# sound & hearing

*This section explores how sound is constructed and described – the different frequencies and dynamics involved, and the terminology used by sound engineers and other PA professionals to characterise specific types of sound; plus comparative sound pressure levels and the impact (good and bad) these can have on our ears and long-term hearing.*

Of all our senses, hearing seems to be able to operate over the widest range – sometimes to an almost inexplicable extent. So it's important for all sound system users to be aware that music's subtler qualities and communication value may be restricted or even prevented when a PA system damages or 'twists' the musical signal.

Compared to the average figures reeled-off in acoustics and electronics text books, some people's perceptive abilities seem to extend up to ten times further than expected. For example, some individuals are sensitive to 4Hz... an ultra-low frequency often described as 'subsonic' (inaudible except through bone conduction), and which is one-fifth of the frequency where normal hearing ceases in most people.

It has also been noticed that some musicians can detect the difference between tones only 0.1 per cent apart up to at least 10kHz – this implies the human ear-and-brain combination is sometimes capable of resolving timing differences of around a tenth of a millionth of a second.

**Frequency ranges**

In terms of the sound spectrum, we usually refer to three basic frequency bands: low-frequency (LF), mid (MF) and high (HF).

Bass energy in music (or bottom-end) is the content with frequencies below 300Hz (Hertz, or cycles per second), and 20Hz is considered the lowest limit of normal hearing. To a greater extent than with mid-range sounds, the useful dynamic range of bass frequencies is compressed naturally by the ear.

Below 150Hz, bass becomes increasingly visceral. At the high sound pressure levels (SPLs) at which heavy metal or hard rock is performed (110dB+), kick-drum frequencies centered around 120Hz can be felt in the solar plexus. These are literally 'hard' and many listeners may find them offensive or at least unpleasant.

> It's possible for sub-bass signals to be felt before they're heard

Below 100Hz, bass softens. Reggae, funk and house music make full use of the 'pleasure' region centered on 80Hz. PA system sound levels in this range have often been observed peaking at up to 135-145dB (which is 10 to 15dB beyond the supposed pain threshold, without any harm or even physical discomfort – see sidepanel). Indeed many listeners describe the experience as cathartic, or giving rise to raised consciousness.

## Music can have low HF power but high HF energy

These lowermost audible frequencies are also the ones most strongly experienced when hearing underwater (an environment not unlike that in the womb, as it happens).

Below 40Hz bass becomes more tactile again, and by 16Hz it is no longer audible through the ears but sensed solely through bone conduction. This kind of frequency range can alter the way we perceive music, since sound is transmitted much faster through solids (earth, floor, feet, skeleton) than through the air – so it's possible for sub-bass signals to be felt before they're heard (you might experience this in thunderstorms sometimes).

In most music there is little explicit, large signal sub-sonic musical content: it's rarely produced by acoustic instruments – with the exception of very large pipe organs, giant gongs, and long horns, and in the sub-harmonics of the lowest notes on a bass guitar. It's much more easily produced by an increasing variety of electronic equipment, and is commonly used for dance music 'sub-bass'.

At frequencies below the fundamentals of musical instruments, say below 15Hz, there's still plenty of sub-bass present in the real world – even if it is just the rumble of stageboards, underground trains, or air conditioning. These sounds may be best preserved for a recording, and are best avoided live, to save using up valuable PA power on sonic 'garbage'.

Unfortunately the abrupt filtering needed to remove undesirable subsonic content slightly delays the wanted bass signals.

Mid-range is anything between 300Hz and 4-5kHz, and mid itself is generally split into low-mid, high-mid, and whatever's in-between.

High frequencies (HF, treble, or top) begin at around 5kHz (5000Hz). Higher still, peoples' hearing rapidly becomes insensitive: depending on your genetic make-up, diet, health, age, and cumulative exposure to non-musical percussive sounds (particularly hammering and gunshots), the upper hearing limit at quite high SPLs (100dB) typically varies between 12 and 20kHz.

Above 3 to 5kHz the average power levels of nearly all kinds of music, integrated over a minute or longer, are less than the levels at lower frequencies, and reduce further with ascending frequency. As a rule of thumb, the power in the mid-to-low bass regions is at least ten times (20dB) more than the power at 10kHz.

A great body of music revolves around relatively abrupt change. Sounds stop and start all the time. Rhythmic sounds may have durations under one second, and the HF components of these can have momentary (but repeated) levels as high as the largest bass signals.

In this way, music can have low high-frequency power, but high HF energy.

Music's HF dynamics are most apparent in live work. Capturing HF dynamics up to 20kHz is aided by capacitor microphones (which can have a far smoother, higher-extending, and less compressed response at HF than most dynamic/ moving-coil kinds). And also by active microphone splitters which buffer (strengthen) signals from mikes, preventing subsequent losses in, and sound-smearing resonances caused by, the stage-to-FOH mix-position cabling. (See Chapter 1 for more on mikes and splitters.)

While our conscious hearing stops at 20kHz, higher 'ultrasonic' frequencies in music, up to at least 80kHz, can be perceived by the human brain (some animals, of course, seem to hear such frequencies much more readily).

## Our conscious hearing stops at 20kHz

In pioneering listening tests carried out by recording mix-console designer Rupert Neve and producer Philip Newell, among others, when frequencies above 20kHz are filtered out of a music signal (or 'programme'), sensitive listeners notice a lack of vitality.

More recently it's been demonstrated 'objectively' – in the sense that specific neural activity and chemical production has been measured – that the subliminal perception of the ultrasonic sounds associated with music enhances pleasure.

Some digital equipment limits PA high-end frequency response in a uniformly hard and unnatural way. By contrast the response of some microphones and pickups continues (to a greater or lesser degree) well above 20kHz.

#### The sound of music

One of the key qualities of music (as it has developed in Western culture at least) is tone. Some tones, called fundamentals, are harmonically (for which read mathematically) connected to others with different but related frequencies.

Together, fundamentals and harmonics, and their phase relations, along with the envelope (the 'shape' of the sound developed by the averaged amplitude) create a timbre – the musical (or otherwise) quality of the note or tone we hear.

Tones which are not harmonically related may be discordant. If they are harmonically related, but adversely so (usually odd harmonics above the 5th), they are 'dissonant'. When a tone changes in intensity, its 'frequency' (as perceived by the ear) changes – this is known in musical terms as 'pitch'.

Sounds that have no dominant, identifiable tones are 'atonal'. They are akin to noise bursts. Continuous sounds, both tonal and atonal, get boring after a while.

The tonal waveform changes over a short period (usually measured in milliseconds) but each subsequent cycle is identical to the first. Continuous atonal sound is considerably more interesting – as exciting as a waterfall can be, say.

Music's most vital component is its dynamic – it creates richness and adds to emotional impact. Tonal and atonal sounds fade and increase, stop and start, and change in pitch and frequency in diverse ways, creating wave-patterns (as can be seen on an oscilloscope – see Chapter 9) which rarely repeat exactly, and appear visually chaotic.

> Continuous sounds, tonal or atonal, get boring after a while

The overall amplitude (size or loudness) pattern is called the 'envelope'. Timing creates the music's meaning, with a precise schedule of the beginning (attack) and build up of each tonal and atonal building block, and its sustain (levelling off), decay and release.

In most locations, sound is reflected off nearby surfaces, causing multiple early reflections or reverberation (reverb). This added complexity makes the sound appear richer. Complex distortions, both gross and subtle, caused by microphones, speakers, electronics and cables can cause deviations in what the musically adept and experienced ear expects.

Tonal qualities can be unduly emphasised or retracted, timing thrown out of sync, subtle dynamic contrasts and 'edges' blurred, and spacial qualities bizarrely warped or flattened.

## Sound terminology

***As an adjunct to the full technical Glossary on p219, this section lists some words commonly used in the description of sound:***

**Asymmetry** – all sounds comprise alternate compressions and rarefactions of the air (or other physical medium) – in other words pressure cycles back and forth.

For a completely pure tone, the net change in air pressure is nil (assuming an average of whole numbers of cycles). For most musical sounds, though, the waveshape that describes the pressure moment-by-moment is skewed or lopsided at various times, leaning more in one direction than the other. This is called asymmetry.

If the music is in a well-sealed room it would have the effect of very slightly varying the atmospheric pressure over periods of several seconds.

When a music programme (the technical term for the original signal) is converted into an electrical waveform, asymmetry causes DC voltage

shifts, which can upset the operation of some PA gear.
**Transients** – most kinds of music in its raw, live state has unpredictable bursts which can be 6, 10 or 20dB higher than the average, and last varying lengths of time. Fast 'edges', quicker than an SPL meter takes to respond, can be 20 to 40dB above the average short-term levels. The ear barely registers these as loudness, yet notices when they are missing, and certainly notices something nasty is happening when these edges cause the signal chain to hiccup for a longer period.

In most PA systems, transients are rescaled with compressor-limiters, which squash rather than remove the effect. The difference between the average level (or root-mean-square, commonly known as RMS) and the highest peak levels of a programme is called peak-to-mean ratio (PMR), where 'mean' is math-speak for RMS. (The term 'crest factor' has a similar definition but is best kept for steady waves, like AC power.) PMR is initially determined by the genre of music.

Some approximate examples of this would be:

- Orchestral, bebop jazz: 20-30dB
- Live rock, most genres: 10-20dB
- House music, digital: 10dB
- Muzak, lifeless 'mall' music: 4-8dB

**Variability** – music is not predictable. There is no algorithm (as yet), and computers are still incapable of differentiating between signals which are music and those which are noise.

***Lots of adjectives have been employed, even invented, over many centuries to try to capture the essence of particular aural experiences – with varying degrees of success.***
***Here's a selection of some of these words and what they mean (roughly) in audio terms – and how they might be usefully employed when mixing (see Chapter 8).***

***First of all, words that seek to define certain frequencies and tones (from high to low):***

**Sheen** – very high treble, above 16kHz: often absent, or heard as hiss/digital noise
**Tizzy** – excess around 12 to 16kHz: usually over-emphasising cymbals' high harmonics
**Airy/smooth/open** – apparently effortless high treble: seeming to extend further than the music
**Closed-in** – treble lacking above 10kHz: almost the opposite of airy
**Enclosed** – dull, coloured, airless
**Dull** – general lack of treble
**Hard/metallic/brittle** – excess of high, metallic-sounding harmonics, usually around 8 to 16kHz
**Bright/brilliant/glassy** – excess around 4 to 8kHz
**Sibilance** – excessive amounts of 5 to 7kHz
**Aggressive** – preponderance of mid-high energy (3 to 6kHz), often phasey and distorted
**Crisp** – plenty of clean 3-4kHz
**Presence** – the frequencies around 2kHz
**Muffled** – where high frequencies are reducing rapidly above 2kHz
**Articulation** – audibility of the inner detail of complex sounds, particularly those in the main vocal range (300Hz-3kHz)
**Nasal** – 1kHz emphasis
**Recessed** – general lack of mid-range
**Barky/woody** – characteristic mid-bass resonances
**Honky** – excess around 600-800Hz: like a Cockney saying 'oi', or improperly used mid/HF horn speakers
**Lean** – slight, gentle reduction below 500Hz: or very clean, transparent bass
**Chesty** – excess in the 200 to 400Hz area: especially with male vocals
**Boxy** – excess around 250-450Hz: as if inside a cardboard box
**Rich** – a downtilt in level above 300Hz: also, a slight excess of reverb

**How music confounds science**

You could say music operates in more dimensions than science can accurately measure. More than being simply soundwaves moving in physical space and time, there's the harder-to-quantify effects that pitch and rhythm changes can have on an individual listener – and the even more complex and unpredictable effects it can have on several individuals in different parts of the same venue, with different physiological and psychological backgrounds and make-ups.
Tables, charts and waves on an oscilloscope are helpful tools for certain audio engineering tasks, but when it comes to the whole picture, the sound of music can only really be gauged by an experienced and sensitive pair of ears – and almost by definition there will be no optimum means of music reproduction that's perfectly suited to everyone, despite all the technological 'advances' made to date.

**Dark** – sound that tilts down from the bass upwards
**Punchy** – around 120 to 160Hz: a high-definition area
**Thin** – overall lack of bass
**Balls/ballsy/gutsy** – low bass that is visceral, ie can be felt
**Boof-boof** – around 80 to 90Hz: soft bass area

**Chunky** – 80 to 90Hz: 'sample' bass with added harmonic definition
**Gutless** – absence of low bass

***This next batch contains some more general terms used to describe the sonic or dynamic properties of music, particularly live music:***

**Ambience** – to do with mood, feeling, atmosphere – subtle, low-level, often non-musical background sounds, mainly subliminally appreciated
**Analytical** – when sound equipment seems to reveal excess of the 'stitchwork' in music. Sometimes describes when a system has distortions that unduly emphasise detail or 'edges'
**Attack** – the speed and crispness with which a note/tone/signal begins
**Boomy** – poor bass damping: a bad loudspeaker-amplifier combination
**Clear** – plenty of contrast
**Clinical** – suggests sound that is clean, bright, sharp, detailed; but may be used as mildly pejorative, perhaps implying emotional qualities are lacking or held-back
**Congested** – see Smeared and Thickened, which are facets of the same effect
**Contrast** – clarity, differences in tone: as in visual art/photography
**Detail** – more spacial version of Dynamic
**Dry** – sound tending to lack reverberation
**Dynamic contrast(s)** – subtle changes in level or pitch embedded among much larger changes
**Dynamic range** – in PA-speak, the 'amplitude performance envelope' of a sound system; in musicians' parlance, the programme's intensity range
**Etched** – finely detailed
**Focus** – sharpness of detail: may vary across the soundfield, in all three dimensions
**Euphonic** – pleasantly distorted at the expense of accuracy
**Fast** – incisiveness of attack, particularly of bass fundamentals; but as bass doesn't move fast, by definition, most likely a reflection of rapid damping, proper synchronisation between the fundamental and harmonics, and correct reproduction of all associated harmonics
**Fuzzy** – spikey yet soft texture caused by high distortion and compression
**Glare** – distorted mid-treble; also tonal imbalance or forwardness
**Grainy** – excess texture: a kind of distortion, usually in the high mid-range.
**Gritty** – like grainy, but harsher and coarser
**Grunge** – like gritty, but more muffled ('grunge' music is closer to being 'gritty' music)
**Hardness** – fatiguing 'wood block'-type of mid-range emphasis
**Harsh** – dissonant and/or discordant: unpleasant
**Hologramatic** – when coherent and correctly focused sound (or light) enables higher dimensions to unfold
**Image/imaging** – ability to portray width, depth, and sometimes height
**Incisive** – conveying the 'slicing' sound of close-miked snares, like a sonic machete or knife: indicative of good attack synchronisation; like Fast & Slam
**Layering** – sounds having a precise depth in a soundfield, with the implication of many depths or infinite gradation
**Lifeless** – superficially perfect, anodyne reproduction conveying no emotion or interest: commonly caused by forcing equipment or system to manifest a perfect measured frequency response without regard for factors affecting space or dynamics
**Loose** – badly damped bass
**Lush** – see Rich
**Micro-dynamics** – lifelike energy (transients) in small, low-level sounds
**Muddy** – see Smeared; especially applied to bass
**Muffled** – no contrast: opposite of clear
**One-note bass** – poor damping of major resonance(s) in low bass
**Pace** – ability to make music seem to unravel at the pace (or beats-per-minute, BPM) it was recorded at, rather than slower
**Phasey** – symptomatic of a frequency response that undulates like a comb. Co-exists with a manic, zig-zag phase response, literally 'phasing' our hearing system
**Pinpoint** – when the image is very stable and finely etched, like some metal sculpture
**Punchy** – similar to Slam, but can have a pejorative element of 'One-note bass'
**Rich(ness)** – lots of coherent reverb: more usually applied to programme (music) rather than equipment

**Rounded** – loss of attack transients, due to poor damping, poor HF response, or slew limiting
**Rhythm** – infectious vibe inherent in a live show, which makes people want to move and dance
**Slam** – convincing, correctly-synchronised attack for a fundamental in the 125Hz area
**Slow** – rhythm seems less fast than it should be
**Smeared** – when an otherwise sharp image seems to be portrayed through butter-smeared glass: caused by excess incoherent reverb, too much harmonic and intermodulation distortion and/or timing errors
**Solid** – well-damped bass
**Sound-stage** – the space between and around a truly stereo-driven, dual-arrayed PA in which a stereo (Greek for 'solid') image appears
**Squashed** – seeming absence of most dynamic contrasts: may be caused by hard limiting
**Thickened** – reduced dynamic contrasts: can be caused by compression or soft limiting, or more subtly by any path component, from microphones to resistors
**Timing** – time is a another kind of 'spacial' dimension: the timing between sound components at different frequencies coming from one or more instruments may be unlike the original sound – compare bass to mid, bass to treble, etc; delays of milliseconds or less can be audible
**Transient** – abrupt, short-lived events in music: skilled ears can resolve differences in attack slopes and harmonic synchronisation down to tens of microseconds
**Transparent** – when you feel you're hearing just the music, not the PA equipment: a sense of there being 'nothing in the way'
**Woolly** – see Loose

## Music & your ears

The bad news is that loud sound can damage the ears. The good news is that music may have a lower risk of doing this compared to non-organised sounds (otherwise known as noise), even at the same sound pressure levels (SPLs). In theory, at least.

The theory is that the ear can take 15 to 20dB higher levels from music than from 'noise', particularly if it's non-stressful – ie enjoyed by, or at least not upsetting to, the listener.

But beware: these figures are based on an ideal sound system set up in a perfect acoustic environment. Unfortunately, in the real world – where PAs and venues are rarely perfect – damage can and does occur in some individuals exposed to loud music, especially over time.

Since professionals in the music industry – whether they're musicians or sound engineers – rely on reliable hearing for their livelihoods, they may be naturally disinclined to own up in public to any ear problems: but an increasing number have privately admitted their concerns.

Tests over the past 30 years on a link between hearing damage and loud music have provided mixed results – often contradictory, and overall surprisingly inconclusive.

It appears likely that certain people simply have a lower hearing-damage threshold than others – so while some can go gigging and clubbing for years with minimal effect, others can show signs of tinnitus (continual ringing in the ears) and other ear problems after only months of exposure to loud music. And sometimes this is just the start of an irreversible deterioration in

> Some people may have a low hearing-damage threshold

**Comparative sound levels (dB SPLs)**

**0dB** – quietest audible sound
**20dB** – quiet recording studio
**60dB** – normal speech (at arm's length)
**70dB** – quiet music (at arm's length)
**80dB** – average acoustic instrument (at arm's length)
**90dB** – large vehicle passing close
**100dB** – loud vocals (at six inches)
**120dB** – aircraft engine (six metres)
**125dB** – toms at close-miking distance
**130dB** – pain threshold
**135dB** – bass drum, close-miking distance
**140dB** – explosion

Note that every 6dB rise in SPLs represents a doubling of sound pressure; adding 10dB is roughly a three-fold increase; a 20dB jump means ten times higher. Which means adding 60dB is an increase in SPLs of 1,000 times ($10^3$)... So the sound pressure when you get to 140dB is one million times greater than it was at 20dB in that quiet studio.

hearing (which worsens with age in most people anyway).

Unfortunately there's presently no way of knowing in advance who is going to be vulnerable in this way. So caution may be the best option if you want to be sure of avoiding harm.

**Measuring sound levels**

Sound pressure levels (SPL) are measured in dB SPL. These dBs (which are 'code' for a range of pressure levels) are absolute 'units'. dB SPLs can be weighted – as is done in equipment noise measurements: 'A'-weighted is centred on 1kHz, with most of the bass and treble filtered away.

This sort of reading is designed to approximately simulate the sensitivity of hearing to mid-range sounds. It will naturally work in favour of loud bassy and toppy music, if keeping down the dB SPL is the reason for monitoring the sound levels.

> Bad quality sound and damaged gear contribute to ear trauma

'C'-weighted readings don't employ filtering, and these come far closer to giving an objectively correct 'flat response' reading. But if used for SPL monitoring, C-weighted readings work against sound levels being high at any frequency. The C-weighted reading is however usually the one to use for reading signals in the room, eg for room EQ, using pink noise (see Chapter 9).

The maximum feasible working range (for average human ears) is from about -10 to +140dB SPL. That's a huge, huge pressure variation, of 30 million to one – this is why dBs are handy, as they can easily cover such vast number ranges, keeping to friendly, easy-to-work-with two and three-digit numbers.

**Causes of ear trauma**

Apart from a biological predisposition to hearing damage (a lower-than-usual threshold), most ear trauma can be put down to the following:

- Bad quality sound – nasty harmonics (even if they measure small SPLs with single tones). For example, any equipment with a 'spiky' rather than 'smooth' distortion residue (test gear is needed to see this). Some poor-quality digital gear also wrecks waveform reconstruction in deeply un-musical and potentially damaging ways.
- Damaged equipment (see also Chapter 9).
- Abused equipment – eg clipping, too heavy a load.
- Peaks in the PA system at aurally sensitive frequencies, between 1 and 5kHz. Caused by drive-units, cabinet interactions and complex acoustics. May be called 'spiky colouration'. It seems some people's ear passages create big response peaks from mid frequencies, to over 22kHz, making them far more sensitive.
- 'Ringing' in metal-diaphragmed high-frequency (HF) horn-drivers. Metal cones and diaphragms generate more unpleasant sounds than other types (paper cones, phenolic or plastic-cloth diaphragms), and some people are much more affected than others (as mentioned above).
- Generation of highly dissonant sub-harmonics (1kHz tone creates a sub-harmonic 'tone' at one fifth of this frequency = 200Hz, say) – made by (mainly) compression drivers. These are not natural harmonic sounds and can be highly unpleasant, even in 'subliminal' doses.
- Sudden (attacking) solo sounds – individual sounds that rise to high levels in thousandths of a second, or less. For example, if a drummer suddenly strikes the snare drum hard, just once, while you're standing near, with no other music going on, it can be unpleasant – though when that identical sound is played within the context of a piece of music, it's nice enough. (The noise of a gun going off at close range is far more sonically stressful than even the loudest heavy-metal drum kits – as it's got even faster attack and higher peak sound levels.)

Getting too close to a loud drum kit is generally more stressful than approaching other loud instruments. First of all, percussive noises – where something is being hammered to make the sound – are the most stressful type to the ear. They combine sharp attack, sprays of harmonics and spiky peaks, and can also seem less powerful than they really are (and also produce a misleadingly low dB SPL reading on average-responding meters).

- In terms of prevalence and potential for doing harm, worldwide public enemy number one is bad venue acoustics.

Briefly, most buildings are 'phased' (sonically confused) by high-energy music. Most are bad enough with less 'spiky' classical or folk playing.

Bad acoustic effects involve massive 'comb-filter' colouration – this means having the sound level rise 25dB for a few Hz, then dip 25dB for a few more Hz, and so on, over most of the musical range. The result is aurally tiring at the very least.

Even the worst graphic-EQ-abusing inexperienced engineer cannot wreck sound as efficiently as an acoustically-unfriendly room that's driven too hard.

It's not so much the size of the room as the shape – nice-looking but overdone features like deep balconies are bad news, but so are boring boxy spaces, not to mention certain surface materials (an excess of harder materials like metal, glass and glossy plaster hardly help absorb reverberant high mid and treble), the walls' thickness (the thicker the better – 12-to-20ft-thick castle walls are suggested for a serious venue), and solidity (older-style constructions are usually best), and so on.

Any areas of undamped metal can cause truly dreadful sounds – like a ripped metal drive-unit.

It's a sobering thought that some of the best buildings for high energy music appear distinctly 'low tech' and often date back to pre-history – for instance tents (marquees, big tops etc), earth and stone buildings (quite open ones are good).

## Percussive noises are the most stressful to the ear

The conclusions are obvious: all public venue architects would do well to be humbled by the terrible damage done to the enjoyment of music (especially in the 20th century) by blind belief in the 'progress' of modern building materials.

In so-called 'pre-civilised' times, most people would have experienced loud music (such as massed drums and horns) at tribal ceremonies and the like, and probably enjoyed better sound quality with it. It's only in recent centuries that architects have forgotten about meeting such acoustic needs. In general, the less 'synthetic' the environment for music, the better.

Even non-structural vibrating objects at a venue can be 'set off' by music. Any areas of metal (sheet, grid and mesh) – for instance security barriers – are regular causes of dissonant sounds (it's no accident that good-sounding metal cymbals are hand-made by craftsmen using centuries-old skills). Metal doors may be deadened by opening them, and replacing them with a security guard if needed (assuming 'sound-escape' is not a problem).

Dance parties in modern warehouses, made almost entirely of undamped corrugated metal, can be sonically unpleasant for the same reason. If you have to use these venues, hang canvas sheets (flame-retardant-treated) along the walls and ceiling if possible – this will help absorb at least some of the more metallic-sounding harmonics produced by the panel vibrations.

### Signs of ear stress

In approximate order of appearance, these can range from a queasy 'sea-sick' feeling, or an inability to focus on the music (the inner-ear balance mechanism may be affected); to buzzing, crackling,

**Earplugs**

There are many kinds of earplugs and ear defenders – some almost useless for PA work. Others are worse than no use – they can actually exacerbate damage. The key point is that the correct, most comfortable and useful type may not be the first and most obvious you'll find. Strictly speaking, ear defenders and plugs should be obtained from a hearing (audiology) clinic that specialises in musical clients, and the best earplugs are custom-made for the wearer so they fit the individual's ear cavity exactly. For help on choosing earplugs, and more information on hearing protection in general, try the RNID (the UK's Royal National Institute for the Deaf) (*www.rnid.org.uk*), or a specifically music-oriented hearing advice group like HEAR (*www.hearnet.com*).

rasping sounds, or a tickling sensation in the ears; to temporary deafness (threshold shift – where the hearing level drops for a while before gradually coming back up); and finally, and most alarmingly, pain.

**If your ears are constantly bombarded, tiny hair cells in the inner ear begin to die**

Pain in the ears is a loud, flashing warning sign. It says, "leave at once or else protect your ears". If your PA system creates pain (or other signs of discomfort), something is wrong. It's not necessarily simply 'too loud', but the sound certainly needs adjusting in some way (see Chapter 8 for more on this). If that's not in your control, distance yourself from the sound as soon as possible.

If your ears are stressed in this way, you could use earplugs (see sidepanel) or other measures to reduce the sound levels they're subjected to, at least for a while, to give them a rest.

If PA engineering is a part-time occupation, try to avoid day jobs that involve regular noise exposure, or exposure you can't control. It doesn't have to be loud – just persistent. (Even quite quiet computer cooling fans can trigger tinnitus – sometimes music played over the top of it actually stops the effect.) Be 'boring' and wear ear defenders when mowing the grass or using power tools – it all helps reduce your overall exposure and possible long-term damage.

Tiredness, jet-lag, having a cold (flu, etc), or otherwise feeling under-the-weather can also make the ears more sensitive to trauma, so be more prepared to protect them. If your job involves making important sound quality assessments, it's best not to even attempt this until you feel better.

### Too loud and too long

Excessive aural stress causes a release of body chemicals which are meant to protect your hearing by shutting down the tiny hair cells in the inner ear. This is what causes 'temporary threshold shift' – basically short-lived deafness. After the loud event, the chemical is withdrawn, though the hair cells still need some time to de-tox and recover.

If your ears are constantly bombarded, the cells begin to die. If enough of them die, your hearing sensitivity is permanently impaired by a certain degree.

As ears are normally most sensitive between 1 and 6kHz, damage tends to occur first at these frequencies. The first sign of this may be that you find it hard to hear people speak (voices are at the lower end of this range).

In the UK, visiting a health-service hospital audiologist costs nothing. Elsewhere, if PA is a regular occupation, it would be worth spending some money for an annual hearing check (it's your most important tool, after all).

Tinnitus – ringing in the ears – is a common after-effect of loud sound exposure (especially aurally distressing PAs), and can be very upsetting for anyone, whether musically inclined or not. The 'ringing' (the actual sound varies from person to person – it can be metallic clanking, rustling, or something similar to feedback), can be at any frequency (bass, mid, top) and can last for any length of time.

There is no 'cure' – though the sufferer can employ techniques to help ignore the sound as much as possible. It may also come and go at random – even long-term sufferers have known it turn off one day, as if a switch has been found by a dozy sound-engineer in your ear.

Sometimes tinnitus has no sonic connection at all – it may be genetic, or brought on by stress, or by some other medical condition (even some drugs can exacerbate or trigger it). But everyone who uses their ears for a living (or even for recreation) should be aware of the facts and the risks.

**Pain in the ears is a loud, flashing warning sign**