Hydrophone spatial directivity and the induced difference in HIFU acoustic field test

T Chen\textsuperscript{1,2}, J M Hu\textsuperscript{2}, W Huang\textsuperscript{3}, W Zhang\textsuperscript{3} and D Zhang\textsuperscript{1}

\textsuperscript{1} Institute of Acoustics, Nanjing University, Nanjing 210093, China
\textsuperscript{2} Jiangsu Province Institute for Medical Equipment Testing, Nanjing 210012, China
\textsuperscript{3} Present Address

Chent_qxs@jsfda.gov.cn

Abstract. Hydrophone has been widely used in testing ultrasonic field distribution. But the hydrophone has a certain directivity, which may bring error in the actual acoustic field measurements. So it is necessary to meet some requirements about the directivity of hydrophone. In the measurement, the spatial directivities of needle hydrophone, membrane hydrophone and robust hydrophone is measured and a comparison about measured data of HIFU acoustic field with them is given. Experimental results indicate that the asymmetric special directivity of hydrophone is due to manufacturing processes and other reasons. As a result, it is not sufficient to test the directivity of hydrophone along one axis. It is necessary to adjust the direction of the hydrophone when characterizing the HIFU field.

1. Introduction

High Intensity Focused Ultrasound (HIFU) is an acoustic ablation technique that utilizes the power of ultrasound to destroy deep-seated tissue with pinpoint accuracy for treatment of cancers. The principle of this technique is to raise the tissue temperature to relatively high values and cause thermal coagulation and ablation of cells by using an ultrasonic focusing transducer. As we know, it is highly desirable in HIFU therapy to produce lesions with well-controlled spatial characteristics. To achieve this purpose, it is important of well understanding of the acoustic field generated by the HIFU transmitter.

Now, HIFU is popular in China. More than 10 companies are developing HIFU instruments, more than 200 hospitals using HIFU machine, and tens of thousands of patients have been treated by HIFU. For industry development and the safety of using HIFU, it is important to measure HIFU device, as excessive power or lost control of the sound field could give the patient harm.

Hydrophone is an important method of measuring the sound field, but its spatial directivity may affect the accuracy of the measurement. The purpose of this study is to examine the spatial directivity of the hydrophone and the induced difference in HIFU acoustic field test.

2. Methods

In order to test the spatial directivities of hydrophone, we set up an experimental system with two degree of freedom as shown in Fig. 1. The first is to determine the hydrophone's sensitivity surface by sliding the hydrophone from -90 to 90 degree. The second is to determine the hydrophone's sensitivity...
surface by rotating the hydrophone from 0 to 360 degree. In the measurement, the emitted signal is a
670 kHz sinusoidal signal with voltage of 70V to drive the HIFU transmitter.

![Diagram](image1.png)

Figure 1. Illustration of the experimental system.

Figure 2 shows the steps of measurement.

![Diagram](image2.png)

Figure 2. Steps of measurement

3. Results and discussions

In this study, total 4 tests are performed to test the influence of the hydrophone spatial directivity. Test 1 is to check spatial property of the measurement system. In the measurement, the sliding angle is from -90 to 90 degree, while the rotating angles are 0, 180, 90, and 270 degrees, respectively.

Figure 3 shows the measured results at 0 and 180 degrees, while Fig. 4 gives the measured results at 90 and 270 degrees. The data between 0 and 180 degrees are symmetrical, and the data between 90 and 270 degrees are also symmetrical. It indicates that the repeatability and stability of the measuring instrument meet our requirement.

![Graph](image3.png)

Figure 3. Measured results at 0 and 180 degrees
Figure 4. Measured results at 90 and 270 degrees

Test 2 is to examine the spatial difference of the hydrophone. In the measurement, the sliding angles are from -90 to 90 degrees, and the rotating angles are set to be 0, 45, 90, 135 and 180 degrees.

Figure 5. Spatial difference of the hydrophone.

Figure 5 compares the spatial difference of the hydrophone at different rotating angles. We can find that bigger differences are observed except for the slide angle close to 0 degree.

Test 3 is to examine the individual difference among three kinds of hydrophones (A/B/C). The type A is a needle hydrophone protected by copper, the type B is a robust needle hydrophone, and the type C is a simple needle hydrophone. In the measurement, the sliding angles are from -90 to 90 degrees; while the rotating angles are set to be 0, 45, 90, 135 and 180 degrees.

The measured results for the three kinds of hydrophones are shown in Fig.6. The difference in directivity and sensitivity for various of hydrophones is obvious. We need test the directivity of hydrophone before using in the HIFU test.
Test 4 is to examine the frequency dependence of the hydrophone. In the measurement, the frequency is changed from 600 to 900 kHz. Figure 7 shows the frequency dependence of the hydrophone B. It is concluded that there exists frequency difference in the measurement using the hydrophone.

4. Conclusions
In the measurement of HIFU acoustic field using hydrophone, the requirement for directivity (5.2.1.3, GB/T19890-2005) and positioning system for the fixture and orientation (5.2.2, GB/T19890-2005) are important. In this study, we performed four tests to examine the spatial directivity of the hydrophone and the induced difference in measurements. It is concluded that it is necessary to test the directivity of the hydrophone before our HIFU acoustic field testing at working frequency. In addition, we also should adjust the hydrophone positioning system in at least two degree freedoms.

References
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