# Instrumentation Corner: How low can you go?

**Ian Campbell HonFIOA.** **Measurement of low frequency noise**

In the previous contribution to the measurement and instrumentation corner we considered the measurement of low level noise: this time we are looking at the measurement of low-frequency noise. The subject has been very topical, with discussion on the problems of low-frequency noise sufferers, and also when considering the propagation of noise from blasting and other impulsive sources.

The first point to consider is the measurement microphone itself. This is designed to respond to a pressure differential across its diaphragm so one side is exposed to the sound we want to measure whilst the other is held at its internal 'reference' pressure. If the microphone was completely airtight, any changes in barometric pressure due to weather systems or changes in altitude would result in a static deflection of its diaphragm which in turn would affect the ability of the diaphragm to respond correctly to changes in sound pressure. This is just same as the case of an aircraft taking off. As the aircraft climbs, the static air pressure in the cabin falls, but the air pressure in the inner ear of a passenger is still at ground level and hence the ear drum is pushed out. As it is stretched it cannot respond properly, that is, until the internal pressure equalisation tube to the back of the throat releases, often prompted by chewing the complimentary toffee. The ear 'pops' and the excess pressure is released, allowing normal hearing to return. A similar but opposite condition then occurs on landing. A comparable pressure equalisation in a measurement microphone is achieved by a controlled air leak to the back of the diaphragm.

As the frequency of measurement gets lower and lower the sound has more time to get round the back of the microphone and hence to the rear of the diaphragm. Once the sound appears on both sides of the diaphragm at the same time, the pressure differential across it will start to fall and hence the output will also go down. These effects can be complex with changes in both the amplitude and phase of the output signal.

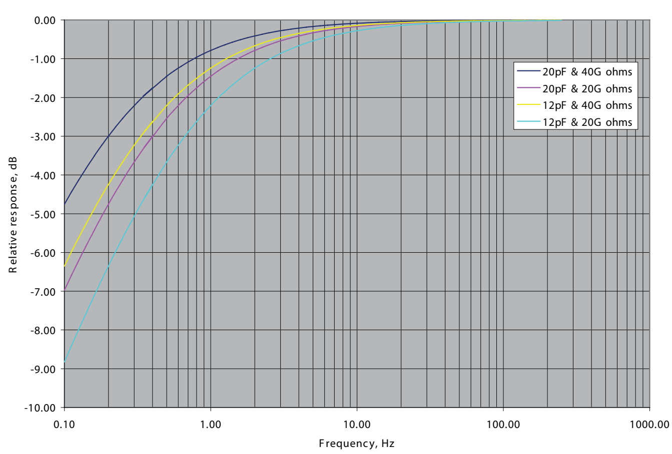
So when designing a microphone the compromises that have to be balanced are making the air-bleed to the rear short enough to accommodate any sudden changes (pushing on a calibrator, changes in altitude, weather *etc*) but long enough to ensure that the low-frequency performance is preserved. Most general-purpose microphones have low frequency limits around 10Hz or so, whilst special low-frequency microphones will measure down to less than 1Hz: in these special microphones the time constant of the air leak is made as long as possible by adding extra components within the microphone. But of course, during their service lifetime microphones may suffer damage that significantly increases the air leak to the rear cavity; the most common of these is small perforations in the diaphragm itself. We have seen microphones that calibrate correctly at 250Hz and 1kHz but are in the order of 10dB down at their specified lower cut-off frequency. This means that any slight damage or mark on the diaphragm needs investigation to ensure there is no air leak.

All of this becomes more important when you realise that the 'traditional' method of testing microphones both in production and re-calibration is to use an actuator that uses an electrostatic force to attract the diaphragm so that it moves in manner  similar manner to that when it is excited by a sound pressure wave. This is fine for higher frequencies but as there is no actual sound pressure wave generated to get round the back there can be no 'back to front' cancellation effect, and hence low-frequency performance will be overestimated. For this reason actuators are not used at frequencies below 100Hz and special test chambers must be used that excite both the back and front of the microphone for testing at less than 100Hz.

Having optimised the design of the microphone you then need to establish that the associated sound level meter can take full advantage, so you need to check the low-frequency limit of the instrument as these can vary widely. Often there is a temptation for manufacturers to limit the low-frequency response to minimise the effect of the self noise rather than produce more expensive preamplifiers and input amplifiers; they are just taking advantage of the fact that even under the most recent sound level meter standards a Class 1 meter does not have to work at all below 16Hz: the tolerance below this frequency is -∞. Some manufacturers fit high-pass filters to remove troublesome wind noise etc (look for pass band settings sometimes called 'wide band mode' or something similar). These will of course impair the measurement of low-frequency noise and should be switched off.

Beyond these considerations the primary element that determines the low-frequency response of the sound level meter is the interaction between the microphone and preamplifier. The equivalent circuit of the microphone can be modelled as a pure voltage source in series with its self capacitance whilst the input to the sound level meter preamplifier is primarily resistive. There is thus a conventional RC time constant producing a high-pass filter. The cut-off frequency of this network can be determined from the reciprocal of the product of the capacitive and resistive elements. So to maximise the low-frequency performance the capacitance of the microphone and the input impedance of the preamplifier need to be as high as possible. Most microphones are around 12pF for electret types and 20pF for conventional air dielectric microphones. A typical value for input impedance of microphone preamplifiers is 20GΩ although special low-frequency preamplifiers having an input impedance of 40GΩ are now becoming available to allow best use to be obtained from the sound level meter's performance.

What this all means is that you should check the specification for your meter, and with a good bit of kit you should be able to measure down to 5Hz - and possibly even lower.




Low frequency limits with different microphone and preamplifier combinations