State Scientific Center
of the Russian
Federation

VNIIFTRI

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National Research Institute for
Physical-Technical and Radio Engineering Measurements

Free-field calibration of an underwater sound receiver in a laboratory water tank at very low frequencies

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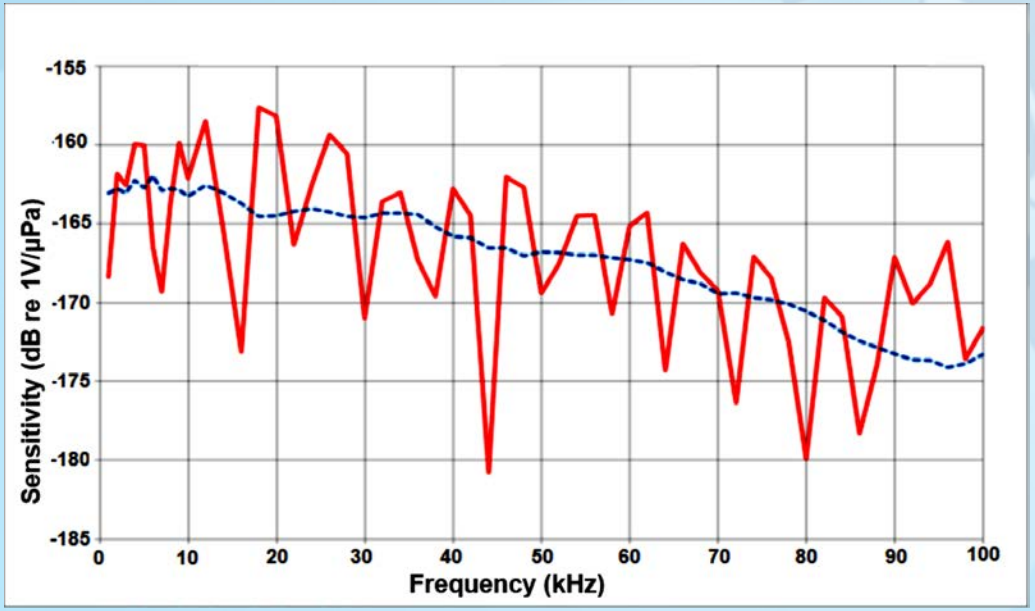
MOTIVATION OF THE STUDY

Underwater sound recorders of the type AURAL M2



Frequency response of the recorder (NPL, UK)

Problem:

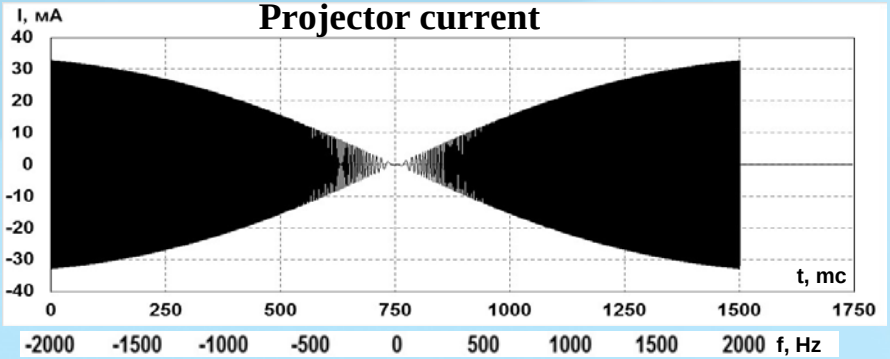
Today free-field calibration of a hydrophone and recorder is possible only at frequencies above 1 kHz

Objective:

To develop a method for free-field calibration of a recorder at frequencies below 1 kHz in a laboratory water tank (EMPIR Call 2015 - EURAMET)

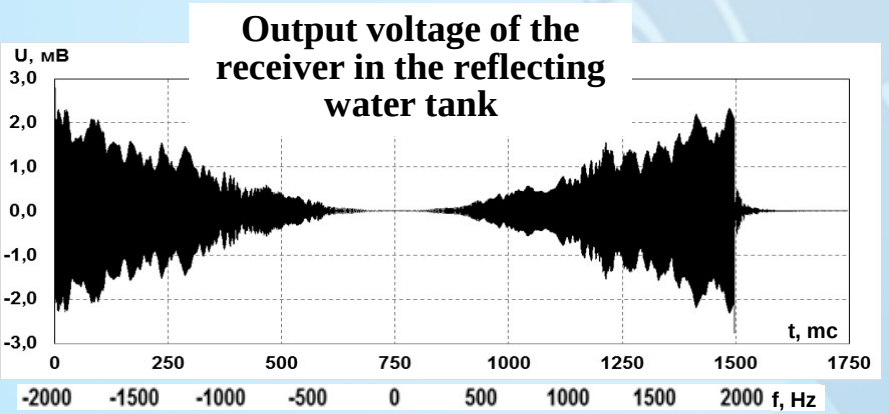
MEASUREMENT PROCEDURE

Step 1: **Excitation of the reversible projector by a linear frequency-modulated signal, recording the projector current and the receiver output voltage.**



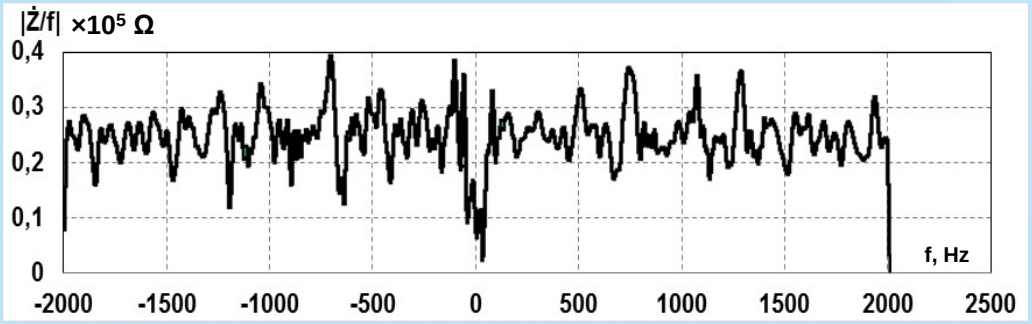
Reciprocity parameter

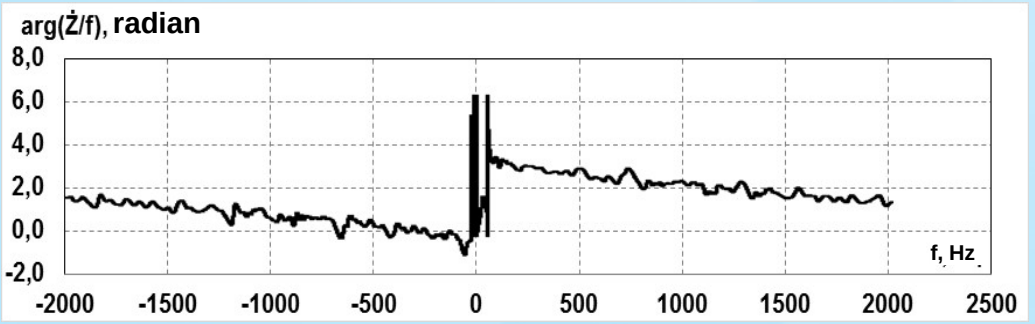
$$J(f)=2/j\rho f$$



Step 2: **Constructing the frequency dependence of the projector-receiver pair transfer impedance:**

$$Z_{PH}(f) = \frac{U_{PH}(f)}{I_P(f)} \qquad Z_{PH}(f) = Z^*_{PH}(-f) \qquad Z_{PH}/f = J(f)Z_{PH}(f)$$

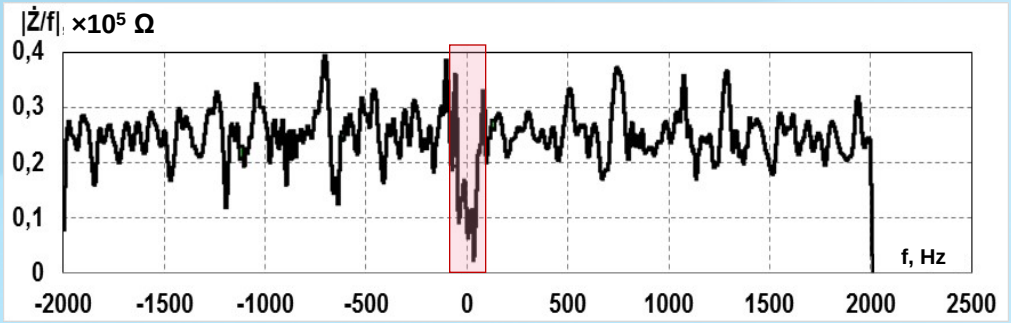


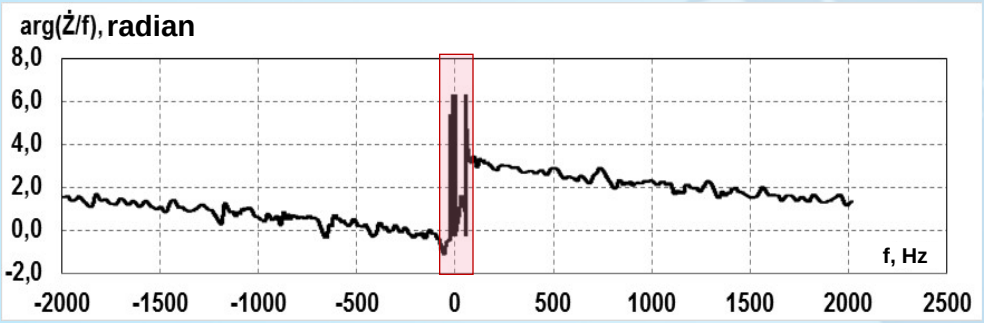


The corrected amplitude-frequency and phase-frequency dependences of the projector-receiver pair transfer impedance in the reflecting water tank

EXCEPTION OF THE EFFECT OF REFLECTIONS AND NOISE INTERFERENCE

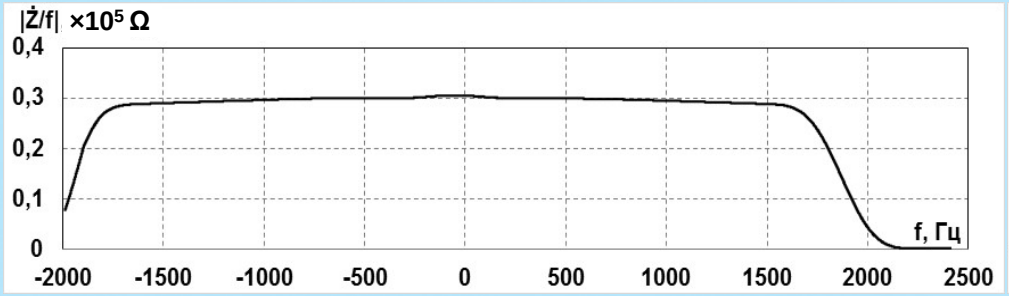
Step 3: Interpolation of the frequency dependence in an area adjacent to zero on the frequency axis

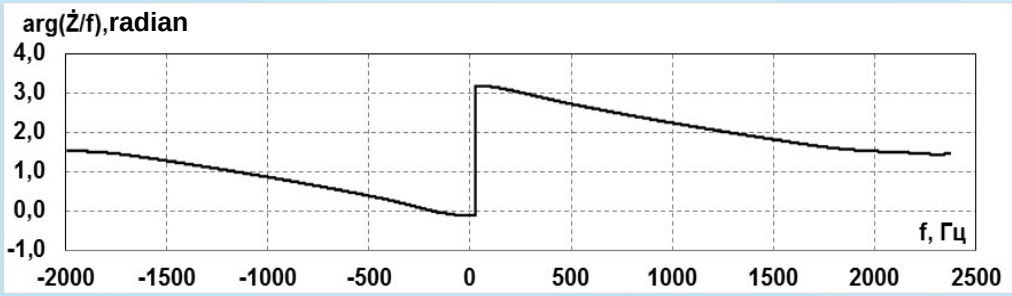




Step 4: Suppression of the effect of reflections using the CMWA technique:

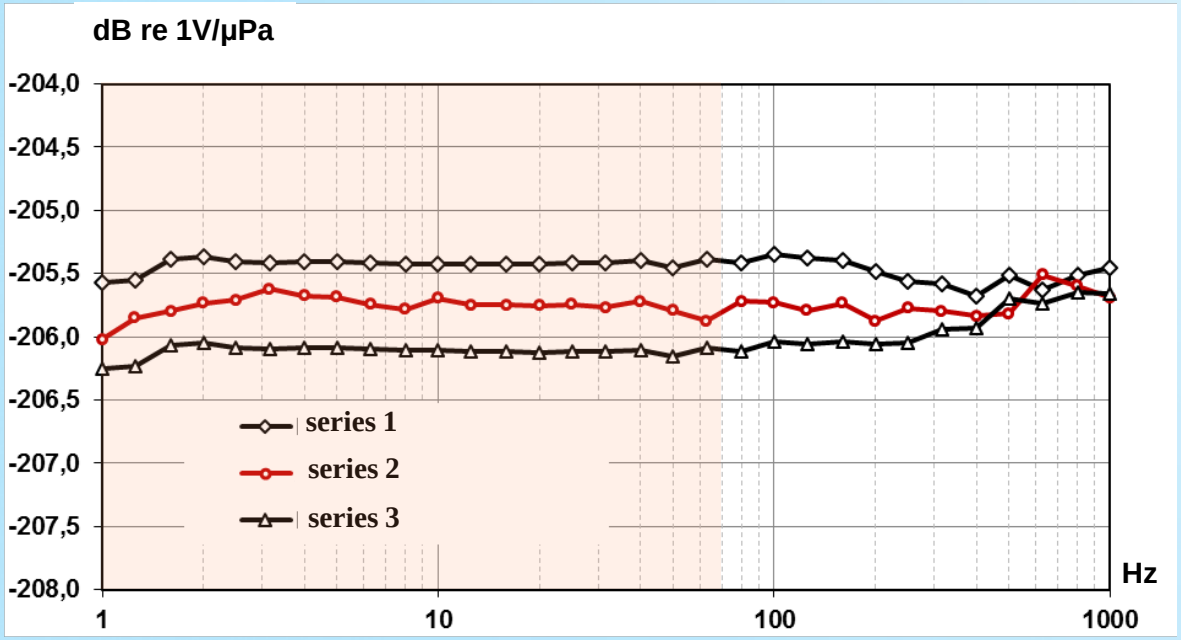
$$Z_{PH}(f, \Delta f_{av}) = \frac{1}{\prod_{i=1}^{n} 1/\tau_i} \int_{f-\Delta f_{av}/2}^{f+\Delta f_{av}/2} Z_{PH}(f - f') W_{av}(f') df'$$





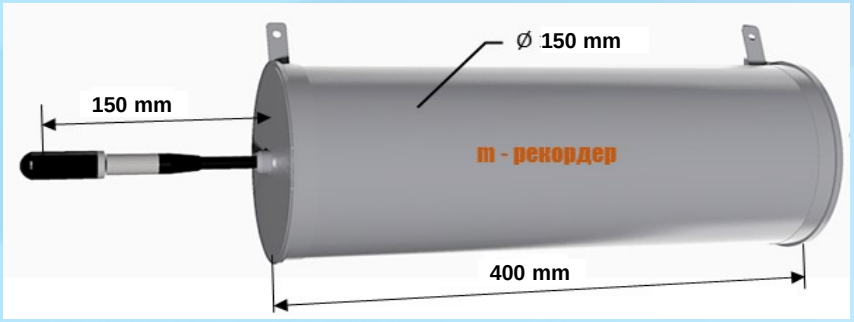
Result: Free-field frequency dependence of the projector-receiver pair transfer impedance in the frequency interval which is symmetric relative to zero on the frequency axis

FREE-FIELD CALIBRATION OF HYDROPHONE AT LOW FREQUENCIES

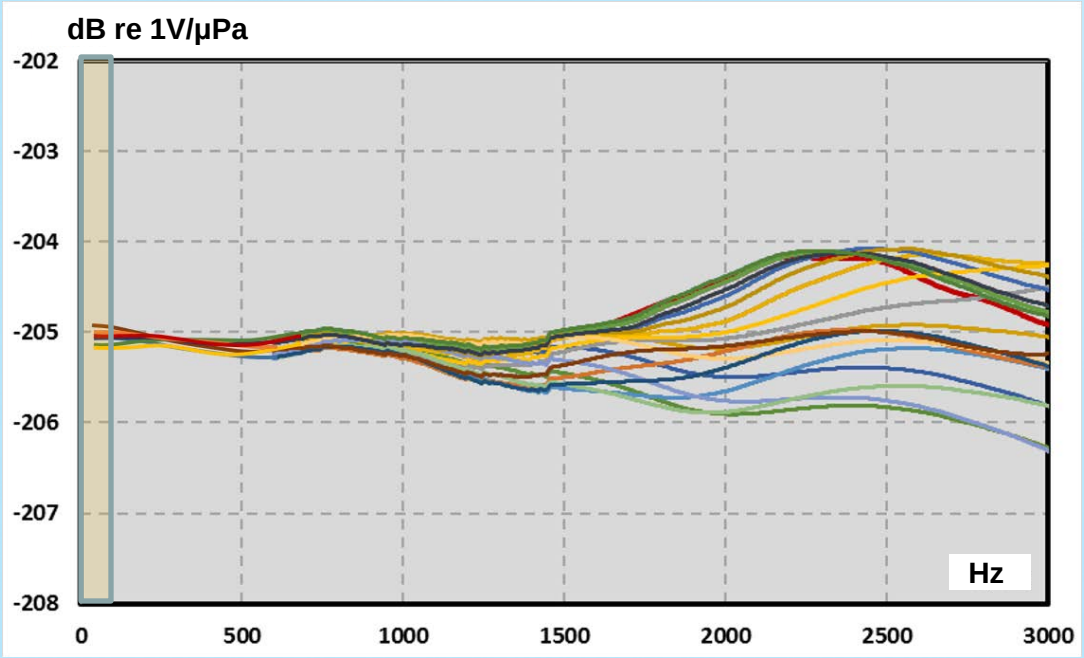


Frequency responses of the B&K8104 hydrophone, obtained in a coupler of the national standard (series 2) and in the water tank at depths of 3 m (series 1) and 1.5 m (series 3)

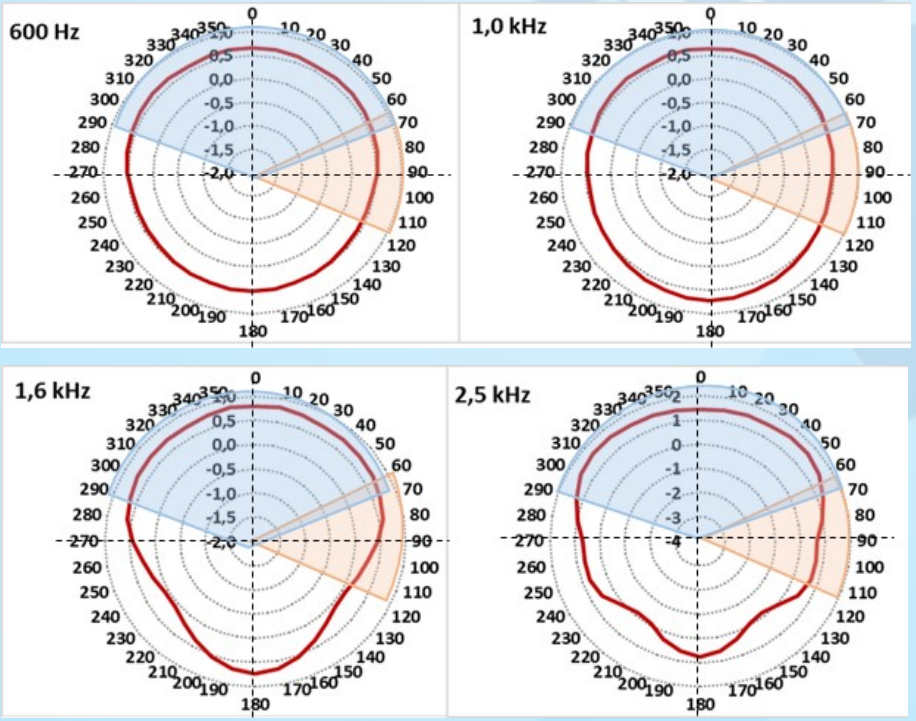
RESULTS OF THE RECORDER CALIBRATION AT LOW FREQUENCIES



Mass-dimensional model of the underwater recorder

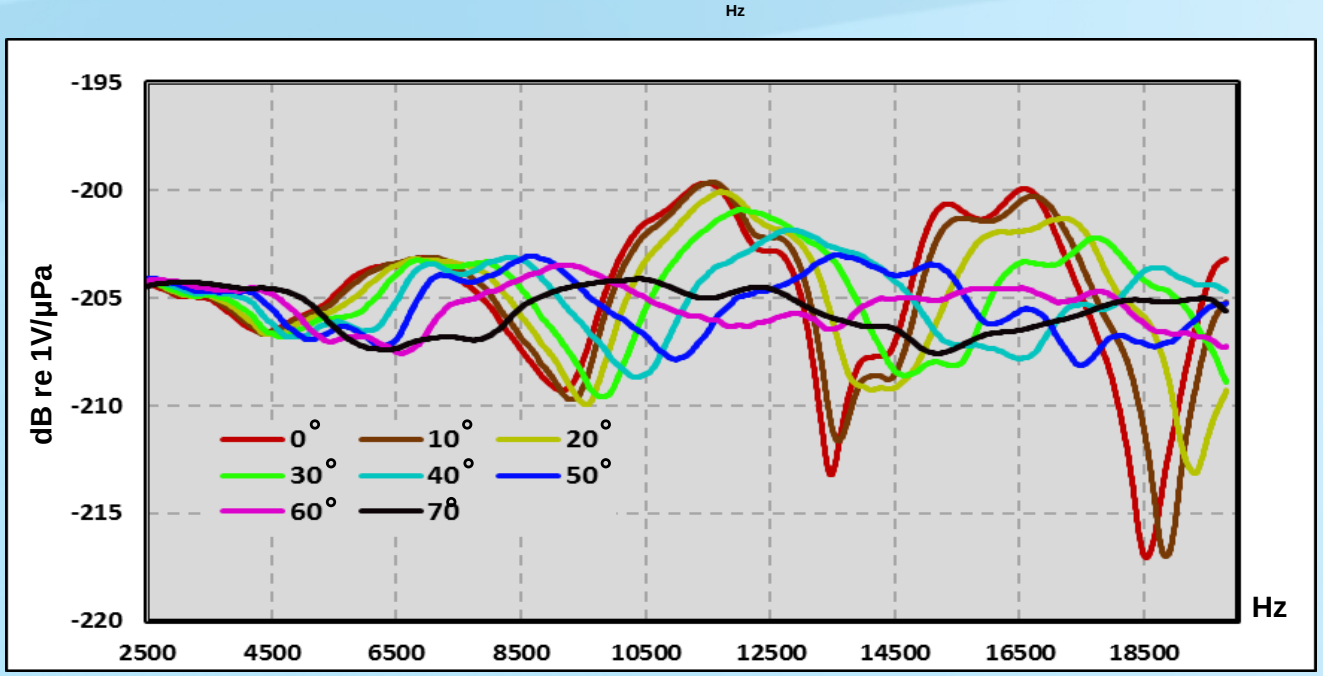


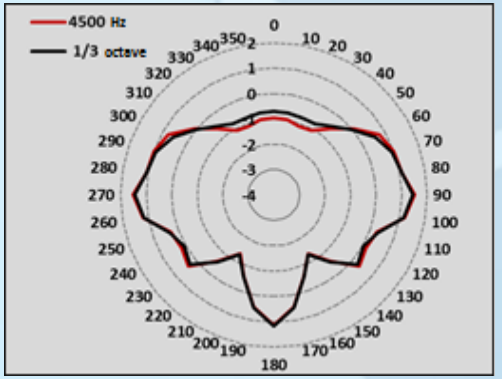
Frequency responses of the recorder depending on the angle of the sound wave incidence (low frequencies)

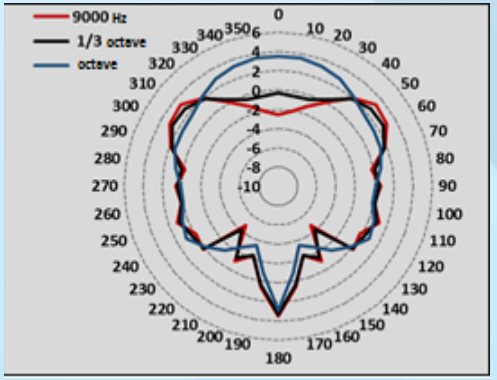


Directivity responses of the recorder at low frequencies

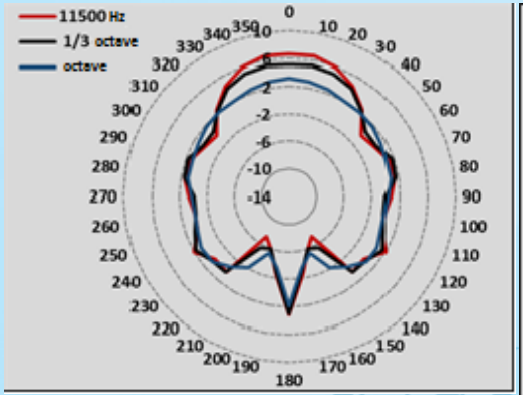
RESULTS OF THE RECORDER CALIBRATION AT FREQUENCIES ABOVE 1 kHz

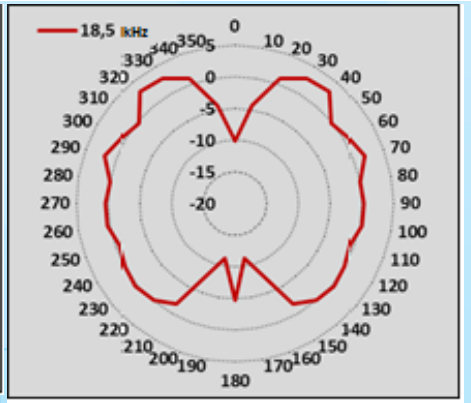






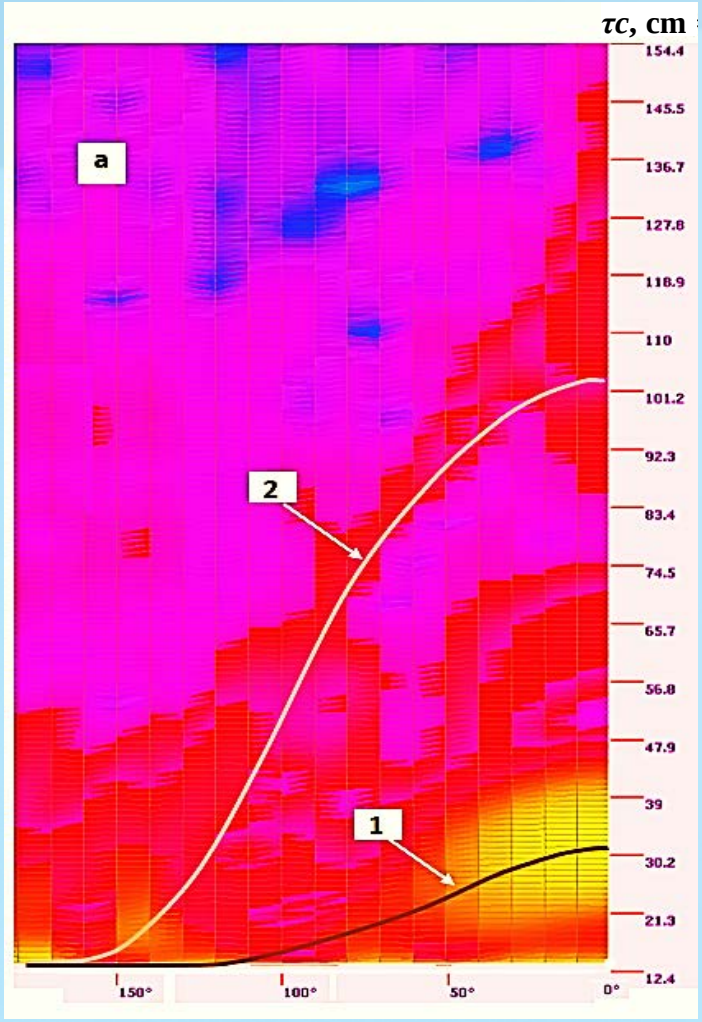
Frequency responses of the recorder in the front sector of the angles of the sound wave incidence

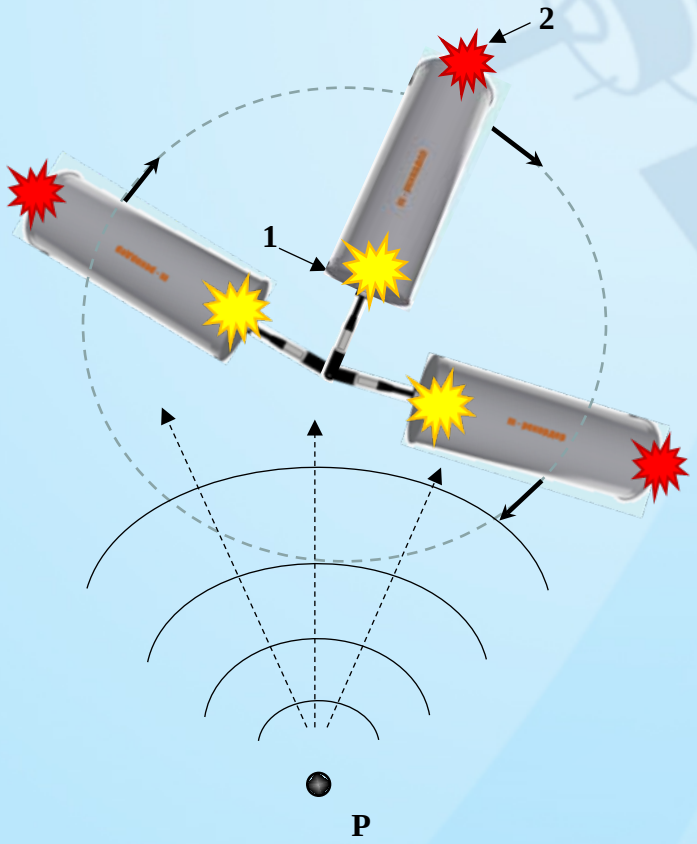




The unevenness of the frequency responses of the recorder reaches 18 dB

DETECTION OF SOUND WAVE SCATTERING SOURCES

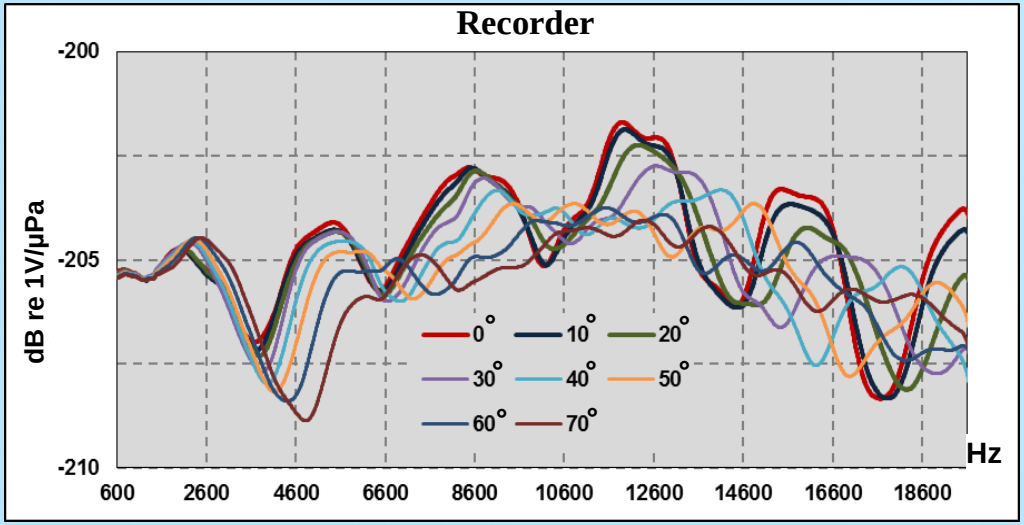


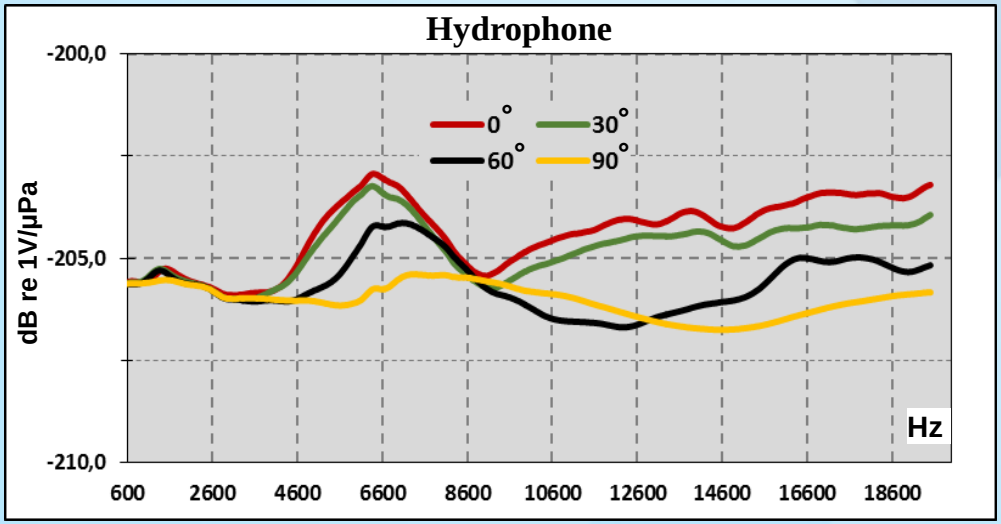


The trajectories of the scattering sources on the front 1 and rear 2 end surfaces of the recorder when measuring the directivity characteristics

ATTENUATION OF THE SOURCES SCATTERING

The use of plastic domes

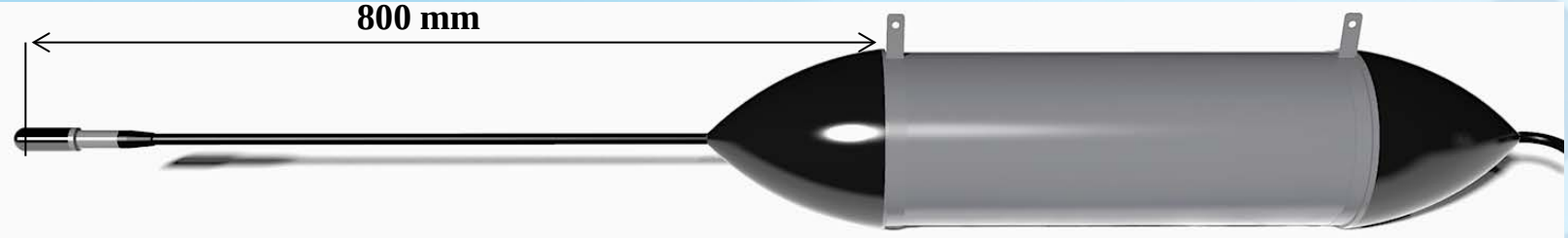




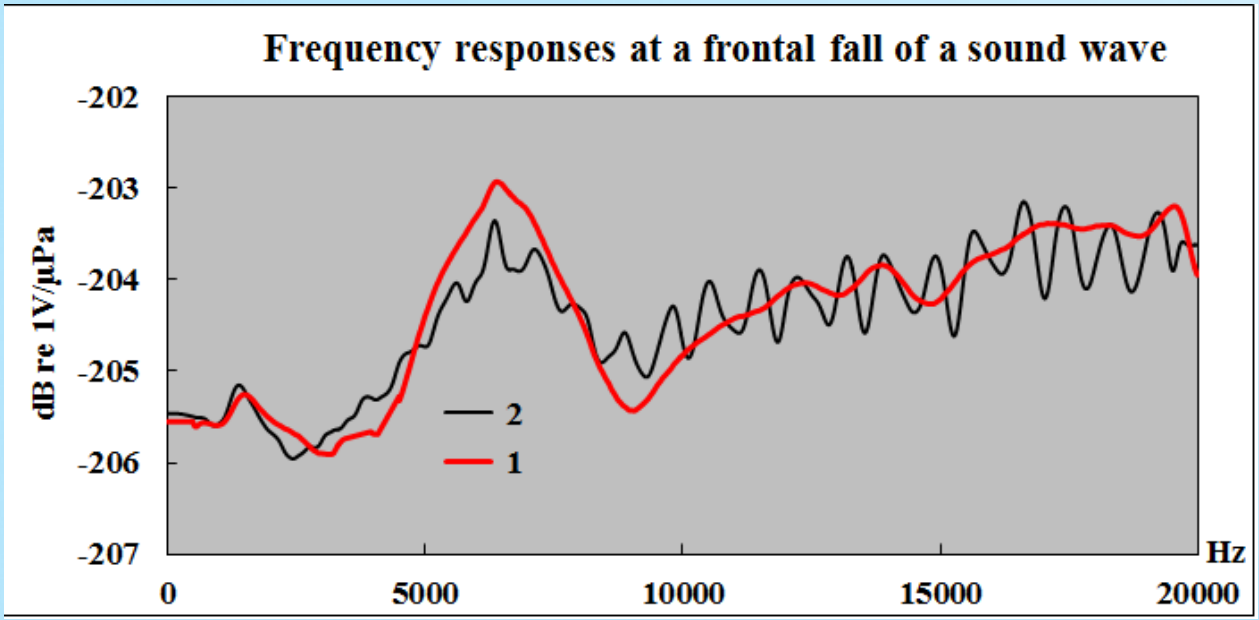
Frequency responses in the frontal sector of angles of the sound wave incidence

With the help of plastic domes , the unevenness of the frequency responses of the recorder is reduced from 18 dB to 7 dB

ATTENUATION OF THE SOURCES SCATTERING



Recorder with a distant hydrophone



1 –hydrophone , 2 – recorder

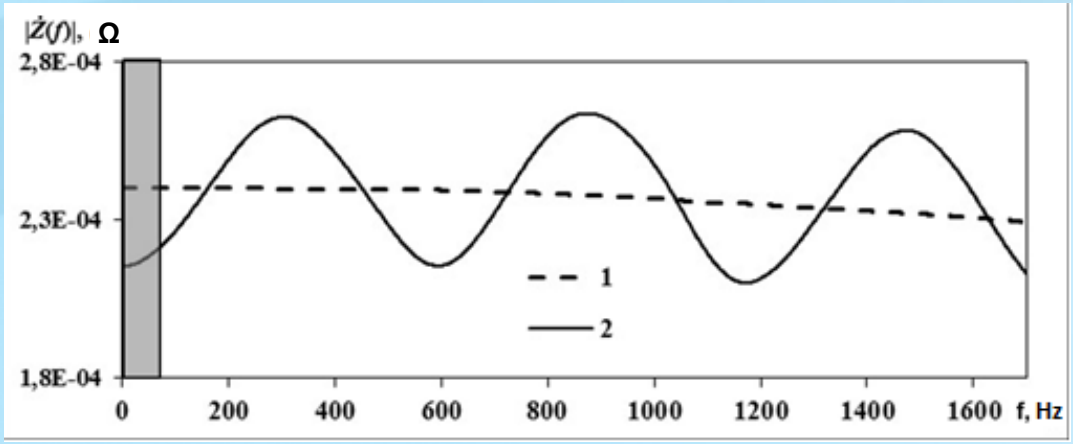
CONCLUSION

The calibration procedure allows:

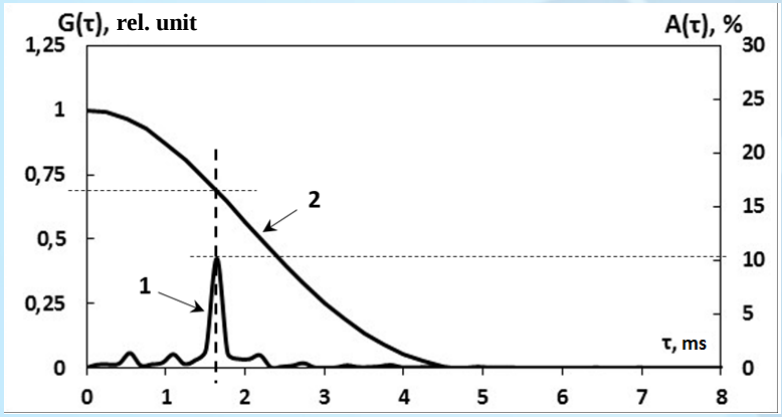
- **To measure the free-field sensitivity of the underwater sound receiver up to frequencies at which the influence of diffraction can be neglected;**
- **To investigate the development of diffraction distortions from their occurrence at very low frequencies that until recently have been unavailable for free-field calibration not only for the recorder, but also for the hydrophone.**
- **In order to take into account correctly the influence of the directivity of the recorder in the budget of the uncertainty of the underwater noise measuring, a family of frequency responses is necessary, but not a traditionally used directivity responses at discrete frequencies.**
- **It is advisable to perform international comparison in a field of recorder calibration, on the results of which to summarize the experience of different laboratories.**
- **The suggested measurement procedure can be considered as a contribution to the solution of the problem of free-field calibration at low frequencies of the recorder as a whole single design.**

Thank you for your attention!

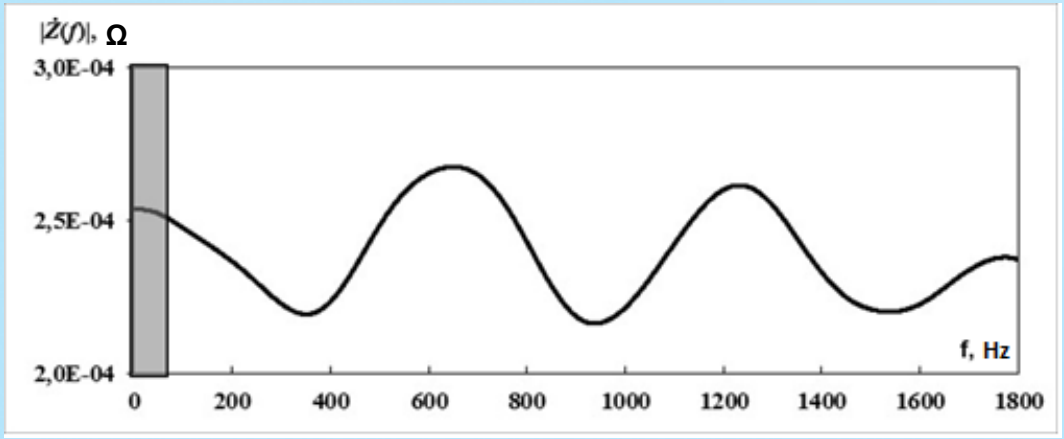
MEASUREMENT OF THE REFLECTION COEFFICIENT FROM THE INTERFACE BETWEEN MEDIA



Frequency dependencies of the projector-receiver pair transfer impedance: 1 - free-field, 2 - distorted by reflection from the water-air interface boundary



Reflection coefficient 98,7 %, phase angle π



Phase angle of reflection 0

Frequency dependencies of the projector-receiver pair transfer impedance distorted by reflection from the water/reinforced concrete interface boundary