the new way for new methods in the NDT (the non-destructive testing) which can solve this problem. The non-linear ultrasonic spectroscopy testing procedure is a new way in non-destructive testing. There are many methods of this kind in the NDT. We have measured two samples of varistors and the results are shown in this paper. The samples were measured by non-linear electro-ultrasonic method. We can found defects in the material by intermodulating of ultrasonic signal and electric signal. The ultrasonic signal changes the contact area between conducting grains in the material structure. Then material resistivity is changing with frequency of ultrasonic excitation. Defects and un-homogeneities are described by the intermodulation signal on frequency f_m which is given by the superposition or subtraction of excited frequencies ultrasonic and electric signal. We have measured on low frequency where intermodulation signal is given $f_m = f_E - f_U$. Intermodulation signal frequency is not the same as frequency exciting signals so we can get extra high resolution susceptibility with appropriate electric filters [1].

2. ELECTRO-ULTRASONIC MEASUREMENT SETUP

The block scheme of the electro-ultrasonic measurement setup is shown in Fig. 1. It consists of two parts, the electric and the ultrasonic.

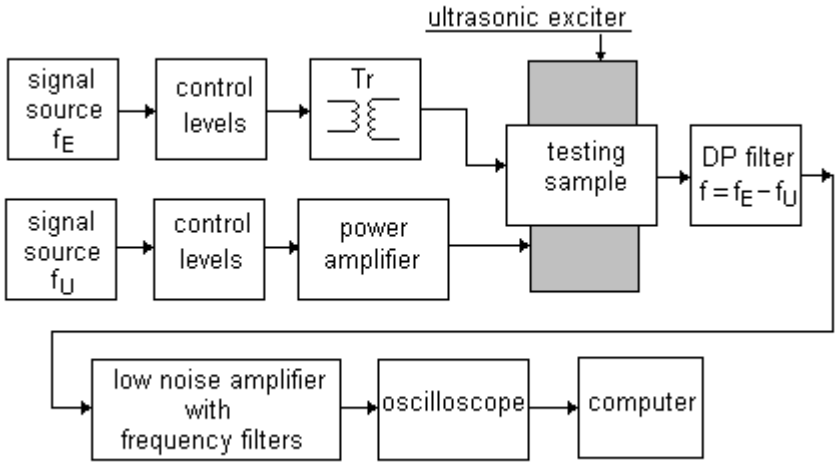

Fig. 1: Electro-ultrasonic measurement setup with AC electric signal.

The ultrasonic part is consists of generator Agilent 33220A which has frequency range 1 μHz – 20 MHz for sine and rectangle functions. Maximum length of the programmed signal is 64.000 points and vertical resolution is 64 bits. The power amplifier is consists of WPD 100 in which it is necessary to have power linear actuating harmonic signal on ultrasonic transducer. The measured sample was fixed on the power piezoceramic transmitter (HTP04) which is used for ultrasonic signal generation. Electric part is consists of generator Tesla BM492 which has convenient linearity and frequency stability. Signal from the generator is transformed on higher voltage from transformer Tr. This signal is led to the measured sample over the protective resistor. Harmonic signals in higher frequency than the differential frequency component actuating signals are trimmed by the low pass passive filter. The passive filter has limited frequency 4200 Hz with inhibition 50 dB / decade. The amplifier (AM 22) with adjustable input gain in the range from -20 to 50 dB by 10 dB step, the frequency band filter with lower frequency 30 mHz, 300 mHz, 0.3 Hz, 3 Hz, 30 Hz, 300 Hz, 3 kHz, 30 kHz and 300 kHz, the high frequency filter adjustable in range 3 Hz, 30 Hz, 300 Hz, 3 kHz, 30 kHz and 300 kHz, adjustable output gain in range from 0 to 50 dB by 10 dB. All parameters are programmed over GPIB or the front panel of the amplifier. The amplified signal is led to the A/D converter. As the A/D converter is used digital oscilloscope Agilent 54624A with sampling rate 200 Msa / s. The digitized signal is stored in the computer and noise spectral density frequency dependence evaluated using discrete FFT. The control software was written in Borland C++ Builder and this version is based on Windows operating system. Amplifier AM22 and exciter HTP04 were produced by 3S Sedlak Company. Power amplifier WPD100 was made with help of Prof. K. Hajek.

3. MEASUREMENTS

We have measured on frequency of ultrasonic actuator f_U = 31.4 kHz. This frequency corresponds with resonant frequency of ultrasonic actuator. The frequency of the electric sig-

nal was f_E = 33.4 kHz so the intermodulation signal was on frequency f_m = 2 kHz. Measurements were made in frequency range from 1 kHz to 10 kHz. Step by step we increased the electric signal and the ultrasonic signal and searched the size of this intermodulation component on frequency f_m. We can see on Fig. 2. noise spectral density measured on sample PL01 with 50 V electric signal, 20 V ultrasonic signal and sampling rate 50 kHz. We can see the intermodulation signal on frequency 2 kHz and noise background decrease on frequency approximately 3 kHz which is given by the electric filters.

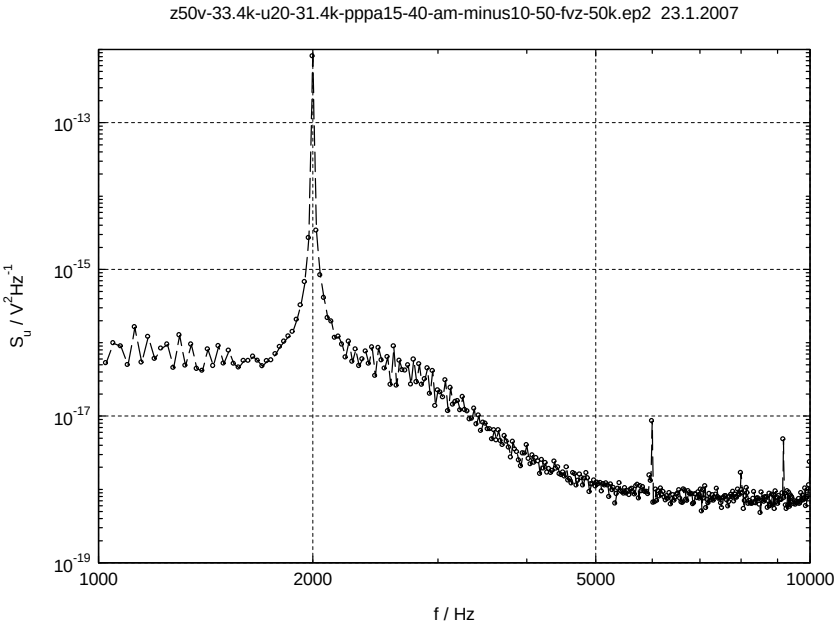

Fig. 2: Noise spectral density of sample PL01 in frequency range from 1 kHz to 10 kHz. Frequency f_E = 33.4 kHz and f_U = 31.4 kHz. U_E = 50 V and U_U = 20V.

Sampling rate *Fvz* = 50 kHz.

The samples were measured with lower sapling rate, Fvz = 10 kHz. The voltage U_S on intermodulation frequency is given by equation (1)

$$U_S = \sqrt{S_u * \Delta f} \tag{1}$$

where S_u *is the noise spectral density [* V^2Hz^{-1}*]*

Δf *is the distance between two successive lines in the signal spectra [Hz]*

For *Fvz = 10 kHz* the step between particular measured points Δf = *5 Hz*.

4. RESULTS

We have measured three samples. Sample PL03 didn't show any increment of the intermodulation signal even with electric signal U_E = 90 V and ultrasonic signal U_U = 60 V with f_E = 33.4 kHz and f_U = 31.4 kHz. The voltage U_S measured on frequency f_m for sample PL01 and PL02 for constant electric signal U_E = 50 V are shown in Fig. 3 and Fig. 4.

The voltage U_S on the differential frequency begins to increase from the certain value of the ultrasonic signal amplitude and increases up to the saturation state.

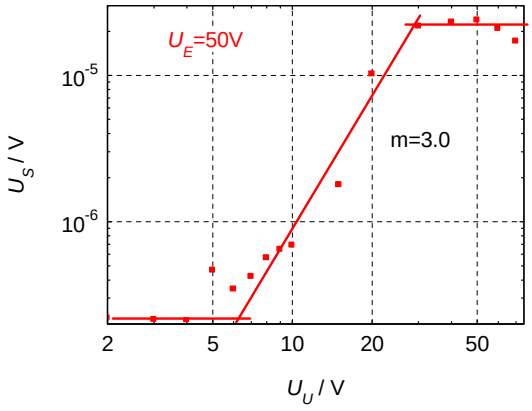

Fig. 3: The spectral density of U_S measured on the frequency f_m vs. the amplitude of the ultrasonic signal for electric voltage 50 V, The Sample-PL01

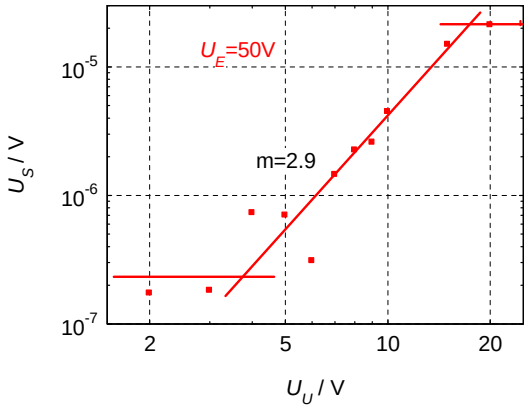

Fig. 4: The spectral density of U_S measured on the frequency f_m vs. the amplitude of the ultrasonic signal for electric voltage 50 V, The Sample-PL02

The voltage U_S on frequency f_m for the sample PL01 and PL02 for three different ultrasonic signals U_U = 20 V, 15 V and 10 V are shown in Fig. 5 and Fig. 6.

The voltage U_S on the differential frequency begins to increase earlier with higher ultrasonic amplitude value than on lower ultrasonic amplitude value. We can see that voltage U_S is increasing linearly with electric AC voltage for both samples PL01 and PL02.

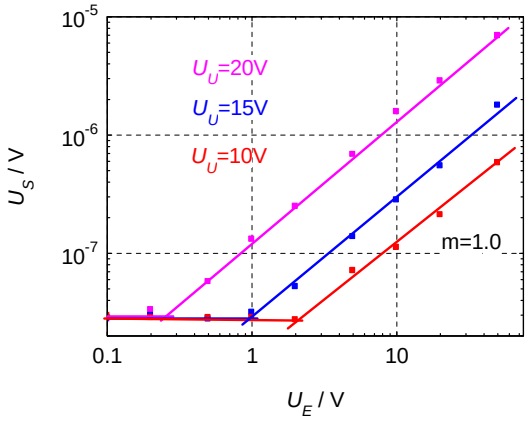

Fig. 5: The spectral density of the voltage U_S vs. AC voltage for different values of ultrasonic signal U_U = 20, 15 and 10 V for the Sample-PL01

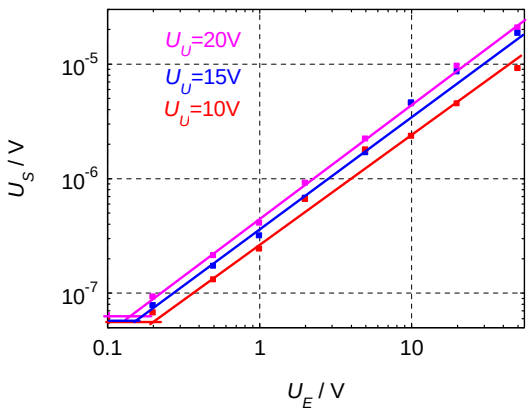

Fig. 6: The spectral density of the voltage U_S vs. AC voltage for different values of ultrasonic signal U_U = 20, 15 and 10 V for the Sample-PL02

5. CONCLUSION

We measured three samples of varistors (PL01, PL02 and PL03) by electro-ultrasonic spectroscopy. The sample PL03 didn't show voltage U_S on frequency f_m for weak electric signal. The sample PL03 is probably sample of very good quality structure contains just a few defects.

The voltage U_S in dependence on ultrasonic excitation appears the saturation. The saturation of ultrasonic excitation occurs for low ultrasonic voltage on sample PL02 (U_U = 18 V) than for sample PL01 (U_U = 28 V) for constant electric voltage U_E = 50 V, how it is shown in Fig. 3. and Fig. 4. The voltage U_S increases approximately with the third power of ultrasonic excitation for both samples PL01 and PL02.

The U_S characteristics of sample PL02 are inflated together in dependence on the electric signal and the constant ultrasonic signal, because they were very close to the saturation.

We got the same sensitivity in 10V ultrasonic signal on sample PL02 as in 20V ultrasonic signal on sample PL01.

The voltage U_S increases linearly with electric excitation for both samples PL01 and PL02.

This method can be used as a diagnostic tool for the quality and reliability assessment of resistors [2, 3, 4]. For given electric excitation the saturation occurs for the lower value U_U for the sample with lower reliability. From our results we can conclude, that the structure of sample PL01 is better that one in sample PL02.

ACKNOWLEDGEMENTS

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