Mobile phones can work amazingly well as music players, web browsers and e-mail clients, but it’s easy to overlook their primary function: enabling two people to converse at a distance. Even the coolest, most feature-rich smartphone is rendered worthless if the user cannot clearly hear the voices of the people they call.

And since ambient noise is one of the factors which can reduce the intelligibility of speech in mobile voice calls, mobile phone manufacturers today employ a range of – mostly software-based – techniques to mitigate its effects.

As anyone who has used a mobile phone in a crowded train station, airport or sports stadium will know, these software techniques still generally leave the user with an unsatisfactory sound quality on voice calls in noisy environments. This is because these techniques – digital signal enhancement and automatic volume control – are crude methods which can only mitigate the effects of ambient noise – not eliminate it.

Active Noise Cancelling (ANC) technology, on the other hand, is a well known method for attenuating unwanted ambient noise highly effectively, but is normally found today only in high-end stereo headsets. Here, it is highly valued by affluent consumers, for instance frequent flyers wishing to cut out the irritating roar of jet engines.

This article argues that the same ANC technology can be used to dramatically improve speech intelligibility for users of mobile phones and mono headsets. The concept of a mono (single ear) ANC implementation might seem counter-intuitive: after all, ambient noise will still enter the user’s other ear.

But this article describes research which shows that the effect of noise cancellation in a single ear has a marked effect on the user’s ability to understand speech in voice calls. This suggests that implementing an ANC circuit in a mobile phone or in a mono headset is now the most effective way to provide users with the high voice quality which they expect under almost any ambient conditions.

Techniques for reducing perceived ambient noise

Strong demand for noise-cancelling headphones and earphones has attracted many new suppliers into the market. But it is important to be aware that many products described as ‘noise cancelling’ do not in fact cancel out noise, even if they implement measures to attenuate it.

In fact, there are a number of different ways to lessen the perceived effect of ambient noise. One simple and cheap way – effective with high frequencies – is through ‘passive attenuation’: that is, using sound-deadening material around the speaker to block the path of ambient noise into the ear canal.
Passive attenuation is almost completely ineffective with lower frequencies, however. To deal with these, mobile phone manufacturers today use various software signal processing techniques (see Figure 1).

![Fig. 1: noise reduction techniques capable of being implemented in mobile phones](image)

The most commonly used noise reduction technique is transmit path noise reduction, typically implemented with a Digital Signal Processor (DSP). The output from the phone’s microphone consists of a combination of a wanted signal (the user's voice) and unwanted signals (ambient noise). Algorithms implemented in a DSP process these signals in an attempt to distinguish voice from noise, filter out the noise, and amplify signals that have a clearly identifiable 'speech signature'. In some designs, an additional microphone is used to sense only the ambient noise, which helps the algorithms to tune their filters to the noise frequencies.

The problem with this approach to noise reduction is that, the higher the noise reduction level is set, the more robotic the voice sounds. By the same token, applying less aggressive digital noise reduction produces a more natural-sounding voice signal, but at the cost of higher noise, a lower signal-to-noise ratio and lower speech intelligibility.

Even if the strange quality of the voice is acceptable, this transmit path noise reduction technique only helps the other party to hear the speaker’s voice more clearly. The opposite of transmit path noise reduction, receive path noise reduction, is implemented in the same way, with the same limitations. What is more, it only modifies the incoming signal from the other party to the conversation; in other words, this system helps you to better understand the person you are talking to if that person is himself in a noisy environment.

Both transmit path and receive path noise reduction help to enhance speech quality, but neither helps a phone user in a noisy environment to hear and better understand the other party.
A third technology – automatic volume control – can help increase speech intelligibility for the listener, but only when the volume of ambient noise is relatively low.

A phone with an automatic volume control function passes the microphone output through a DSP or analogue circuit, which is configured to distinguish ambient noise from the user’s voice signal. This compares the sound level at the receiver amplifier with the ambient noise level, and calculates the signal-to-noise ratio. When the SNR drops below a given threshold, the automatic volume control feature increases the gain of the receiver amplifier to boost the SNR into positive territory. The louder the ambient noise, the higher the Sound Pressure Level (SPL) generated by the phone’s speaker.

This technique becomes ineffective above a certain level of ambient noise, however. This is because the maximum output power of the headset’s speaker is limited either by the construction of the speaker itself or by the specification of the speaker amplifier. At a low level of ambient noise, the speaker’s output power can be increased to maintain a specified SNR. As the ambient noise level rises, the speaker’s output power rises in step to maintain the SNR, until it reaches its maximum. If the ambient noise level then continues to rise, the SNR falls, and intelligibility is impaired.

**The operation of Active Noise Cancelling**

It would therefore be more effective – and would also impose a lower SPL on the user’s ear – to reduce the ambient noise volume instead of increasing the speaker’s output volume; this is the function of active noise cancelling (ANC). An ANC system creates an anti-noise signal with the phone’s speaker, lowering the noise level in order to increase the SNR.

The implementation of an ANC application, no matter in which product it is deployed, needs three components: a microphone, a speaker and an ANC circuit (see Figure 2).

The microphone senses the ambient noise and feeds the noise signal into the ANC circuit. The ANC circuit creates an anti-noise signal which is an inversion of the ambient noise signal. This electrically inverted signal is fed to the speaker, which generates an acoustic reproduction of the inverted ambient noise. In theory, the two signals cancel each other out perfectly.

In practice, stereo ANC headphones such as the AKG K490NC on the market today achieve typical noise reduction of 20-30dB across a broad frequency range of 20Hz – 1kHz. The AKG K490 NC uses the AS3430 ANC speaker driver from ams.
Does ANC make sense in mono applications?
ANC systems are normally used today in stereo applications; mobile phones and headsets are normally mono, single ear devices. So does it make sense to put an ANC system in a mono application?

Of course, the second ear is exposed to ambient noise without cancellation. But a test initiated by ams and performed by an independent research company Joanneum Research\(^1\), shows that mono active noise cancellation can markedly improve speech intelligibility in noisy environments.

The test set-up is shown in Fig. 3. The subjects were exposed to random noise similar to that experienced in a crowded restaurant, reproduced by a 5.1 surround sound system. Joanneum Research’s specialist Institute of Information and Communication Technologies performed the test in a standards-approved acoustic chamber.

The subjects wore in their right ear an in-ear mono ANC earbud with an average ANC noise reduction performance of 10dB in the voice frequency band. The subjects listened to single-syllable words and two-digit numbers played through the mono ANC headset. (The words and numbers were processed through a standard GSM codec to simulate over-the-air transmission.) They were asked to repeat the words they heard, enabling the scientists running the test to make an intelligibility score.
Fig. 4: results of the mono ANC speech intelligibility test

The test results (see Figure 4) show an astonishing differential between the intelligibility of speech with and without the assistance of the mono ANC headset. The two curves show how speech intelligibility varies depending on the SNR. Without ANC activated, the scores follow an S-shaped curve, a result which matches the results from speech intelligibility tests carried out previously by other companies and organisations.

With the mono ANC function activated, the curve shifts markedly upwards, showing how mono ANC noise reduction enables improved intelligibility at higher ambient noise levels. It does this by attenuating the ambient noise through active noise cancellation, which has the effect of increasing the SNR.

According to the Joanneum Research report, ‘the results of the listening test highlight the improvement [in] speech intelligibility in noisy environments by employing the active noise cancellation technique to one-ear in-ear headphones.’

It is important to note that the results in Figure 4 were achieved with a headset that delivers a small 10dB noise reduction, but even this, according to Joanneum Research, produced an improvement in speech intelligibility of as much as 40%. If a headset with higher ANC performance were used, ams expects that the improvement in intelligibility would be even bigger, because, as the graph shows, the ANC performance directly correlates with the improvement in speech intelligibility.

Complete low-power ANC implementations for stereo headsets have been available from ams for some time, but with the introduction of the AS3400 and, in 2012, of the AS3420, ams has two products optimised for mono ANC applications. The AS3420 is particularly well suited to Bluetooth (wireless) headset designs, since its differential input enables direct connection to wireless chipsets with differential outputs. The devices can easily be used to turn a standard mono headset into a real ANC mono headset, delivering greatly increased comfort, enjoyment and speech intelligibility to the user and markedly increasing the value of the end product.

1. The Joanneum Research report is available on request from ams.