ELECTRO-ULTRASONIC SPECTROSCOPY OF CONDUCTIVES 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 procedure of conductive 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.

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. Two samples lightning arresters measured 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 measurable variable is a harmonic signal with the frequency determined by the difference or summation ultrasonic and electric signal frequency. Intermodulation signal frequency isn't 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.

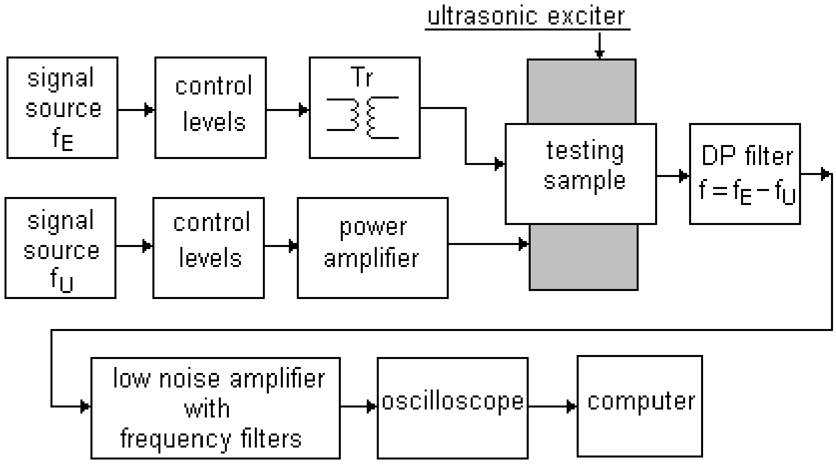

Fig. 1: Electro-ultrasonic measurement setup with AC electric signal.

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

The frequency of the electric signal and the ultrasonic signal were selected so that the differential frequency component of the intermodulation signal was 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 differential component.

We can see on Fig. 2. noise spectral density measured on sample (lightning arrester) PL01 with 50 V electric signal, 20 V ultrasonic signal and sampling rate 50 kHz.

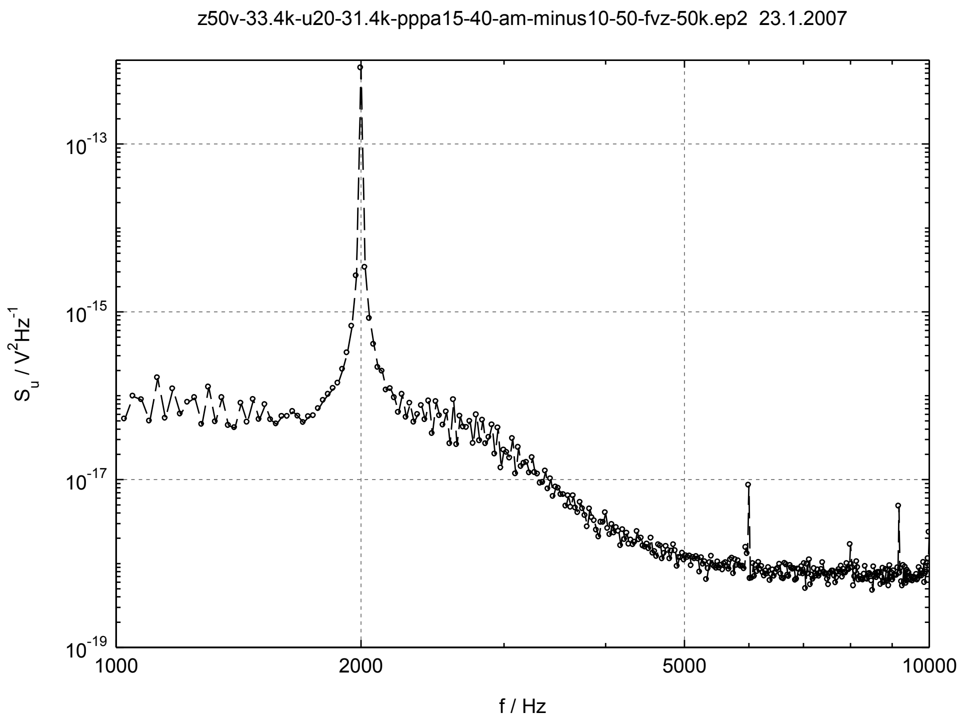

Fig. 2: Noise spectral density of sample PL01 in frequency range from 1 kHz to 10 kHz. Frequency f_E = 33.4 kHz and f_U = 31.4 kHz. Tension U_E = 50 V and U_U = 20V.

Sampling rate Fvz = 50 kHz.

The samples were measured with lower sapling rate, Fvz = 10 kHz. The differential frequency on this sampling rate peaks recalculated on Am by equation (1) was higher than in the other sapling rate.

$$A_m = \sqrt{S_u * \Delta} \qquad V \qquad (1)$$

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

Δf is the step between particular measured points [Hz]

For *Fvz = 10 kHz* the step between particular measured points $\Delta f = 5$ *Hz*.

4. RESULTS

We have measured three samples. Sample PL03 didn't show any increment of the differential component 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. We observed a little increment in sample PL03 (where S_u = *1,17 e* $^{-13}$ V^2Hz^{-1}) with frequency f_E = 18.1 kHz and f_U = 16.1 kHz with electric signal U_E = 140 V and ultrasonic signal U_U = 70 V. The other samples were measured with frequency

f_E = 33.4 kHz and f_U = 31.4 kHz. The samples PL01 and PL02 harmonic signal amplitude on the differential frequency, recalculated on A_m, according to the size of the ultrasonic signal U_U with the invariable amplitude electric signal U_E are shown in Fig. 3 and Fig. 4. The harmonic signal amplitude on the differential frequency begins to increase from the certain value of the ultrasonic signal amplitude and increases up to the saturation state.

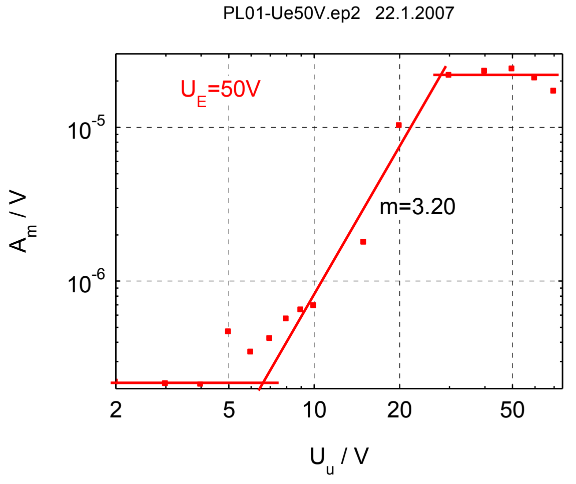

Fig. 3: Sample PL01: $A_m = f\,(U_U)$

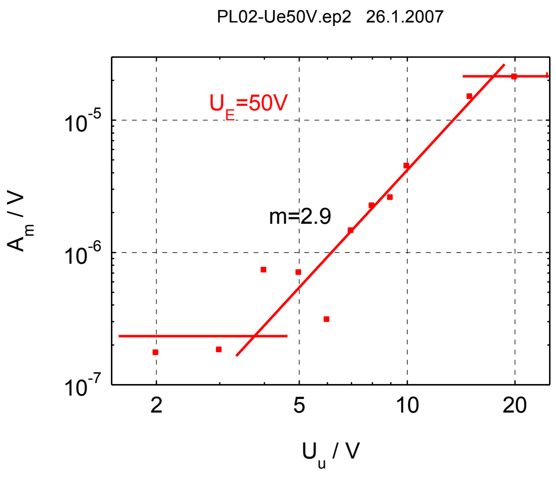

Fig. 4: Sample PL02: $A_m = f\,(U_U)$

The samples PL01 and PL02 harmonic signal amplitude on the differential frequency, recalculated on Am, according to the size of the electric signal U_E with the three levels invariable amplitude ultrasonic signal U_U = 10 V, 15 V a 20 V are shown in Fig. 5 and Fig. 6.

The harmonic signal amplitude on the differential frequency begins to increase earlier with higher ultrasonic amplitude value than on lower ultrasonic amplitude value. Increasing value A_m, in dependence on the electric signal with invariable the ultrasonic signal has linear dependence.

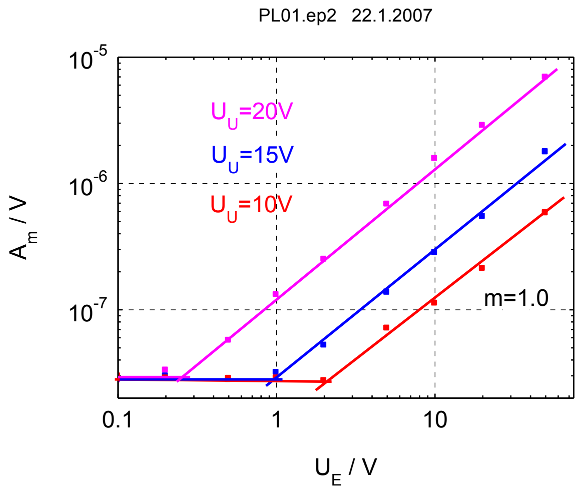

Fig. 5: Sample PL01: $A_m = f\,(U_E)$

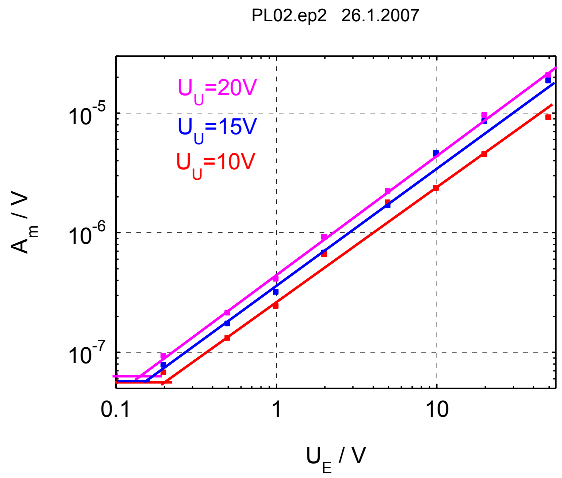

Fig. 6: Sample PL02: $A_m = f\,(U_E)$

5. CONCLUSION

We measured three samples of lightning arresters (PL01, PL02 and PL03). Two of them show various values of A_m and the third one can't be measured because of weak electric signal or the sample contains just a few defects. Difference of A_m values on samples PL01 and PL02 is probably caused by contacts quality.

On sample PL02 we got higher sensitivity then on sample PL01. With unchanging 50V of the electric signal we reached a saturation on sample PL01 on 28V and on sample PL02 on 18V of the ultrasonic signal, how it is shown in Fig. 3. and Fig. 4.

The A_m 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.

ACKNOWLEDGEMENTS

This research has been supported by the Czech Ministry of Education in the frame of MSM 0021630503 and by grand GACR 102/06/0866.

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