

## The design and development of high performance loudspeakers

The aims of the forefathers of the industry seem to have been completely forgotten and many loudspeakers of today's manufacturers are described as being musically involving, having pace, rhythm and slam or as just being a musical experience, words which might have a definite subjective meaning to the originator, cause confusion and suspicion in the mind of the public, and provide the less scrupulous with a cover for rather cynical products poorly engineered.

To be able to describe a loudspeaker as being of high performance it must comply with a range of related yet quite complicated criteria. These, when detailed, may appear obvious, however, the significance of the following simple ideas and design criteria, and their relative importance to each other in the design of a high performance loudspeaker, are all too often not properly understood.

The performance of a loudspeaker can be defined by its linear and non-linear behavior. Linear performance is defined by the impulse response and non-linear performance by harmonic distortion measurements.

The most important elements to consider in a practical design, which are encompassed by the characteristics of linear and non-linear behavior, are detailed under the following headings:

1. Magnitude Response

2. Phase Response
3. Time Domain Anomalies
4. Dispersion and Directivity
5. Harmonic Distortion
6. Amplitude Intermodulation Distortion
7. Hysteresis Distortion
8. Dynamic Range
9. Motional Impedance

### Linear Distortion

#### 1. Magnitude Response

The magnitude response of a loudspeaker, measured using analogue techniques, has been the mainstay of most loudspeaker assessment for decades.

By definition a "Linear Magnitude" refers to a magnitude response that has a constant level with frequency and only then will it not cause any linear distortion. We all know that this is practically not achievable and that the impulse response of a loudspeaker is largely dominated by the low and high frequency roll-off characteristics and by any resonant peaks in the amplitude response.

It is possible, however, to produce loudspeaker systems that maintain a variation in magnitude response within +/- 1.5dB consistently between 100 Hz and 10 kHz and that have an excellent overall balance between bands. We believe that the balance between drive unit frequency bands is critical, particularly between bass and midrange in three way systems, and should always be better than 1dB.

Time is well spent on drive unit development in order to meet this magnitude response limit. It is much more elegant to use properly developed drive units which will then enable the use of simple crossover filters than to use complex equalization in an effort to correct drive unit magnitude response anomalies.

#### 2. Phase Response

As with the magnitude response, the phase response of a system is usually measured on a single reference axis, midway between the bass/mid and high frequency drive units in a two way system and on the axis of the midrange drive unit for a three way system.

A system will be defined as being "Linear Phase" if the phase response is a straight line, when the frequency response has a linear scale and passes through the origin. The effect is then of a true time delay and will therefore not cause any linear distortion.

In practical loudspeaker systems however, the aim is to



design for a minimum phase response free from any abrupt changes that are usually indicative of high Q resonances. Even order frequency dividing networks using Butterworth filters offer the special characteristic that the phase of complimentary low and high pass filters are the same. The result is a greatly improved polar response and therefore improved coherence of the audio signal.

It is also relevant to include here that the delay between drive units due to acoustic centre misalignment is not audible, we believe, for delays below 2 ms. Therefore, providing the overall delay is within 2 ms. and there are no sharp phase response irregularities, then the system should be free from any subjective phase effects. ATC has incorporated analogue phase correction, operating through the crossover regions, in its active loud-

speakers since 1982. This is achieved by the addition of an all-pass filter (i.e. one with a magnitude response of unity for all frequencies, but a varying phase response) enabling correction for the delays due to the extra sound path length from the various drive units in a multi drive unit system. Such correction



serves to steer the main radiation lobe at the crossover frequency toward the listener. The result of such active filtering is to give much better control over the filter shapes with greater phase coherence and therefore a more uniform group delay characteristic. The subjective result, when compared with the same loudspeaker system but with a passive crossover, is of a broader and more stable stereo sound field with much more coherent drive unit integration and improved openness and timbre of reproduced sounds.

Digital signal processing promises several advances in phase response manipulation in the future:

#### A. Linear Phase Crossovers

Delays enables crossover filters to be constructed with a constant group delay, i.e. no changes in phase in the audio band. ►