Proceedings of the Institute of Acoustics

UK INTERLABORATORY COMPARISON OF ULTRASONIC ATTENUATION AND VELOCITY MEASUREMENTS - A PRELIMINARY REPORT

B Zeqiri

National Physical Laboratory, Teddington,
Middlesex, TW11 OLW

1 INTRODUCTION

Measurements of the ultrasonic properties of materials have become important in a number of areas of applied science such as medicine, NDT and the food industry. The properties of principal interest are attenuation or absorption and phase velocity (speed), and these may be be determined using a variety of measurement techniques. In general, velocity can be measured with greater accuracy than attenuation. For measurements of attenuation, significant discrepancies between different laboratories or different techniques are observed even for measurements on simple materials.

This paper is a preliminary report of a project aimed at assessing UK capabilities for measurements of ultrasonic attenuation and velocity. Samples of well characterised homogeneous liquids have been used as reference materials and supplied to ten measurement centres within the UK, with NPL acting as the coordinating laboratory. A similar exercise has been carried out in the USA [1], primarily for the medical ultrasonics field, using samples of scattering material.

2 COMPARISON PROTOCOL

The liquids used in the comparison were supplied to eleven laboratories; four universities, the Medical Physics departments of three hospitals, three Government laboratories and a commercial laboratory in the agrochemical sector. Although two reference liquids were supplied to each laboratory, this paper reports on measurements made on Liquid B used in the intercomparison to illustrate the level of agreement achieved by the different laboratories. The actual identity of Liquid B was Dow Corning 710 (DC-710) silicone fluid, a material which has now been established at NPL as a reference standard for ultrasonic attenuation, and for which values for the acoustic attenuation in the frequency range 2.25 to 10 MHz have been published [2].

There was no restriction on the frequency at which the measurements should be made by a laboratory or on the number of techniques a laboratory could use. Consequently, many laboratories used the availability of the reference liquids as an opportunity to test a range of measurement techniques, and in some instances as many as three sets of measurements were supplied to NPL.

Due to the temperature dependence of the attenuation and velocity of the silicone fluid, one stipulation was that the temperature for the intercomparison should be 20 °C. Where temperature control was not available - and three laboratories provided measurements at different temperatures - a correction was applied by NPL to normalise the measurements to 20 °C and so enable a direct comparison.
Laboratories were offered the option of using a suitable quantity of the base liquid in their own system or of using the NPL liquid reference cells [2]. These are stainless steel cells containing a specified path length of the reference liquid defined by two taut Mylar acoustic windows. Three of the laboratories made measurements using the reference cells. Corrections for the interfacial losses and the phase advance caused by the window material were applied to these measurements by NPL. In cases where a reference cell was used, a reference cell of 10 mm thickness containing the DC-710 fluid was supplied. At 5 MHz the approximate transmission loss of this reference cell was -12 dB.

3 MEASUREMENT TECHNIQUES

Measurements of attenuation and velocity were made by the laboratories using a variety of measurement techniques. Clearly, of ultimate interest and the major benefit of carrying out the interlaboratory comparison is the correlation of measured values of attenuation and phase velocity with the particular measurement technique used. In this way, it may be possible to achieve an improved understanding of the measurement techniques used, both in terms of identifying important sources of measurement uncertainty and in better defining absolute accuracy. Details of the measurement techniques used and the accuracies claimed by the laboratories lie beyond the scope of the current paper and will be left to a future publication. Some of the noteworthy characteristics of the measurement techniques used include:

- continuous wave (cw) interferometry
- through transmission
- immersion measurements in reference liquid itself
- displacement method
- broadband measurements (pulsed)
- narrowband measurements (quasi-cw)
- focused transmitters
- focused receivers
- plane-piston transducers

However, as a general comment, common to all of the techniques used has been the use of a piezoelectric transducer or hydrophone as the acoustic receiver. This forms an important distinction with the techniques used during the USA intercomparison [1], where a number of measurements of attenuation were made using systems that measured radiation force.

4 RESULTS

4.1 Measurements of attenuation coefficient

To date, measurements made by eight of the participating laboratories on Liquid B have been received and analysed with results covering a frequency range from 1 to 25 MHz. It is customary to represent the frequency dependence of the attenuation coefficient of a material, α, in the form $\alpha = af^b$, where f is the frequency in MHz and a and b are constants. From the published measurements of α for DC-710 silicone fluid [2], a and b values of 0.63 and 1.79 describe the attenuation coefficient between 2.25 and 10 MHz. In a preliminary study of the results for Liquid B, a regression analysis has been performed on all the measurements received from the participating laboratories to establish Group mean values of a and b.

Broadly, the techniques used during the intercomparison may be divided into two main classes, those that provide measurements at discrete frequencies and broadband techniques that provide measurements over a range of frequencies, typically 3 to 7 MHz. In order that the broadband measurements be included in the calculation of the Group dependence without introducing bias, any broadband range of measurement points was represented in the linear regression by a set of discrete points. The procedure adopted involved representing the range by single points at the beginning and end of the frequency span, and intermediate points at approximately 1 MHz intervals. In this way 60 measurements were included in the linear regression and the Group mean attenuation coefficient, α_g, could be represented by a_g=0.5 and b_g=1.889.

For the eight laboratories that provided attenuation results, Figure 1 shows the percentage deviation of their measurements from the Group mean calculated value. The various lines represent different broadband measurements, and the various symbols represent different discrete frequency measurements. Although the rms deviation is 7%, deviations greater than ± 30% occur at frequencies below 2 MHz and it has not been possible to include these in Figure 1.

It is of interest to note that in general $\alpha_g < \alpha$ and differences between the Group mean data and the reference data vary from -14% at 2.25 MHz to -0.4% at 10 MHz.

4.2 Measurements of phase velocity

Figure 2 shows measurements of phase velocity supplied by six of the laboratories taking part in the intercomparison with the lines again representing measurements of phase velocity performed using broadband techniques. Where available, the measurement uncertainties provided by the laboratories have been included. The results indicate a degree of dispersion in the frequency range 1 to 15 MHz of 6 $m\ s^{-1}$. In general, the agreement between different laboratories for measurements of velocity is good, and is typically within the measurement uncertainties claimed, a finding consistent with the conclusions of the USA interlaboratory comaparison [1].

5 SUMMARY

A UK interlaboratory comparison of ultrasonic attenuation and velocity measurements has been carried out using two reference samples of homogeneous silicone fluid. The results presented in this paper are for Liquid B, DC-710 silicone fluid, and they indicate good agreement for measurements of phase velocity determined by the different participants. Agreement for measurements of attenuation is typically better than $\pm$ 10% of the calculated Group mean for measurements above 3 MHz. However, for measurements below 2 MHz differences between the measured values and the Group mean can be larger than $\pm$ 30%.

6 REFERENCES

[1] E L MADSEN, G R FRANK, P L CARSON, P D EDMONDS, L A FRIZZELL, B A HERMAN, F W KREMKAU, W D O'BRIEN, K J PARKER & R A ROBINSON. "Interlaboratory comparison of ultrasonic attenuation and speed measurements", J Ultrasound Med, 5, p 569. (1986)

[2] B ZEQIRI. "Reference liquid for ultrasonic attenuation", Ultrasonics, 27, p 314. (1989).

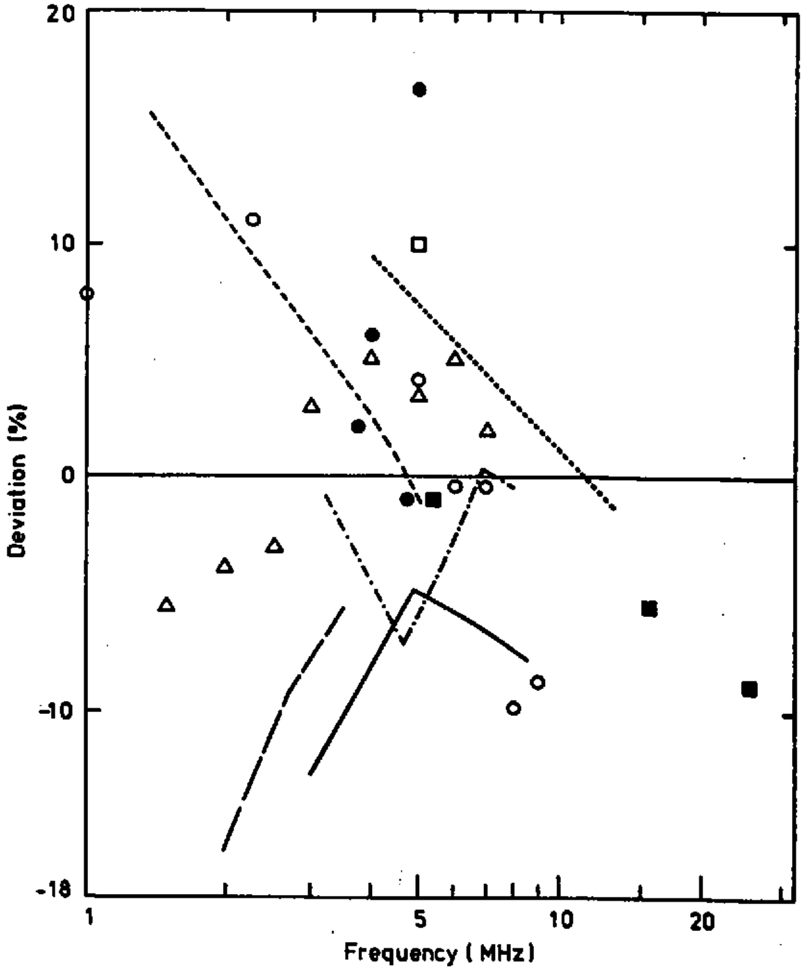

Figure 1: Percentage deviation of attenuation coefficients measured by laboratories from the Group mean attenuation coefficient. The measurements were made on DC-710 silicone fluid (intercomparison Liquid B). The different lines represent different broadband measurements. The various symbols represent different discrete-frequency measurements.

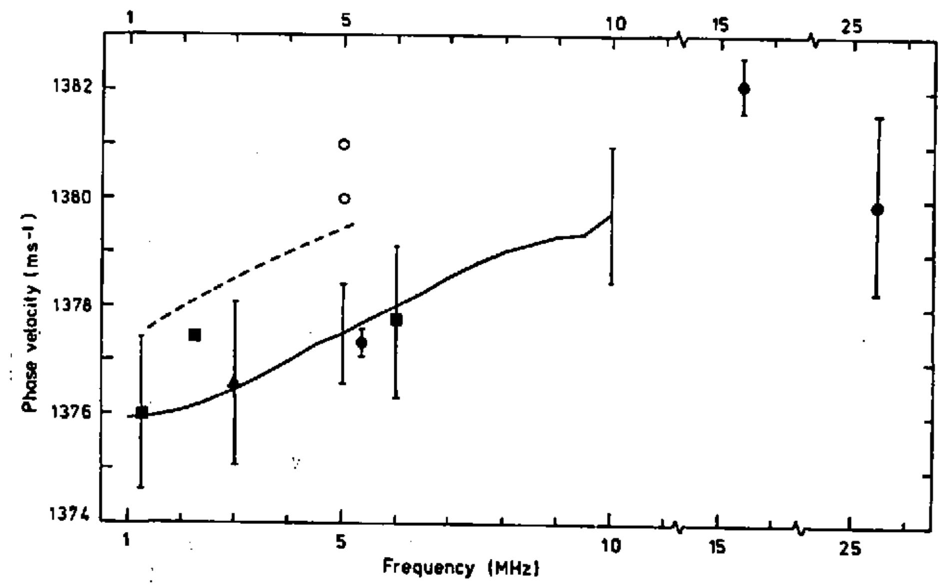

Figure 2: Phase velocity of DC-710 (Liquid B) as measured by six of the laboratories participating in the UK intercomparison. The solid and dotted lines represent different broadband measurements. The various symbols represent different discrete-frequency measurements.