Instrumentation corner

Paul Hopwood. The difficulties of headset measurements

Following an announcement from Meglena Kuneva, European Commissioner for Consumer Affairs, it has been widely reported that Europe wishes to limit the output of MP3 players to eighty decibels.

Currently no such decision on levels has been made, but rather CEN, CENELEC and ETSI have been given a mandate to produce or modify a standard to ensure that under foreseeable conditions of use portable music players (PMPs) are inherently safe. This mandate is likely to be published within the next 24 months and will require more people to become familiar with specialist equipment and the issues which surround it.

Performing measurements on devices which are closely coupled to the ear is not easy, ISO 11904 part 1 (microphone in real ear) and part 2 (manikin) being good starting points for the techniques needed, and BS PD 6545 a good but lengthy guide to the uses and limitations of ear simulators and manikins in acoustics. With most tests using ear simulators or manikins the difficulty is not in obtaining a single measurement, but in performing a correct and repeatable measurement. Those undertaking the work should be prepared to get very familiar with the guide to uncertainty in measurement produced by NPL! Even in the simplest measurement case there is a complex interaction between the types of music source used, the PMP itself with an inherent gain and frequency response, and the headphones, which also have an electrical sensitivity and frequency response. These all act together to form the noise source. Adding in the response of the human ear coupled to the headphones, and the behaviour of an average human, being only makes the situation more complicated.

There is no one single piece of instrumentation in use for assessing sound sources coupled closely to the ear: different types of artificial ears, couplers and manikins are available and are suited to assessing different earpiece types in different situations. Correctly choosing an ear simulator for the task at hand is important! ITU-T recognises six types of ear simulators in recommendation P.57 and five different headphone types with which they are to be used, whereas IEC 60263 has four different types of ear simulator with IEC 60268 recognising eight headphone types and a further two subgroups for each type.

Acoustic couplers are simple cavities of known dimensions presenting a known and fixed acoustical load, whereas artificial ears go beyond just presenting a load and attempt to have complex acoustical characteristics to provide impedances which match those of an average adult ear. The most basic device used is an IEC 318 coupler (ITU-T P.57 type 1) which is suitable for supra aural headsets, whereas an IEC 711 ear simulator (ITU-T P.57 type 2) is suitable for insert type earpieces. A manikin is the most flexible device allowing the widest range of investigations: manikins were developed in the 1970s to fulfil a requirement for the objective assessment of psychoacoustic effects experienced with hearing aid fittings.

Measurements performed on a manikin often need careful consideration, as many recent earphones which have foam inserts are compressed and then expand again in the presence of body heat to occlude the ear canal. As the manikin does not have any body heat, great care must be taken to ensure that a reliable seal is formed and that the position and orientation are correct. A human would complain or adjust the earphones, but a manikin does not!

Different results will normally be obtained when measuring the same headset or earpiece on different types of ear simulators, in fact two measurements performed on the same ear simulator with slightly different placements are likely to give surprisingly different results. When in the ear the acoustical impedance of the earpiece is presented with the ear's impedance as a load. An earpiece which has a high acoustical impedance acts as a constant volume velocity source and is very sensitive to the ear's impedance. This makes it very sensitive to placement of the device on the ear, and to leakage paths, as both will change the impedance of the ear and hence the measured level and frequency response. An earpieces that has low acoustical impedance is generally not sensitive to the impedance of the ear and instead acts as a constant sound pressure source.

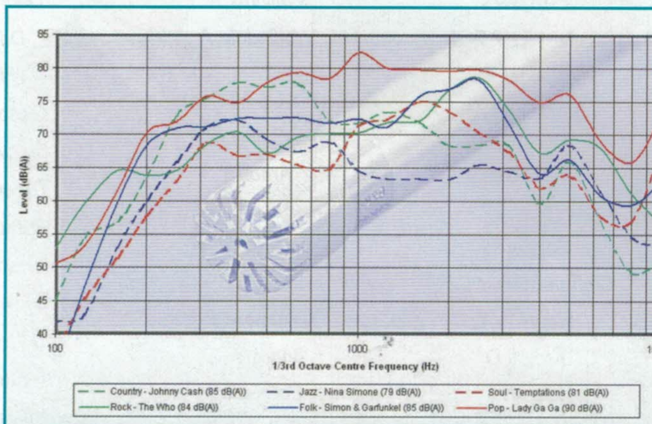

Figure 1

Measured Music Spectra

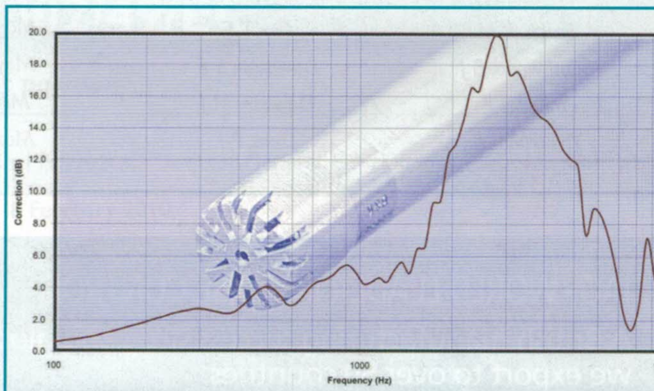

Figure 2

Typical Freefield to Drum Correction Factor

The measurements shown in Figure 1 show different musical styles measured using an acoustic manikin with a constant drive volume and the earpiece secured in position. The results show a range of 11dB and different frequency responses between the different musical genres. Clearly, for any assessment a correct and representative source of noise is needed and for this purpose the ITU has a reference based on filtered white noise known as ITU programme noise. Whilst this cannot represent all types of music it seems to be a good average and is a definable reference point that can be used to compare results from different acoustical laboratories.

With the exception of the ITU type 1 ear simulator (which uses the ear reference point) the results of measurements made on ear simulators must be converted from the measurement point (the drum reference point) to the free field (the ear reference point) using a transfer function. The inverse of a typical manikin's transfer function is shown in Figure 2, which demonstrates how much higher the ear simulator's measurement at the drum reference point will be than one at the equivalent free field. It is not a flat response, with a typical peak of 15 to 20 dB over the free field!

The transfer function is the result of the ear canal forming a quarter-wave resonator. A typical ear canal has a length of 25 - 30mm, producing the peak response at around 3kHz seen in Figure 2. The ear pinna and concha causes further reflections and resonances in combination with the ear canal, and this has a large effect on the measured frequency response. The transfer function for a manikin also includes the effects from diffraction of the head which can be (simplistically) modelled as the diffraction around a sphere with reflections from the shoulders and upper torso, causing cancellations at specific frequencies which tend to be governed by the length of the neck. Whilst the testing of earphones avoids many of these difficulties (insert-type earpieces placed directly into the ear canal, for example) the measurements must still be corrected, as what is usually wanted is the equivalent external (free or diffuse) field that would give the same result.

In recent years, American schools have been using clothes shop manikins fitted with cheap sound level meters to show students what levels they are listening to on their PMPs. This setup does not have a representative human ear and does not have a transfer function, so the idea is good - but simply guessing the level is likely to produce more accurate results!

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Figure 3

Typical manikins used for earphone testing