LABORATORY OF ELECTROACOUSTICS

EXERCISE 6.

Measurements of ultrasonic transducers.

The purpose of the exercise:

The aim of the exercise is to measure the amplitude-phase characteristics to determine the replacement circuit of two piezoelectric transducers. The exercise should analyze the differences in the operation and use of attenuated and non-attenuated transducers.

1. Laboratory tasks.

a. The first task is to sketch a simplified electrical system (near the resonance) of the piezoelectric transducer. It is also necessary to name the individual elements of this system and give their physical interpretation. Each member of the group performs this task alone on a piece of paper.

b. In the second task, you should sketch the characteristics that allow you to determine the elements of the eletrical system. Here, the most important thing is to mark which quantities are on the OX and OY axes and to sketch the shape of the characteristic. In this case, too, each member of the group sketches the characteristics on a sheet by himself.

c. The third task is to determine the formula that will allow to calculate G (conductance) and B (susceptance) having |Z| (impedance module) and φ (phase shift). For this purpose, it is necessary to know how the exponential and trigonometric form of the complex number is presented and the relationship between the impedance (Z) and the admittance (Y). In this case too, each member of the group independently makes a move on a piece of paper.

d. The results from sub-point a., B., C. Should be consulted with the teacher.

e. Next, we go to the measurements of the attenuated transducer (labeled as Lab 2). An exel file was prepared on the computer allowing to save measurement results and simultaneous conversion of |Z| and φ on G and B. At the same time, you will be able to observe how the characteristics are drawn up. The file's name is "template_PiezoELE_lab2". The measurements are made using a generator and impedance bridge to which the operating instructions are included in APPENDIX A and B. Measurements are first carried out in the air, and then immersed in water, taking care that there are no air bubbles under the transducer. Both measurements are performed in the frequency range from 320kHz to 350kHz. Step what to do measurements is phase change (φ) every 5°. It should be remembered that we are interested in changing the phase when the phase is growing or decreasing.

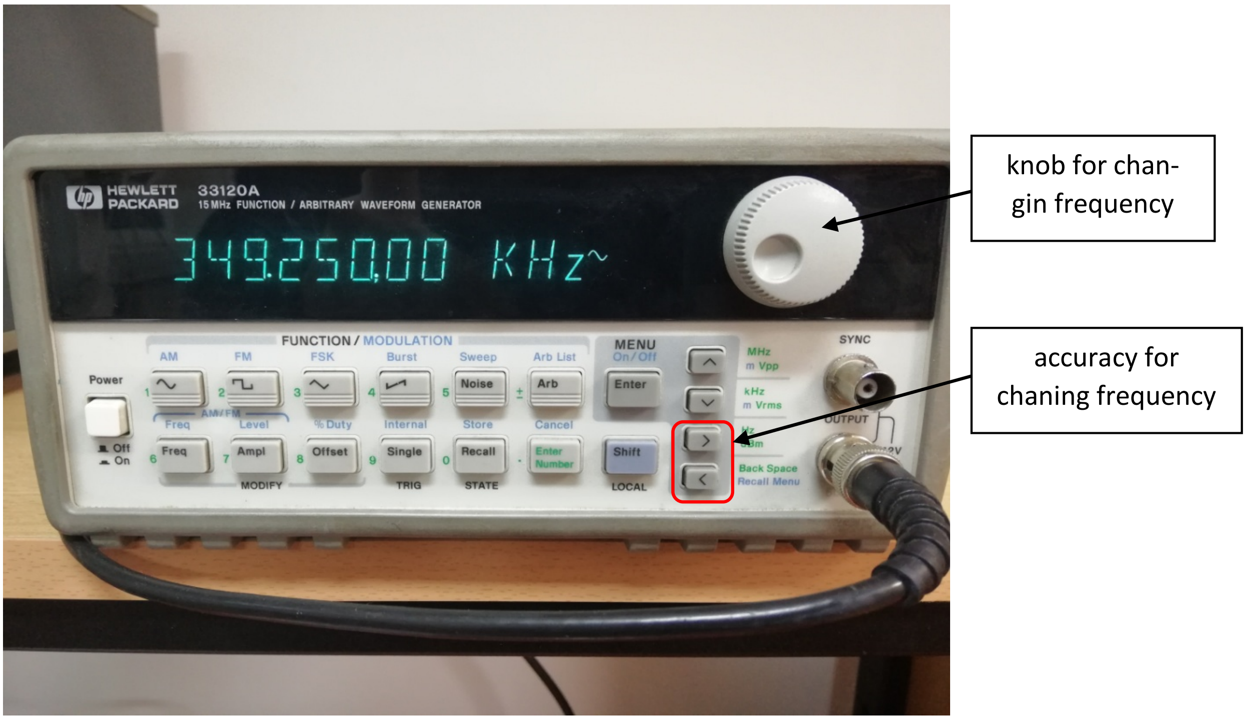
f. In the next step, we proceed to measure the transducer without attenuation (labeled as Lab 1). As in the previous case, we first measure in the air and then in the water. The frequency change range is 335kHz to 350kHz. Step what to do measurements is phase change (φ) every 5°. The name of the file that you can use is "template_PiezoELE_lab1".

g. After completing the measurements, save the results in the "Student files" folder and save to your own pendrive.
h. At the end of the exercise based on the results (including the characteristics included in the materials at the post) you should answer the following questions:
   i. Which of the transducers (attenuated or not attenuated) can be used for passive applications (eg diagnostics - ultrasound imaging), and which for active applications (therapy) due to the length of the impulse generated by the transducer.
   ii. Which transducer will generate a short and which long pulse and why. Here it is worth to refer to the bandwidth for both transducers. One has a wide band and the other is Barrow one.
   iii. If the transducer bandwidth is large, is Q "goodness" of this transducer big or small? Why?
   iv. If the goodness Q of the transducer is small, the impulse generated by the transducer will be long or short?

2. Report. The report must contain elements such as:

a. The purpose of the exercise.
b. Description of the elements together with the electrical system of the piezoelectric transducer.
c. The results of measurements of the amplitude-phase characteristics for the attenuated and not attenuated transducer. On two graphs the results of measurements from air and water for both transducers.
d. Draw on one characteristic the elements (f', f'', f_r, G', itd.) that are necessary to determine the electrical system.
e. Calculation of: G', Q, C_m, L_m, k, η_{ea}, R_m, R_v, R_p. Examples of calculations for one selected case.
f. Table with all results for four cases: transducer not attenuated and attenuatted in air and water.
g. Conclusions. On the basis of the table, the differences in results should be analyzed and the not attenuated and attenuatted transducer should be compared as well as the case of the water and air environment. Try to explain where the differences come from. Based on bandwidth, goodness and efficiency, determine which transducers are better suited for passive and active use.

APPENDIX A. User manual for the function generator.



On the display, set the initial frequency with the knob. Then set the correct frequency change accuracy. For a not attenuated transducer this will be a change of 100 Hz, and for an attenuated transducer the accuracy must be increased to 10 Hz.

APPENDIX B. User manual for impedance meter.

On the right side of the device we have black buttons in vertical rows. They refer to the reading of the impedance module |Z|. The first row from the right will have the [Ω] button pressed. In the second row, set the appropriate range (eg 300Ω). In the display marked with the letter "Z", the values should be read from the upper scale (because the [Ω] button was pressed). If we have pressed the range which on the "3" at the beginning (eg 300Ω) then we use the lower part of the upper scale (where we have "3" in a circle). Instead of this "3" we have, for example, 300Ω. If the range is pressed to "10" at the beginning (eg 1000 Ω) then we use the upper part of the upper scale. The phase is read from the screen marked with the letter φ.

APPENDIX C Piezoelectric transducers.

1. Simplified replacement circuit of the piezoelectric transducer.

For the analysis of the piezoelectric transducer vibrating thickly near the resonance, the following replacement system is used.

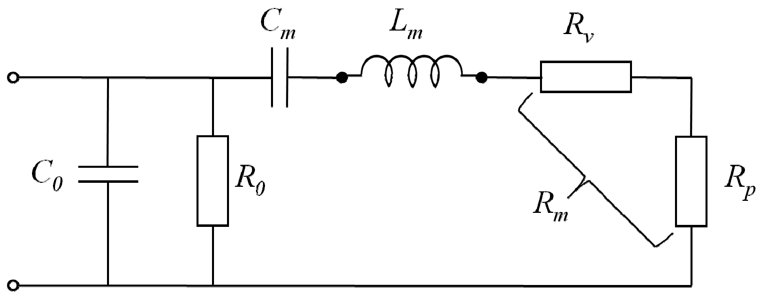


Fig. 1 Simplified replacement circuit of the piezoelectric transducer.

The C_0 and R_0 elements are the static capacitance and the electrical resistance of the transducer. The elements L_m and C_m are mass and susceptibility of the transducer. R_v and R_p are mechanical loss resistance and radiation resistance.

2. Measurement of the amplitude-phase characteristics of the admittance and determination of the transducer parameters.

On the basis of measurements of electrical impedance and determination of amplitude-phase characteristics, it is possible to determine the elements of the piezoelectric transducer replacement circuit.

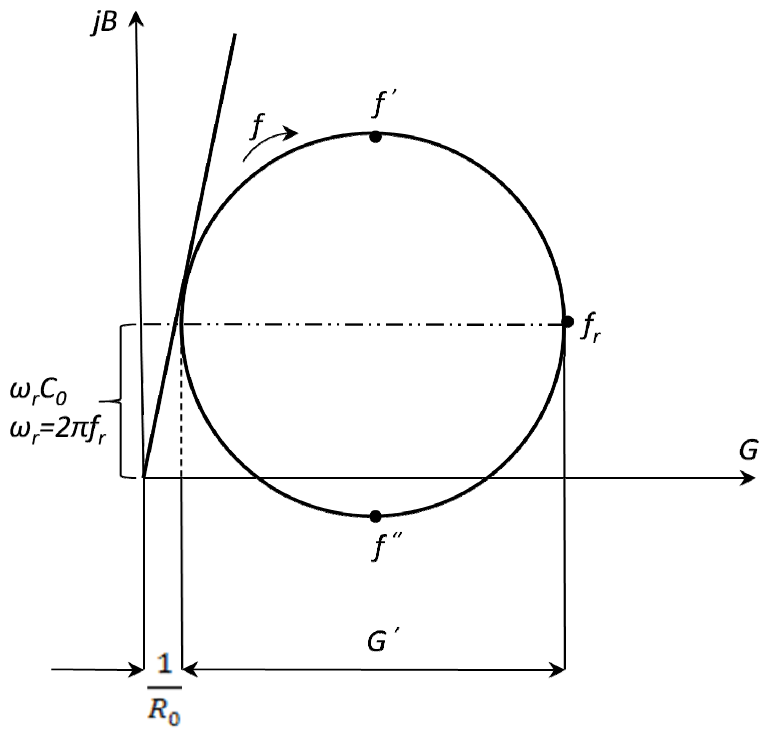


Fig. 2 Amplitude-phase characteristics of the admittance of the piezoelectric transducer.

The basic parameters of the transducer can be determined from the amplitude-phase characteristics of the admittance. The circular part of the characteristic corresponds to the serial connection of the elements L_m, C_m, R_m. The diameter of the circle is equal to the conductance:

$$G' = \frac{1}{R_m}$$

On the basis of frequency f', f'', f_r goodness is determined.

$$Q = \frac{f_r}{f'' - f'}$$

Goodness is also equal to:

$$Q = \frac{G'}{\omega C_m}$$

Therefore:

$$C_m = \frac{G'}{2\pi f_r Q}$$

Inductance:

$$L_m = \frac{1}{4\pi^2 f_r^2 C_m}$$

Coefficient of electromechanical coupling:

$$k = \sqrt{\frac{C_m}{C_m + C_0}} \approx \sqrt{\frac{C_m}{C_0}}$$

Electroacoustic efficiency:

$$\eta_{ea} = \frac{R_p R_0}{(R_v + R_p)(R_p + R_0 + R_v)}$$

The mechanical loss resistance R_v is calculated from the transducer measurements in the air because the equation $R_m = R_v$ is true for air. Mechanical resistance $R_m = R_v + R_p$ is calculated on the basis of transducer measurements in the environment for which it is intended.