Dogadov A.A., Gladilin A.V.

A NONINVASIVE MEASUREMENT OF RESEARCH OBJECT PARAMETERS BY USING FOCUSING ULTRASONIC RADIATORS WITH ELLECTRICALLY VARIED SPATIAL AND TIME DISTRIBUTION OF CREATED FIELDS

N.Andreyev Acoustics Institute
4, Shvernika Ul. 117036 Moscow Russia
Ph: (095) 126-9814, Fax: 126-8411
E-mail: hfus@mail.ru

Using of focusing ultrasonic radiators with electrically controlled spatial and time distribution of created fields allows to set up a noninvasive channel for measurement parameters of a research object. These measurements can be performed within oscillating of focal area. Physical nature of the channel formation is the amplitude modulation of driving voltage of radiators. Acoustic parameters of object are determined by changing the amplitude modulation index and its frequency response. Main parameters of such channel are determined, including information rate equal to 0.1 Mbit/sec.

The piezoelectric plates with non-uniform thickness can be excited in the range of the frequencies [1]. The distribution of the particle velocity over working surface of such plates is varied with frequency modulation of excitation voltage. It is a basis for creation of focusing ultrasonic radiators with single-channel electrically controlled spatial and time structure of the generated fields (EC STS) [2]. The following variants of control of spatial structure of the generated fields are possible: swing of the focal area (in a direction normal to that of the ultrasound propagation), displacement of the focal area (in the direction of the ultrasound propagation), and rotation of the focal area (about the direction of the ultrasound propagation).

The response of inhomogeneous viscoelastic media to focused ultrasonic fields with EC STS gives rise to an amplitude modulation of the frequency-modulated excitation voltage of the corresponding radiators. The origin of this effect lies in the variation of the acoustic impedance of the object (i.e. its heterogeneity). Frequency dependence of the amplitude modulation of excitation voltage of radiators with EC STS maps spatial distribution of acoustic characteristics of the research object within the limits of a variation of focal area defined by constructive characteristics of radiators. These limits are commensurable with length and diameter of the focal area generated by radiators of the same sizes with uniform distribution of particle velocity over their working surface [3]. Thus the estimation of parameters of research object is made by noninvasive way.

Maximum frequency of the modulation of excitation voltage of radiators with ET STS is restricted by inertial and elasticity properties of their piezoceramic plates. It is defined experimentally and the method of measurement is described below.

The block diagram of experimental setup for definition of a frequency range of modulation of excitation voltage of the radiators is shown on fig.1. Experiment was carried out in the damped water pool with the radiators providing a swing effect of focal area.

The circuit of excitation of radiator /Rad/ contains the generator of modulating frequency /GMF/ and the frequency modulated ultrasonic generator /FMG/. The carrier frequency, factor of a frequency modulation and a level of excitation voltage are accordingly controlled by the frequency meter /FM/, the meter of factor of a frequency modulation /MFFM/ and the voltmeter/V1/. As it was shown in work [2] the amplitude of a swing of focal area is proportional to factor of frequency modulation of excitation voltage of a radiator. A radiator /Rad/ is focusing one with spherical curved piezoelectric plate which has a diameter 45 mm and a radius of curvature of 75 mm. Calculation of profile of piezoelectric plate of the radiator providing a swing of focal area with amplitude up to 5 mm was produced accordingly to work [2].

Fig. 1. *The block diagram of experimental setup for definition of the frequency range of modulation of excitation voltage of the radiators.*

The reception circuit contains the receiver /Rec/, the amplifier /AMP/, the amplitude detector /AD/, the filter /F/, the voltmeter /V2/, the oscilloscope /OSC/ and the voltmeter /V3/. The piezoelectric spherical receiver is with external diameter 5mm is fixed on the three-coordinate displacing device.

At the beginning, when frequency modulation was switched off, the receiver was disposed so that the center of focal area of a radiator was in the middle of its working surface (max level indicated by voltmeter /V3/). After switching on frequency modulation (the factor of frequency modulation was less than 1 %) the inaccuracy caused by stray amplitude modulation of the output voltage was evaluated. The principal cause of stray amplitude modulation is nonuniformity of amplitude-frequency characteristic of a tract at the selected radiator and receiver and the given amplitude of swing of focal area. The measured value of factor of stray amplitude modulation F_{SAM} was approximately 5 %. After that the receiver was displaced in direction of swing of focal area up to deriving maximum factor of amplitude modulation F_{AM} of receiving signal. It reached 25-27 % in the lower part of a range of modulating frequencies.

The dependence of factor of amplitude modulation on modulating frequency of excitation voltage of a radiator with described parameters producing a swing of focal area (at constant factor of a frequency modulation F_{FM}= 1%), is shown on fig. 2. The dependence of the factor of stray amplitude modulation F_{SAM} on frequency is also shown on fig.2.

Fig. 2. *Dependence of the amplitude modulation factor on frequency of excitation voltage.*

Thus the frequency range of modulation for electric control of spatial and time structure of the fields generated by the radiators with typical for practical application sizes is limited to 10 kHz.

For determining a dynamic range of measured values of factor of amplitude modulation the receiver was replaced by the research samples of a biological tissue and amplitude modulation of the excitation frequency modulated voltage was measured. The input of the amplifier was connected through attenuating circuit to the radiator; thus the noninvasive channel for the measurement of research object parameters is created.

The dynamic range of the channel for the measuring the amplitude modulation factor is defined so:

(1)

Where F_{AM} - the greatest possible value of factor of the amplitude modulation caused by a differentiation of acoustic impedance of research object within the limits of a variation of focal area, F_{SAM} - factor of stray amplitude modulation defined at replacing of research object by homogeneous simulator, F_{DSAM} -determined component factor of stray amplitude modulation that is defined primarily by the radiator.

Determined component factor of stray amplitude modulation in according to [4] is:

(2)

Where ***Zmax*** and ***Zmin*** - maximum and minimum values of the module of an entering impedance of radiator in a band of working frequencies, $\boldsymbol{R_i}$- internal resistance of a generator of excitation.

For experimental samples of focusing radiators with EC STS providing a swing of the focal area the calculated magnitude F_{DSAM} appeared commensurable with F_{SAM}. Thus the dynamic range of measured values of the factor of amplitude modulation reaches 30-40 dB. It depends on the frequency of modulation.

Information efficiency of the noninvasive channel of measuring of parameters of research object is:

(3)

Where DF_c – the width of a spectrum of raised signals $(DF_c \approx Fmax)$, P_s/P_n -the ratio of a powers of a signal and the noise that appropriates D_{AM}.

With the account experimentally obtained outcomes DF_c is 10^4 Hz and minimum D_{AM}=30 dB, the maximum value of information efficiency of the noninvasive channel exceeds 0.1 Mbit/s.

It ensures a high enough of characterization of research object on its acoustic parameters.

R E F E RE N C E S

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