Active Noise Cancellation – a quiet revolution

DESIGNED TO EXCLUDE EXTERNAL SOUND FROM HEADPHONES, DOES THIS CLEVER TECHNOLOGY AFFECT THE MUSIC, TOO? KEITH HOWARD INVESTIGATES

What's almost universally known today as active noise cancellation (ANC) has been called other things in the past, such as active noise control and active noise reduction. But this is one occasion where the best nomenclature won out, because 'active noise cancellation' embodies two vital features of the technology's operation: first, it's an active system (it consumes power because it involves signal processing and amplification); and second, it operates by exploiting what physicists term destructive interference. Sum two equivalent signals of the same polarity and the interference is constructive: they add. Sum two equivalent signals of opposite polarity and the interference is destructive: they cancel.

This is how ANC operates. It identifies external noise, inverts the polarity of the noise signal, and adds it to the wanted signal so as it cancel the noise from what you hear. It's used in the best modern ear defenders and in military headsets, but you and I know it best from its use in consumer headphones, particularly those intended for use on the move where loud, intrusive external sounds can include cabin noise in cars and aircraft, or the din of a tube train carriage.

ANC is not a new idea. It was first described in a German patent of 1934 [1] although that seems to have been a statement of concept only, with no working system ever built. Two decades later in the USA, Simshauser, Hawley and Meeker [2] developed active ear defenders. Bose started the ball rolling with ANC headphone research in the late 1970s, supposedly after company founder Amar Bose found the cabin noise intrusive during a commercial aircraft flight. The first working examples, built in 1986, had external electronics and were used by Dick Rutan and Jeana Yeager during their epic continuous round-the-world flight aboard the Model 76 Voyager that same year, to obviate the danger of permanent hearing damage. Later, self-contained versions were developed for military purposes and aviators before the first smaller, lighter ANC headphone for music listening went on sale to the public in 2000.

ANC is not limited to headphones (or ear defenders or military headsets) alone. It can also be applied to acoustic spaces such as car cabins. (For an example, see silentium.com for information on its Quiet Bubble restricted-zone ANC technology.) But the wavelength of sound in air makes noise cancellation difficult across larger spaces. For instance, the wavelength of a 1kHz tone in air is about 34cm – a little over a foot. This means that a misalignment of the noise cancelling waveform of just 17cm will be enough to turn destructive interference into constructive; the unwanted signal won't be cancelled but boosted. Even in headphones, where the enclosed air volume is small, this factor still limits the frequency range over which ANC operates to, typically, below 2kHz. But effective ANC is much easier to achieve with headphones than elsewhere, which is why the technology has boomed in this application.

Since Bose's first ANC model, the technology hasn't merely flourished: it has also improved markedly. This article looks to explain how it has improved, and how ANC might have an effect on perceived sound quality beyond noise reduction.

Types of ANC

ANC systems come in three different types, the third being a combination of the previous two. The first is based on feedforward and uses one or more microphones on the outer surface of the headphone to sample the external sound field. The noise cancellation signal is generated by filtering the external sound based on the known passive isolation behaviour of the headphone. Feedforward has the advantage of being incapable of causing oscillation, and the external microphone(s) can be exploited to provide a 'hear through' capability (also termed 'monitor mode', etc) which allows the wearer to hear external sounds such as conversation or station announcements. Some such systems are controlled by the wearer; others are automatic, relying on detection of vocal patterns in the external sound. The principal downside of feedforward is that its behaviour is fixed whereas external sounds and the headphone's interaction with different wearers' ears are both variable.

Feedback ANC, by contrast, places its microphone(s) within the closed acoustic volume created by the headphone. (ANC is usually applied