Crossovers

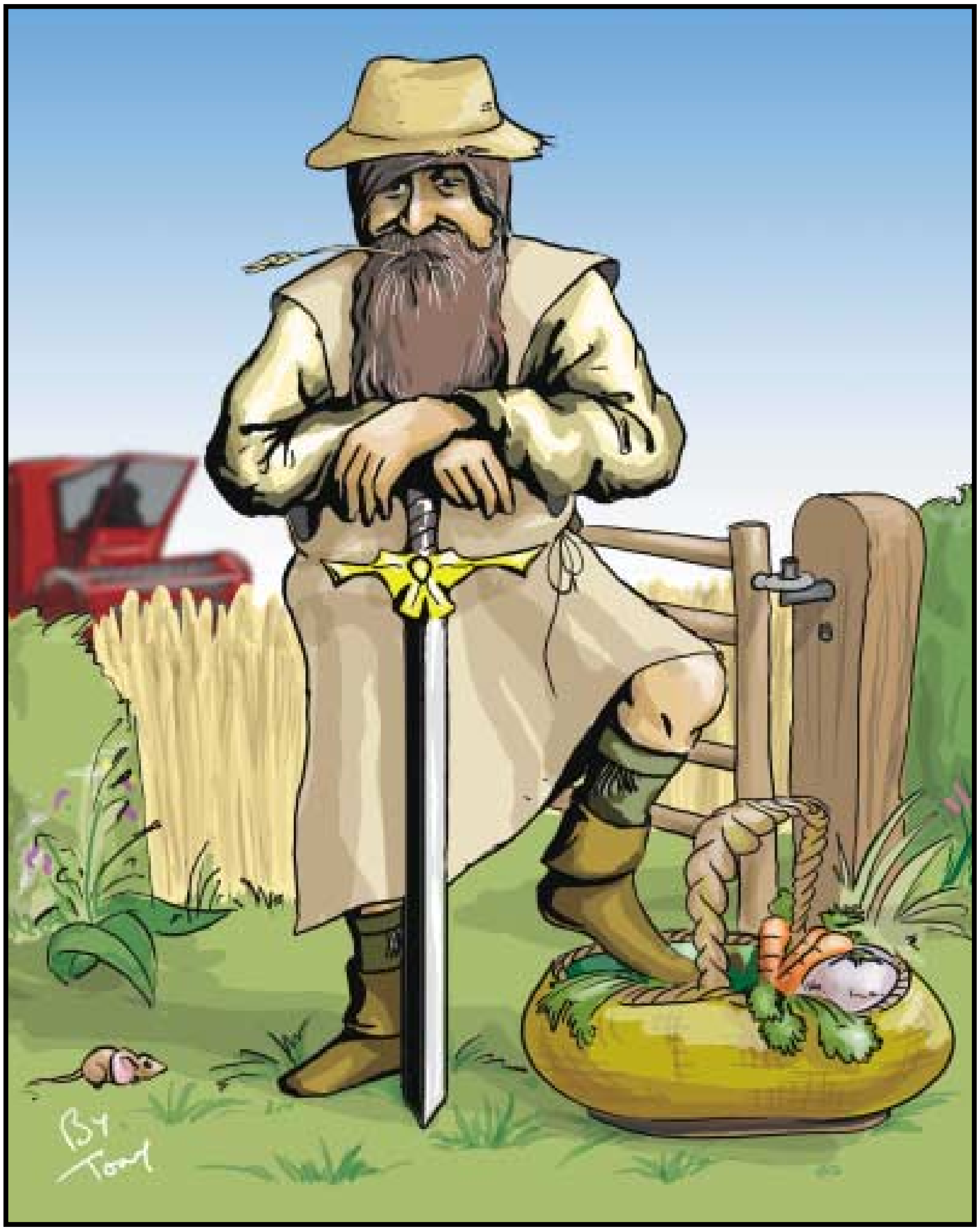
This month the Watkinson sword goes through the traditional loudspeaker crossover. Hardly any resistance was felt and the sword wasn't even scratched.

JOHN WATKINSON

IT'S A DIRECT CONSEQUENCE of the way that sound is radiated that more than one drive unit will be needed in a loudspeaker. The lower the frequency, the larger the area of the diaphragm has to be to couple to the air. The higher the frequency, the smaller the diaphragm has to be to prevent the sound coming out in a narrow beam. Thus the ideal diaphragm has to be large and small at the same time and clearly that's difficult.

The same problems exist in aircraft design. Aerodynamics is essentially the DC component of acoustics, so there's a lot of crossover between the subjects, epitomised by the honeybee that obtains lift from the reaction to emitting sound. Thus in order to fly slower, aircraft need more wing area whereas to fly faster all that area causes drag, hence the use of flaps to vary the wing area.

Like all industries, aviation has its dragons to be slain, top of the list being the popular view that Bernouilli's theorem explains where lift comes from. To hold this view, you have to neglect the fact that Bernouilli himself made it clear that his theorem doesn't apply to that case. However, aviation is a money-where-mouth-is discipline, whereas audio isn't. Thus on the whole there are fewer aircraft that don't fly than loudspeakers that don't reproduce anything like the original sound.



A lot of this has to do with the crossover. While in one sense of the word a crossover is an electronic circuit that divides the input spectrum up, to make progress in a loudspeaker we have to redefine it. Thus the crossover has to be considered holistically as the problem of how to make two or more practical drive units behave as if there was only one ideal drive unit.

Thus the problem of the crossover becomes a series of smaller problems. Assuming a two-way speaker, the crossover itself must produce a pair of signals that sum to the original waveform. The drive units themselves must have sufficiently good phase and frequency responses and directivity characteristics that there is a reasonably wide band of frequency in which either drive unit could be used. The crossover frequency can then be placed within this band. Finally the physical arrangement of the drive units must be such that the acoustic summation of sounds from two drive units must be the inverse of the subtraction that took place in the crossover. Failure to address any one of these problems will result in a system that has audible deficiencies.

Looking first at the crossover itself, it's an obvious requirement that the two output signals, high pass and low pass, should be capable of being summed together to recreate the original signal. Unfortunately in the vast majority of loudspeakers this doesn't happen. It's a simple fact that in order to get a pair of complementary signals it is necessary to use a subtraction stage in the crossover. This is fundamentally impossible in a passive crossover because passive circuitry can't subtract. Thus passive crossovers are not crossovers at all, but a pair of filters, one high pass and one low pass, whose turnover frequencies happen to be similar.

The outputs of these crossovers cannot and do not sum to the original waveform. Instead the crossover frequency range is subject to a variety of deficiencies in amplitude, power and timing. The vast number of passive crossover topologies available simply fuels an endless debate about which one does the least harm, when the goal ought to be to do no harm at all. Thus, by definition, a passive two-way loudspeaker cannot reproduce the input waveform and cannot display linear phase through the crossover band.

The obvious solution here is to use an operational amplifier based crossover that truly subtracts to obtain complementary signals. Such a device needs power and so cannot be used in a passive speaker. In an active speaker such a line-level crossover can then drive one power amplifier for each frequency band. Such an approach will produce fewer intermodulation products than a single amplifier driving through a passive crossover.

In the past active speakers would have been expensive to build, but today it is not so. If the cost of a high-quality passive crossover is considered, those large value, air-cored inductors and decent grade capacitors are expensive. Given the low cost of modern amplifier technology it's not necessarily more expensive to adopt an active solution, and it will sound better if properly engineered.

Assuming a decent crossover system, the next requirement is for drive units of appropriate quality. Each drive unit must have a frequency response that extends well into the range of the other. If this is not the case, frequency response irregularities result in phase errors that mean the acoustic signals from the two drivers simply don't add up.

In the typical two-way speaker having a woofer and a small dome tweeter, this requirement is seldom met. In practice the woofer won't go up far enough and the tweeter won't come down far enough. The result is that whatever the crossover technology, the listener forms the impression of two different sounds that don't fuse. To make matters worse the directivity of the two drivers will be quite different at the crossover frequency so the frequency response off axis could be extremely irregular. For example, if the woofer has started beaming at the top end of its range, the off-axis response will fall below the crossover, only to rise again to the correct level at the frequency where the tweeter comes in. Speakers displaying this problem usually have a dip in their power response at the crossover frequency that further prevents the two drivers fusing.

Off-axis irregularities are easy to check for. With the speakers set up normally, assess the quality from the normal listening position, then go just outside the open door of the listening room and listen again. In most cases the sound quality will be noticeably coloured. It shouldn't be. A good loudspeaker will have a sufficiently accurate response off-axis that it produces an uncoloured sound field that will be acceptable in the next room. Listening from the next room, a very good loudspeaker playing an accurate recording might make you unsure whether the source was a speaker or the instruments themselves. Very few loudspeakers can pass that test.

It is important to test speakers for realism with suitable recordings. Any instrument that has a spectrum straddling the crossover frequency is a good candidate. The cello is one such instrument. Female speech is also a good signal for testing.

If the equipment is to hand, formal testing of the frequency and phase response is very instructive. Speakers showing little frequency response or phase disturbance at the crossover will sound better. A very good active speaker will remain phase linear even at the crossover frequency and should be able to reproduce square waves. This performance should be maintained off-axis, with no dip in the power response. I only know of one loudspeaker range that has these characteristics. It can all be put into practice and it works.

The way forward in loudspeaker performance is clearly to use active technology. The problem is that just because a loudspeaker is active it doesn't mean that it meets any of the criteria explained here. An active loudspeaker may be no more than a passive loudspeaker and passive crossover with a built in amplifier. An active loudspeaker having a line level crossover might be a better bet, but the crossover may just be a line level version of the traditional passive crossover. In this case the only benefit is reduced intermodulation. A further problem is that when the speaker is active, it costs more, so the manufacturer may be tempted to cut corners to get the price down. This isn't logical, as the purchaser doesn't need to buy a power amplifier, but then we don't live in a logical world.

To produce good work, audio engineers need to be able to hear what they are doing. This is only possible with accurate loudspeakers. As the price of recording and processing equipment falls, people expect speakers to get cheaper as well and so have totally unrealistic expectations. ■

DON'T

- **Use passive crossovers. They are fundamentally incapable of producing waveforms that sum to the original.**
- **Assume that an active speaker is anything more than a traditional speaker with an amplifier in it.**

DO

- **Use active crossovers and a separate power amplifier for each frequency band.**
- **Insist on seeing the phase response of a speaker, especially in the region of the crossover.**
- **Listen to loudspeakers in the next room through an open door. This reveals off-axis problems and resonances.**