Low-Frequency Underwater Acoustics Sensitivity Calibration In A Chamber

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ABSTRACT

The primary calibration of the low frequency hydrophone in an enclosed volume (chamber) using the comparison principle is proposed. Simulated results using the element program is presented, using the transducer as a projector and the hydrophones as receiver. An experimental test with 14 points in the circumferential direction of the closed cavity, and three positions taken in the depth direction (totally including 42 test positions) was carried out to measure the magnitude of the open-circuit voltage at a number of frequencies between 5 Hz and 1 kHz. The sound pressure field is evenly homogeneous and the sound pressure non-uniformity is quantified to be less than 0.5dB within the tested region, demonstrating the accuracy of the sensitivity calibration system.

1 INTRODUCTION

With the continuous exploration of deep-sea unknown areas and the development of underwater acoustic technology to low-frequency band, how to effectively evaluate the performance of underwater acoustic equipment in high hydrostatic pressure and low-frequency band has become particularly important. Acoustic Institute of Chinese Academy of Sciences has established a set of low-frequency receiver sensitivity testing and calibration system based on closed chamber, which can effectively meet the needs of this task.

The technology of comparative calibration is commonly used to establish sound field in a small sealed water chamber so that the standard hydrophone and the hydrophone to be measured are subject to the same sound pressure at the same time. Through the analysis and measurement of sound field in the sealed water chamber, the uniform area of sound field in the cavity can be found and the standard hydrophone and the hydrophone to be measured can be placed at the same depth. Measurement and calibration of low-frequency receiver sensitivity of hydrophone in hydrostatic pressure range of 0-500 meters.

2 ANALYSIS OF SOUND FIELD IN CLOSED CHAMBER

In the closed sound system, the precision of test depend on the distribution of the pressure, and the uniform pressure field is expected. in order to analysis the sound field in the chamber, the system is simulated using the element program ANSYS.

2.1 MODEL OF THE SYSTEM

The axisymmertic model is shown in figure 1， including the transducer , the steel chamber and the water.A longitudinal transducer was used in this system for its pressure stability. as shown in the right side of the figure, the transducer is a stack with eight piezoelectric slice. according of the resisitance curve in the figure, the main resonace frequency is known about 36.5khz. The transducer will operate far below the resonace to achIeve uniform vibrating velocity.

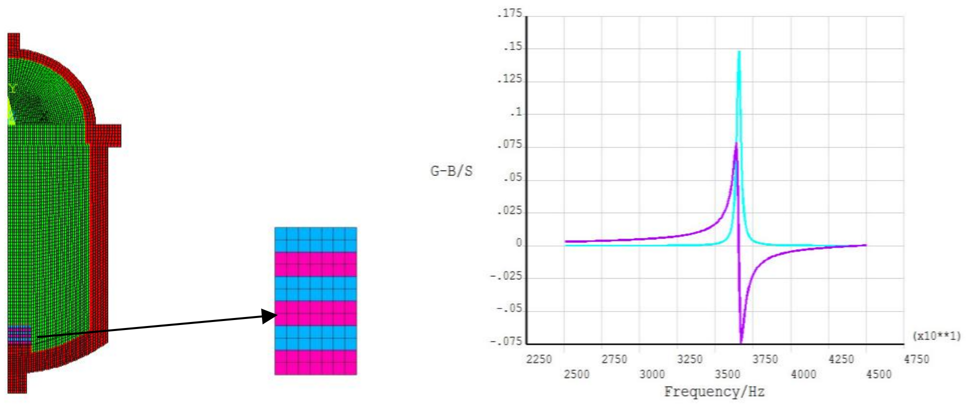


Figure 1: The main resonace frequency

2.2 SOUND FIELD IN THE CHAMBER

When the drive signal is applied to the transducer, the sound field will be formed in the sound tube. The sound field distribution of the transducer at some typical frequencies is shown in the figure2-5. At low frequencies, the sound field in the chamber is basically uniform, and the sound field is the same everywhere. As the increasing of frequency, the gradient distribution of sound field in the vessel gradually appears. When the frequency is greater than 1 kHz, the nodes appear in the inner sound field of the sound tube.

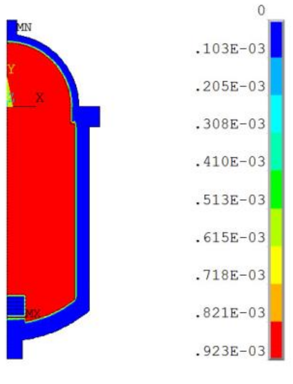


Figure 2: 10Hz sound field in chamber

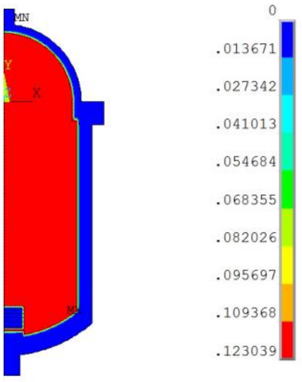


Figure 3: 100Hz sound field in chamber

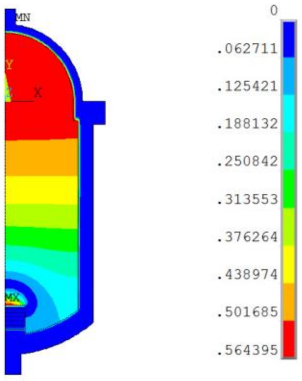


Figure 4: 1000Hz sound field in chamber

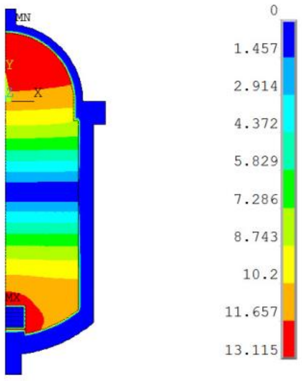


Figure 5: 2000Hz sound field in chamber

From the results of finite element analysis, it can be seen that the reflection of the end cap of the sealed cavity causes the formation of standing wave in the cavity. As the increasing of frequency, the phenomenon of standing wave with shorter wavelength becomes more obvious, and the sound field is distributed in a longitudinal gradient distribution. The impedance of the end cap of the tank is much larger than that of water. The belly acoustic wave is superimposed near the end cap. In order to improve the test accuracy, the standard hydrophone and the hydrophone to be tested should be placed in the same horizontal position on the top of the tank. When the frequency is more than 1 kHz, the gradient of sound field becomes larger gradually, which will affect the accuracy of hydrophone measurement. Therefore, the upper limit of measurement system is set to 1 kHz.

Ordinary open standing wave tubes (VSWTs) have absolute soft boundary conditions near the opening. They are located in the wave node position and have a large acoustic pressure gradient. Moreover, acoustic wave cancellation is serious at low frequencies. Unlike ordinary open-ended VWT, the closed acoustic tube uses metal end cap to form a hard boundary. The standing wave field near the end cap is a belly, and the direct wave and the reflected wave are superimposed in the same phase. Therefore, the signal-to-noise ratio of the closed cavity is much higher than that of the ordinary open VWT at low frequency. The low frequency test system designed in this paper can reach 2Hz, and it can be lower with high impedance preamplifier.

3 MEASUREMENT OF SOUND FIELD DISTRIBUTION IN A PRESSURE CHAMBER

The pressure calibration is performed in an enclosed volume (chamber), where the dimensions of the chamber are very small compared to the acoustic wavelength. In such a situation, the sound pressure may be regarded as constant throughout the chamber [1-3]. According to the structure of the upper cover of the pressure chamber and the position of the bolt, the circumference direction is divided into 14 test points. The standard hydrophone and the measured hydrophone are placed at the same depth in the sealed chamber.

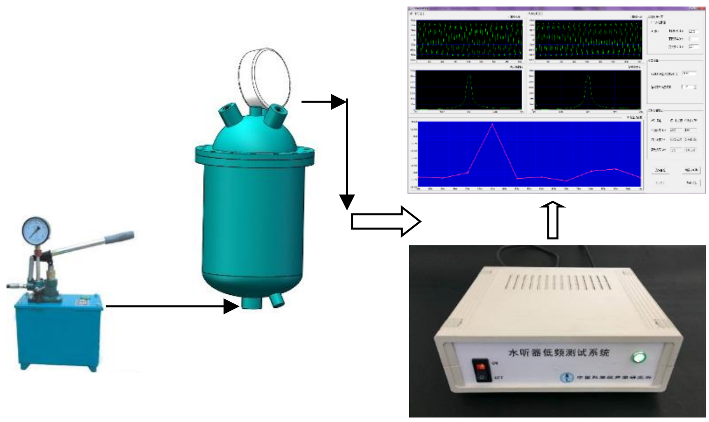


Figure 6: Schematic diagram of hydrophone low-frequency calibration system

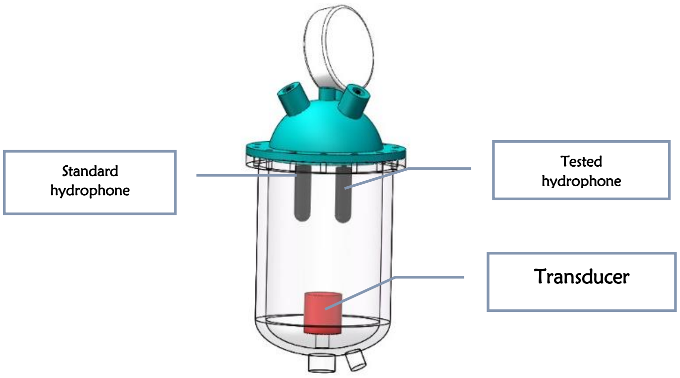


Figure 7: The measuring status inside of the chamber

The circumferential direction of the pressure chamber body is divided into 14 equal parts according to the bolt structure position of the end cap part. One of the positions is position 1, and the two standard hydrophones are placed in position 14 counterclockwise. The distance between the two standard hydrophones in the pressure chamber body is 200 mm, 150 mm and 100 mm from the launching transducer at the bottom, respectively. The measurement of sound field distribution in pressure chamber is mainly based on the acoustic wave emitted by the transmitting transducer at the bottom of the chamber at the frequency of 5Hz-1000Hz. Two standard hydrophones are installed in the pressure chamber at the same depth and the distance is 100mm. The sound pressure level at this depth is measured. The distribution of sound field in pressure chamber at this time is obtained by comparing the difference of sound pressure level at two corresponding positions.

Table 1: Measuring Instruments and Equipment Table

	Equipment	Model	Technical index	Verification number
1	Standard hydrophone	HTI-96-MIN	Receive sensitivity：-180dB	Manufacturers provide
2	Signal source	Agilent33220A	Working bandwidth：20MHz	WB16-2532
3	Oscilloscope	TEK-TDS2002B	Working bandwidth：60MHz	WC16-1649
4	Power amplifier	NF BA4825	Working bandwidth：DC-1MHz	WB16-2568
5	Standard hydrophone	HTI-96-MIN	Working bandwidth：2Hz-30KHz	Manufacturers provide
6	Pressure chamber	Customized	Size:220mm(internal diameter) 400mm(height)	

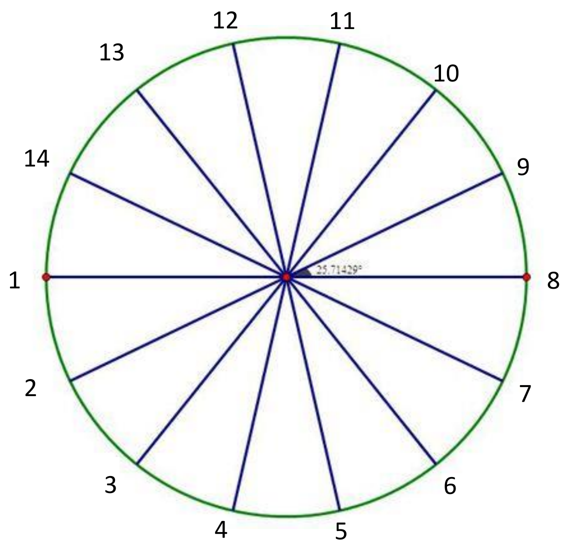


Figure 8: Diagram of placement position of two hydrophones

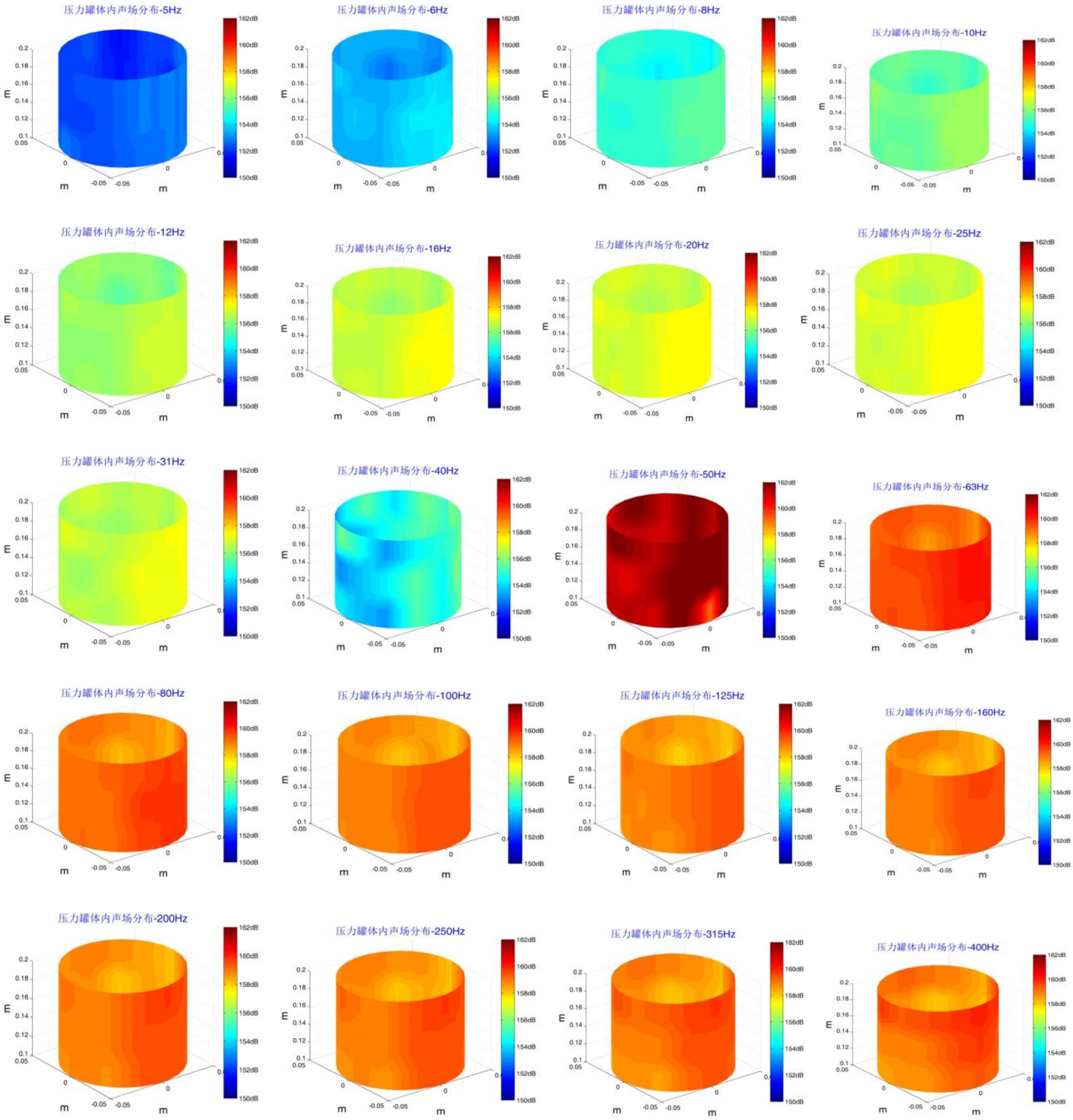
The corresponding position of two standard hydrophones in the pressure chamber is showing blow in the table2.

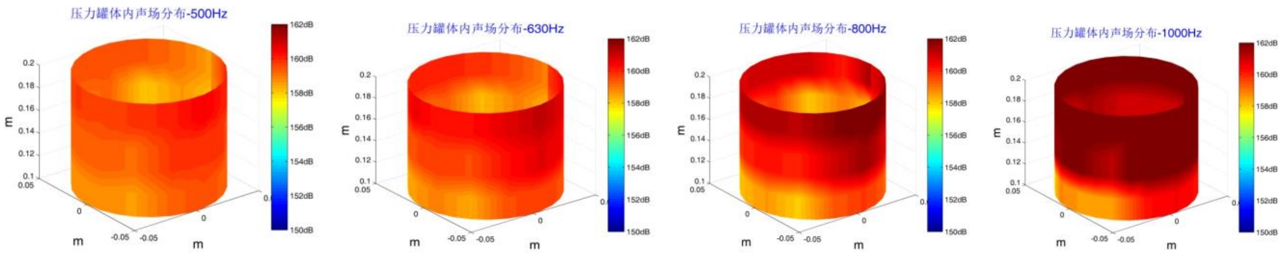
Table 2: The corresponding position of two standard hydrophones in the pressure chamber

Position 1————Position 8
Position 2————Position 9
Position 3————Position 10
Position 4————Position 11
Position 5————Position 12
Position 6————Position 13
Position 7————Position 14

The experimental conditions are as follows:
(1)Hydrostatic pressure in the pressure chamber is 1MPa;
(2)The test frequency range is 5Hz to 1kHz.

After the signal acquisition of 14 points, we can draw the sound field inside chamber.We can see the sound pressure change was very small when the two hydrophones at the same depth in the chamber.It means an appropriate course of action when we take the experiment for sensitivity calibration of hydrophone





	Maximum difference of sound pressure level at different positions in circumferential direction			
Frequency（Hz）	Depth200mm	Depth150mm	Depth100mm	Conclusion
5	0.32dB	0.29 dB	0.28 dB	Difference value less than 0.5 dB
6	0.14 dB	0.42 dB	0.39 dB	
8	0.22 dB	0.23 dB	0.12 dB	
10	0.20 dB	0.40 dB	0.30 dB	
12	0.20 dB	0.28 dB	0.35 dB	
16	0.27 dB	0.28 dB	0.26 dB	
20	0.37 dB	0.44 dB	0.37 dB	
25	0.36 dB	0.48 dB	0.48 dB	
31	0.36 dB	0.55 dB	0.46 dB	Difference value less than 0.6 dB
40	0.49 dB	0.53 dB	0.45 dB	
50	0.47 dB	0.47 dB	0.44 dB	
63	0.52 dB	0.58 dB	0.50 dB	
80	0.53 dB	0.55 dB	0.54 dB	
100	0.54 dB	0.53 dB	0.54 dB	
125	0.53 dB	0.53 dB	0.54 dB	
160	0.14 dB	0.23 dB	0.16 dB	Difference value less than 0.5 dB
200	0.27 dB	0.23 dB	0.14 dB	
250	0.27 dB	0.23 dB	0.28 dB	
310	0.26 dB	0.27 dB	0.27 dB	
400	0.27 dB	0.40 dB	0.33 dB	
500	0.49 dB	0.40 dB	0.26 dB	
630	0.45 dB	0.49 dB	0.48 dB	
800	0.94 dB	0.70 dB	0.49 dB	
1000	**0.96 dB**	**0.82 dB**	**0.93 dB**	Difference value less than 1dB
Remarks:	“Depth” means the distance between the transducer and hydrphone			

3.1 Figures and Photographs

Incorporate all graphics, charts, tables, illustrations, photos, etc. are required to be referenced, directly into your manuscript shortly after their first mention. All figures/photographs/illustrations must be individually numbered and captioned. Illustrations must be sharp and clear, including any lettering or labels on the figure. Figure captions are 10 point Arial font with 6 point spacing before and after. These captions should always be positioned *below* the figure. Captions should be centred.

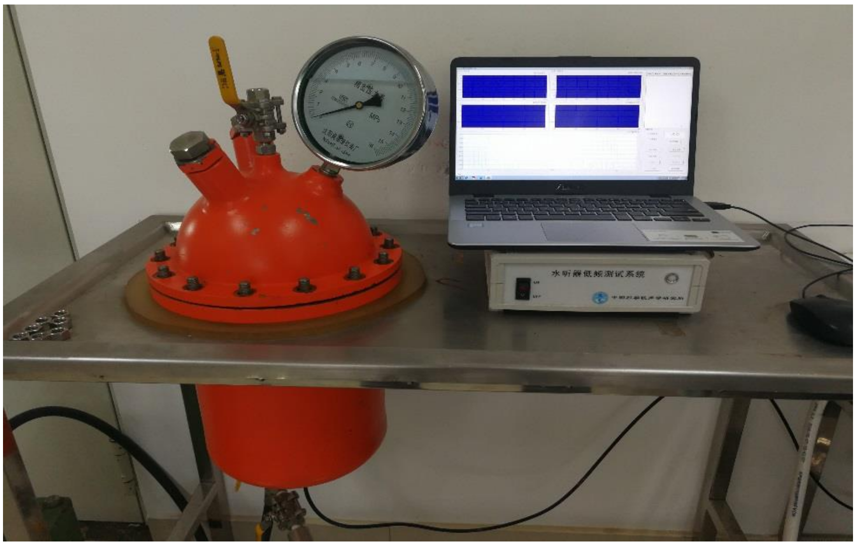


Figure 9: Low-Frequency Underwater Acoustics Sensitivity Calibration system

4 CONCLUSIONS

Through the analysis of the sound pressure level data at different locations in the enclosed chamber, it is concluded that the sound field in the enclosed chamber distributes uniformly in the region, so as to obtain the range of the region which meets the test and calibration of the low-frequency receiving sensitivity of the hydrophone. Through testing, the sound field distribution varies uniformly with the frequency of the transmitted signal in the 100 MM-200 mm area of the sealed chamber from the bottom of the transmitting transducer, which is suitable for low-frequency underwater acoustics sensitivity calibration.

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