CIRA(EXT) 008

May 1996

Use of a coupled microphone simulator to compare measurements of electrical transfer impedance in the reciprocity calibration of microphones - Euromet project A312

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ABSTRACT

The NPL coupled microphone simulator mimics two IEC type LS1P microphones coupled by a 3 cm^3 coupler, in order to test measurement systems used for the primary reciprocity calibration of microphones. This report presents results obtained with the device at NPL (National Physical Laboratory, UK), PTB (Physikalisch-Technische Bundesanstalt, Germany), the Danish Primary Laboratory for Acoustics (DPLA), and the Danish Technical University (DTU). The coupled microphone simulator has helped to identify and eliminate a number of small errors in the performance of these systems and has been shown to be a very effective tool for monitoring the stability of such systems over periods of several years.

ISSN 1361-4053

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CONTENTS

1 INTRODUCTION

The standard of sound pressure is realised through the calibration of laboratory standard microphones by the reciprocity technique. The principle of this technique is that the product of the sensitivities of two coupled microphones, one of which is transmitting sound and the other receiving, is given by the ratio of the electrical and acoustical transfer impedances of the pair. The acoustical transfer impedance can be calculated from a knowledge of the coupling geometry and the sound propagating medium, and the electrical transfer impedance is determined by measurements.

During the last decade there have been several intercomparisons of primary standards for sound pressure in Europe. Although the agreement has always been acceptable there have remained some unexplained differences. In order to investigate these differences two separate Euromet projects were agreed between the UK, Denmark and Germany. One project involved the creation of a set of reference data files to test the computer programs used. The other project involved using a `coupled microphone simulator' at NPL (National Physical Laboratory, UK), PTB (Physikalisch-Technische Bundesanstalt, Germany), the Danish Primary Laboratory for Acoustics (DPLA), and the Danish Technical University (DTU). This report presents the results of the latter project.

The international Standard[1] describing the reciprocity technique deals fully with the calculation of the acoustical transfer impedance, but leaves open the method of measuring the electrical transfer impedance. Different standards laboratories therefore use different measurement methods and apparatus. Consequently, when investigating discrepancies between the results of microphone calibrations carried out at different laboratories, there is a basis for comparing calculation methods but not for assessing the electrical measurements. To address this problem a device, termed a coupled-microphone simulator, was developed at NPL to investigate the accuracy of apparatus used to measure the electrical transfer impedance.

The design of the coupled microphone simulator has been presented elsewhere[2], for the purposes of this study it is sufficient to say that it mimics two IEC type LS1P microphones coupled by a 3 cm^3 coupler. It has an electrical transfer impedance which is stable, reproducible and calculable and given by $1/(\omega CN)$ where N is the turns ratio of a transformer, C is a measured capacitance, and ω is the angular frequency of the input signal. In the device used in these measurements N = 193, and C = 55.067 pF. Some systems make an allowance for the capacitance of the cables carrying the current from the transmitter microphone; the coupled microphone simulator adds 122 pF to this value.

The coupled microphone simulator is simply connected to a reciprocity calibration system and then the system measures the electrical transfer impedance of the device as if it were a pair of coupled microphones. The ratio between the measured electrical transfer impedance and the calculated electrical transfer impedance is an indication of any error in the electrical measurements. The resulting error on a microphone sensitivity level is

$$10 \lg \left(\frac{\text{measured impedance}}{\text{calculated impedance}} \right)$$

The uncertainty on the calculated impedance is equivalent to 0.001 dB on a microphone sensitivity level.

2 MEASUREMENTS

The coupled microphone simulator was used on the following systems:

NPL-A This automated system measures the electrical transfer impedance by comparison with a resistance that is traceable to national standards. It has been in use at NPL as the primary standard since 1981.

NPL-B This automated system was under development at NPL at the time of the measurements as a replacement for **NPL-A**. It also measures the electrical transfer impedance by comparison with a traceably-calibrated resistor.

NPL-C This manual system uses a Brüel & Kjær type 4143 reciprocity apparatus. It is not normally used for reciprocity measurements as it is only traceable to a factory calibration of the reference capacitor.

DPLA This automated system uses a Brüel & Kjær type 4143 reciprocity apparatus. It is used as the Danish primary standard. The device is specially modified to allow the reference capacitor to be calibrated with a dummy microphone and a coupler in their normal positions. The reference capacitor is calibrated at a number of frequencies and is traceable to national standards.

DTU This automated system measures the electrical transfer impedance by comparison with a traceably-calibrated resistor. It has been in use at DTU since the early 1980's, and used in many international intercomparisons.

PTB-A This manual system measures the electrical transfer impedance by comparison with a resistance that is traceable to national standards. It has been in use at PTB since the early 1980's, and used in many international intercomparisons.

PTB-B This automated system was under development at PTB at the time of the measurements as a replacement for **PTB-A**. It also measures the electrical transfer impedance by comparison with a traceably-calibrated resistor.

3 RESULTS

The results from 1994, in terms of the predicted error on the calibration of a LS1P microphone, are shown in Figure 1. The DTU and PTB-A systems had also been measured in 1988[3] and those results are reproduced here for comparison.

Following these measurements PTB found some cross talk in their development system (PTB-B) and changed the grounding arrangements. Measurements in the spring of 1996 showed that the error had been reduced to less than 0.005 dB below 4 kHz.

The DPLA and NPL-C systems utilise a reference capacitance. The reference capacitance is slightly dependent on frequency, and whereas for the DPLA system this dependence is measured and taken into account, in the NPL-C system it is ignored. This explains the steady increase with frequency in the predicted error for the NPL-C system, which is absent for the DPLA system.

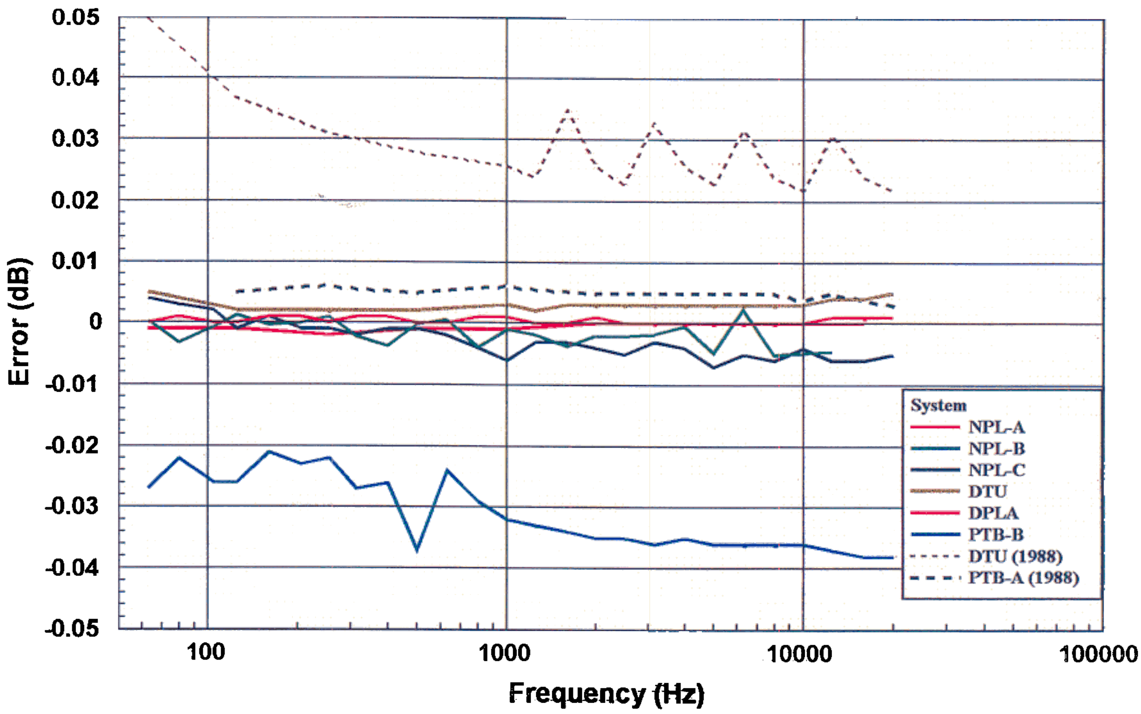

Figure 1 Predicted error on the sensitivity level of a LS1P microphone using the various systems

4 CONCLUSIONS

The coupled microphone simulator has demonstrated its usefulness in developing new primary microphone calibration systems. The NPL systems have benefited from continual monitoring and fine tuning[2], the DTU system improved considerably between 1989 and 1994 following the development of a correction for stray capacitance identified by the simulator, and the new PTB system has also benefited during this project.

Measurements on the two Brüel & Kjær type 4143 reciprocity apparatus (DPLA and NPL-C) highlight the need for the reference capacitor in the apparatus to be calibrated as a function of frequency and for the calibration to be performed with a dummy microphone and coupler in place. If this is not possible then the nominal frequency dependence of the reference capacitor given in the Brüel & Kjær instruction manual can be applied.

The coupled microphone simulator has proved its value on a variety of systems. It has proven particularly useful when applied regularly to monitoring the stability of an individual system. Consequently there are now plans to reproduce the coupled microphone simulator and make copies available to other laboratories.

5 REFERENCES

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