A COMPARISON OF BACKPLATE DESIGNS FOR HOMEMADE MICROPHONES FOR AIRBORNE ULTRASOUND.

Justin A. T. Halls[1]

[1] Huntleigh Research Institute, Brunel Institute for Bioengineering, Brunel University, Uxbridge, Middx UB8 3PH. justin.halls@brunel.ac.uk

1. INTRODUCTION

Microphones for airborne ultrasound have a wide range of uses in fields as diverse as bioacoustics and robotics. Simple and cheap transducers are not always readily available and even bat detector manufacturers at the lower end of the market resort to the use of audio electret microphones or narrow band piezo-electric transducers. Transducers may also be subject to severe trauma when used in the field, with rodents or with some of the more aggressive forms of robots. It is then advantageous to be able to repair and replace the microphone capsules on a regular basis.

The general principles of capacitance microphone construction for ultrasonic applications are well established [1][2][3][4] and the historical development of these transducers has been well described. In more recent times there is a trend towards the development of extremely wideband transducers, with frequency response up to 1MHz [5][6]. However these transducers require complex micro-machining fabrication techniques that are not available to most bioacoustic researchers. Schuller[7] described an ultrasonic earphone with a wide frequency response up to 120kHz, but his design is not easily adaptable to general purpose applications and relied on components from a commercial transducer (AKG, Type CK-40) which is no longer available.

There is still a need for simple ultrasonic microphone capsules, which can be made using simple tools and readily available materials, and which can be easily repaired if damaged. For many applications accurate calibration is not required and wide bandwidth and good sensitivity are more important parameters.

The microphones described here are suitable for use with bat detectors or ultrasound recording equipment, or for ultrasonic sonar systems for robotics or similar applications.

2. MATERIALS AND METHODS

All transducers were calibrated against a Bruel and Kjaer (B&K) 6.4mm (1/4") calibrated microphone[8]. Microphones and loudspeakers other than QMC Instruments production microphones, were calibrated in the QMC anechoic chamber [9]. QMC Instruments production microphones were calibrated on an open bench in the centre of a large room.

For loudspeaker calibrations the experimental transducer was fixed in the centre of the anechoic chamber and the B&K 6.4mm (¼") microphone type 4135, connected to a headstage amplifier type 2615 or 2619 by an adaptor type UA0035, was attached to the centre of a vertical, semi-circular arm at a distance of 40cms from the loudspeaker. The B&K microphone was always used with the protective cap removed. The loudspeaker was driven by a valve amplifier through a 2m length of co-axial cable. The loudspeaker amplifier was located inside the chamber, while the driving signal came from a Venner signal generator type TMA625/2 located outside the chamber. The loudspeaker was normally driven by a constant voltage of 10V r.m.s., which was measured at the loudspeaker terminals by a Levell microvoltmeter type TM3A, the output of which could be monitored from outside the chamber. For performing reciprocity checks the current through the loudspeaker could be monitored by measuring the voltage drop across a 10 ohm resistor in series with the loudspeaker.

The same arrangement was used for the calibration of microphones, except that the B&K microphone and adaptor could be replaced by the experimental microphone attached to an adaptor type JJ2614. Complete responses for the standard and test microphones were obtained alternately and the means of three responses in each case were taken.

Routine calibration of QMC Instruments production microphones was performed by positioning the standard microphone next to the test microphone and taking readings from both simultaneously. The loudspeaker and microphones were positioned 30cms above bench height, with foam wedges on the bench and attached to the loudspeaker and microphone stands to reduce reflections. The test microphone, mounted in a QMC Instruments headstage, was held in a clamp stand with a 6.4mm B&K microphone and headstage held next to the test microphone, with its diaphragm slightly in front of the front ring of the test microphone to prevent shielding. The loudspeaker was aligned by transmitting a high frequency signal (ca. 180kHz) and rotating the loudspeaker to a point midway between the positions for which the outputs of the two microphones were greatest. This technique is adequate for frequencies up to 120kHz.

The loudspeaker was driven by a valve amplifier as before, with a Farnell function generator type FG1 as the signal source. Microphone signals from both standard and test microphones were filtered with 1kHz high pass passive RC filters and measured using Levell TM3A microvoltmeters. The outputs of the microvoltmeters were monitored on a Telequipment D63 oscilloscope.

At each frequency the loudspeaker drive signal was adjusted to give a nominal sound pressure of 51dB SPL (20 µPa) as measured by the B&K microphone and the corresponding reading for the test microphone was recorded. When calculating the final frequency response of the test microphones corrections were included for the frequency response of the B&K headstage amplifier and the QMC Instruments headstage amplifier. The latter was measured using a dummy microphone with a capacitance of 20pF.

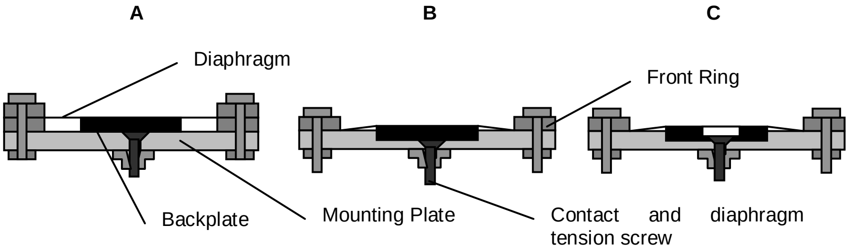

Figure 1 Construction of experimental microphones

Construction of experimental microphones is shown in Fig.1. Type **A** microphones are similar in construction to the simplified design described by Pye and Flinn [1]. The diaphragm tension can be adjusted by advancing the backplate on its threaded mounting screw. Type **B** is similar, but omits the space ring for use with thin backplates such as TV shadow mask. The spacer ring may also be omitted for thick backplates by recessing them into the mounting plate. Type **C** shows the construction of the QMC Instruments microphones, with a recessed backplate held in place by means of a recessed screw through the backplate.

Several existing microphones were tested in addition to the experimental microphones. The Holgate microphone [2][10] is a complex design using a backplate 13mm in diameter with 10 concentric grooves 0.25mm wide, 0.25mm apart and 0.1mm deep. The original 6µm thick diaphragm was replaced with 3.5µm aluminised Mylar. 'Brass microphones' were constructed as described by Pye and Flinn [1] and either used clock or watch balance wheel hairspring backplates or disks of TV shadow mask material [2]. Hairspring backplates have a single helical rail 0.05mm wide with a spacing between turns of 0.5mm and a depth of 0.5mm. The diameter of the backplate was 13mm. TV shadow mask material consists of thin, soft iron sheet 0.25mm thick, perforated with small holes. The holes are arranged in staggered rows 0.5mm apart with the holes 0.7mm apart. The holes are conical in shape with a front diameter of 0.5mm and a rear diameter of 0.2mm. Backplate diameter was approximately 17mm.

Experimental microphones used a variety of sintered metal discs as backplates. Three types of sintered bronze disc were obtained from Sintered Metal Products Ltd, of Sutton in Ashfield, Notts. These discs, from the Porosint range, were 12.7mm diameter, 3.3mm thick and of three different grades, A, C and E. Grade E was the coarsest and was specified to pass particles with a maximum diameter of 37.5µm. Grade C would pass particles of 12.5µm and grade A, particles of 2.5µm. Electrical connection was made to the sintered metal dics by attaching a 6 B.A. screw to the centre of the rear face of the disc with Elecolit 336 silver epoxy resin.

All microphones were fitted with diaphragms of 3.5µm aluminised Mylar, cemented to the front ring with Cow Gum for ease of handling.

Loudspeakers were constructed in the same style as Type A microphones, but used a larger backplate, and a diaphragm of 6µm aluminised Mylar. Two styles of backplate were used: a 38mm diameter sintered metal disc obtained from Micropore Ltd, and a brass disc 30mm diameter, with parallel grooves 0.5mm wide, and 0.5mm apart, extending right across the disk.

3. RESULTS

Several different styles of experimental microphones were tested, as well as several examples of existing designs. These included: a Holgate bat detector microphone, which uses a backplate with concentric grooves similar to the design of the WE640AA microphone and the McGrath microphone used with the Lincoln bat detector[11]; brass microphones constructed as described by Pye and Flinn[1] with hairspring backplates; brass microphones of the same design but using TV shadow mask material as a backplate.

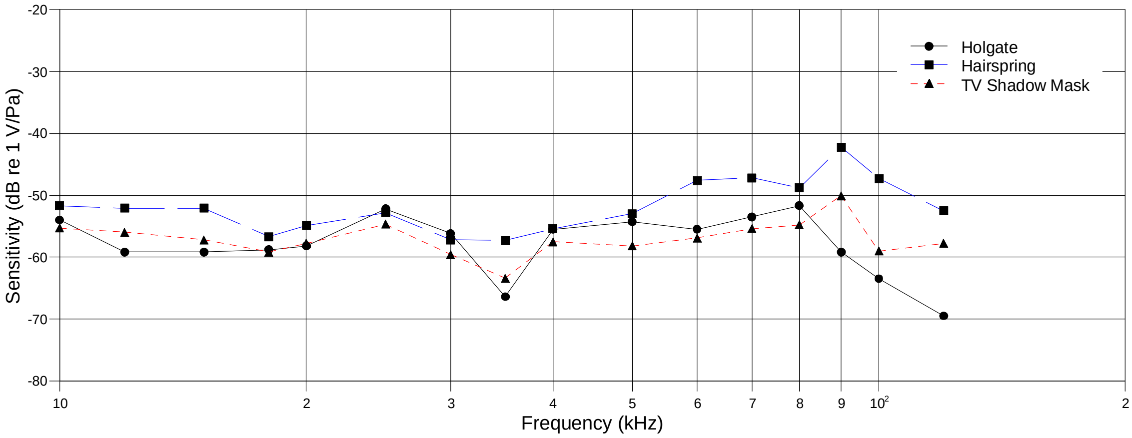

Figure 2 Frequency response of microphones with different styles of backplates

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These microphones had very similar responses, as shown in Figure 2, with an overall sensitivity of about -55 db re 1V/Pa, a high frequency resonance of 80-90kHz and an anti-resonant dip at 35kHz, very similar to the dip in the response of the WE640AA microphone as described by Rudnick and Stein [12], and Beranek[13].

Experimental microphones were constructed using simple handtools, and used backplates of TV shadow mask material, or a variety of sintered metal discs. The microphones using TV shadow mask backplates used a design similar to that in Figure 1A, except that the spacer ring was omitted. The responses obtained were similar to those obtained with the brass microphones with TV shadow mask backplates.

Microphones with sintered bronze backplates of three different grades were tested both as loudspeakers and as microphones. In both cases it was evident that the smoother grades were slightly less sensitive, but had a slightly higher frequency response. However, the anti-resonant dip at just over 20kHz was very pronounced with the finest grade of backplate as shown in Figure 3.

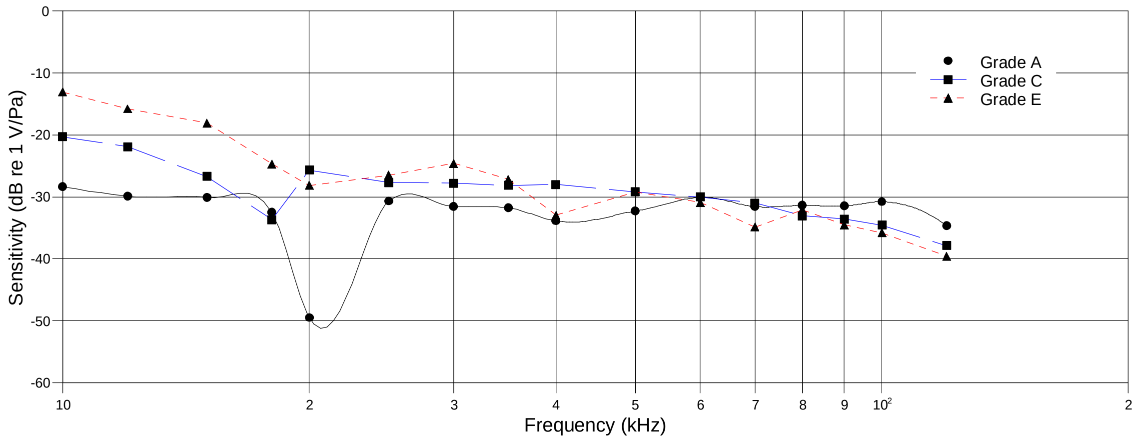

Figure 3 Frequency responses of experimental microphones with sintered disc backplates

The anti-resonant dip could be reduced by making a small hole in the centre of the backplate, and by reducing the diaphragm pre-tension so that the diaphragm is initially just in contact with the backplate, but is pulled tightly against it by the polarising voltage. For the QMC Instruments microphones the hole was used to attach the backplate to the mounting plate with a countersunk screw. Varying the diameter of the hole from 3-5mm had little noticeable effect on the response of the microphones, and neither did changing the width of the front ring. However, it was found that bevelling the inner edge of the front ring, and minimising the amount of the front cap that protruded in front of the microphone, did improve the consistency of the response. This can be seen in Figure 4 which shows the response of three QMC Instruments microphones, of style C in Figure 1. The anti-resonant dip is very small, the high frequency resonance is greater than 100kHz. and consistency between different microphones is very good.

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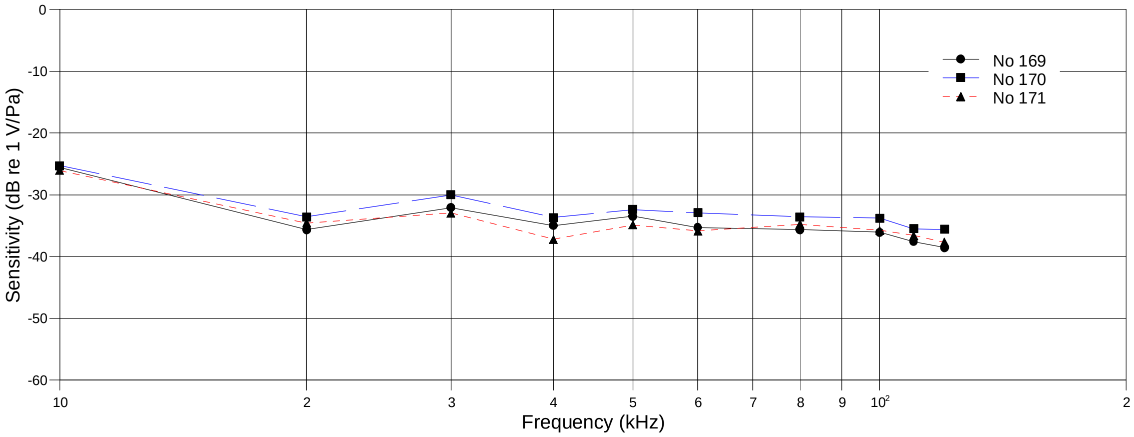

Figure 4 Frequency responses of three QMC Instruments microphone capsules

4. DISCUSSION

The construction of home-made microphones and loudspeakers, using the designs in Figure 1 is quite straightforward. The mounting plates may be any convenient disc of insulating material of about the right size, drilled and tapped as necessary. The front ring may have carefully bevelled edges such as the QMC Instruments example in Figure 5 , or may be quite crude in design. A convenient option is to use a 2mm thick copper washer, which is wide enough to accommodate 10BA mounting screws.

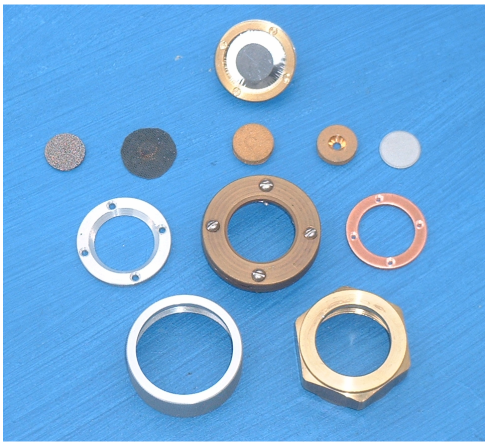

Figure 5 Microphone components: top - assembled microphone capsule; 2nd row - Aqualung filter disc, TV shadow mask backplate, Grade C sintered disc, Grade A sintered disc with mounting hole, 2µm chromatography frit; 3rd row - QMC Instruments front ring, homemade front ring, Copper washer front ring; 4th row – QMC Instruments front cap, Plumbing fitting front cap.

Backplate selection is probably the greatest influence on the final performance of the microphone. Designs with adjustable diaphragm tension and hairspring or TV shadow mask backplates can give good performance, but are very variable from one microphone to another and even for one microphone with different diaphragms. Over a range of 8 brass microphones tested the high frequency resonance varied between 40 and 110kHz and the overall sensitivity ranged from -40 to -80 dB re 1V/Pa.

Sintered bronze discs with a pore size of 2.5µm perform well, especially if the diaphragm is allowed to be only just in contact with the backplate. There are a number of manufacturers of discs similar to the Porosint discs used here, but it may not always be easy to obtain them in small quantities. An alternative source are 2µm stainless steel sintered frits which are readily available for chromatography applications at very low cost. For loudspeakers a coarser grade of sintered disc, such as the aqualung filter shown in Figure 5 works well.

Suitable diaphragm material is probably the most difficult item to source, and there is little alternative to begging small samples from plastic film, or capacitor manufacturers. Clingfilm, smeared with graphite on one side has been tried but gave very poor sensitivity and a frequency response to only 40kHz.

Microphones need to be closely associated with a headstage amplifier, circuits for which have been published elsewhere [14][15][16]. A convenient housing for the amplifier and microphone capsule is a brass 'pipe repair section' available from plumbing suppliers. The fittings even include a suitable front cap, even though this is rather more bulky than the QMC Instruments design shown in Figure 5.

Having constructed a microphone it is always a good idea to check its performance. The simplest approach is to do spot checks against a piezo-elctric transducer, which can be driven at several different resonant frequencies. If a more detailed check is require, it is possible to use the reciprocity technique, which does not require a primary standard. However, microphones with Mylar diaphragms do not strictly obey the reciprocity laws and the results may not be accurate at the higher frequencies.

5. ACKNOWLEDGEMENTS

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