IMPULSE TESTING OF MONITOR SYSTEMS (The only way to achieving a better understanding of the path to the perfect monitoring environment)

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There is one characteristic which is shared by all of the world's finest, currently available monitor systems. All of them are "wrong"! Not one can claim to be definitive in any sort of absolute sense. The physics of low frequency sound reproduction is almost diametrically opposed to the physical requirements for high frequency reproduction. Whilst the generation of sound at low frequencies demands a large source area in order to keep diaphragm velocities low; high frequency drivers need to be as close as possible to a point source in order to prevent phase cancellations. Such cancellations are due to the short wave-length sounds interacting in the event of them being generated over an area whose dimensions were approaching or greater than one wavelength of the highest frequency to be reproduced. For the above mentioned reasons, there is no loudspeaker available which is anywhere near capable of delivering 10 Hz to 40 KHz $\pm$ ½dB at 125dB S.P.L. from a single drive unit. What is more, even if such a unit were available, it would have to be phase accurate to within a matter of only two or three degrees over its entire, usable frequency range in order to have any hope of being capable of accurate transient reproduction. In short, the unit would have to be capable of reproducing, absolutely faithfully, any square wave from 20 Hz to 20 KHz. We are still looking for a loudspeaker which is capable of the faithful reproduction of <u>any</u> square wave, let alone a full range of them. Only electrostatics can even come close, but unfortunately, they suffer from poor low frequency performance and lack of overall output S.P.L.

Even the "massless" ionic high frequency drivers which offered so much potential in having no moving parts, fell flat on the three problems of radio frequency interference, low acoustic output, and the potentially human-damaging ozone which they produced as a result of their corona discharges.

Any half cycle of a square wave contains all frequencies in very specific phase and amplitude relationships. As any waveform distortions, by definition, will upset the harmonic balance of a system, then obviously no accurate square wave reproduction would be possible if distortions were present. In order to accurately reproduce a square wave therefore, an accurate pressure amplitude response, commonly referred to as "frequency response", and an

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accurate phase response must be prerequisites. In view of this, accurate square wave responses of loudspeakers should be the ultimate goal. For testing purposes, the two extremities of square waves are frequently more convenient signals to use. At one extreme, the delta function or pulse, is a square wave with an extremely short duration, and is usually accompanied by a short mark/space ratio. At the other extreme is a step function, a square wave with long duration "on" cycle. In order to prevent comb filtering of the measured results due to truncating the data as a conventional square wave rises then falls, the test signal should have either an infinitesimally small "on" time, or an infinitely large "on" time. The delta function and the step are practical realisations of these requirements. During the subsequent signal processing, either can be re-generated from the other by a process of differentiation or integration, so the choice of which one to use is down to convenience.

The pulse, or delta function, does have certain practical draw-backs. Firstly, it is difficult to generate accurately without overshoots or ringing. Secondly, as the burst of power is so brief, it is difficult to either hear, or see by means of an oscilloscope whether any part of the system is clipping. If clipping did occur, non-linear distortions, whilst imperceptible aurally, would render the measurements useless. thirdly, the low frequency content of a delta function is so low that the bass drivers really don't get chance to be put through their paces, nor are they given the power to excite any resonances to a measurable degree. A step function is easier to generate, works the bass drivers much harder, and is generally much more easily judged in terms of the "loudness" of the impulse, giving the person performing the test a good indication of the overall power level being fed to the loudspeakers. There is thus less chance of clipping the system or encountering accidental gross, non-linear distortions.

By means of Fast Fourier Transform, a white or pink noise source can also be used to produce an impulse or step function finger-print, but this requires an anechoic chamber, as the effects of the rooms on the steady state signal cannot be separated from the responses of the loudspeaker systems themselves. The use of gating techniques allows a step to produce its characteristic time history fingerprint, along with both pressure amplitude and phase responses in F.F.T. analysis, in situ. Except in the smallest of rooms, where the first reflexions appear before the low frequency component of the step function can be fully integrated into the F.F.T., there is no requirement for the monitor system under test to be removed from their daily working surroundings, and hence from their "real world" loading conditions.

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Remember, the room is itself a part of the loudspeaker's air loading. Changing the position of a loudspeaker cabinet from being flush mounted in a wall, to being free standing in a room, or even to being placed in a corner, may significantly affect the character of the air loading. In a location where the low frequency drivers have more air to push on, more work can be done. Where this extra work manifests itself as a change in acoustic output, effectively, the performance of the loudspeaker has been altered. Irrespective of room reflexions, a loudspeaker is not the same under all conditions. It is necessary to measure a loudspeaker in its particular working environment for accurate assessment, especially of the low frequencies. It is for this reason that the impulse/step function fingerprints are more practically achievable from an impulse source, rather than from noise sources, which would require the loudspeakers to be removed to anechoic conditions if the room effects were to be separated out.

At the Institute of Sound and Vibration Research in Southampton, we are currently studying in considerable depth, the perceptible differences in mid-range drivers. From a representative sample of around thirty, high quality mid-range systems, whilst most sound very similar on signals with a highly tuned content such as resonant drums, sine waves or smooth enveloped tonebursts, not one like sounding pair can be found when listening to white noise or a recording of a waterfall. Not even identical drivers from the same batch of the same production line. Ironically, less expensive, lower quality drivers can be matched more easily, as inherent flaws tend to cause an easily recognisable pronouncement of a certain response characteristic. Such characteristics, together with other response limitations often tend towards a matching process of considerably greater simplicity. The more accurate a mid-range unit becomes, the more the differences appear to stand out.

Taken to an extreme, a dozen loudspeakers of different shapes, sizes, and of differing materials, all with a response from 1000 Hz to 1002 Hz, when subjected to a noise signal will all give a remarkably good impression of a 1001 Hz sine wave. Widen the response band, smooth out the major irregularities, and increase your problems of subtle consistency!

We recently met with Emile Ford, who had patented a loudspeaker system which he claimed always sounded the same, irrespective of room acoustics or response deficiencies in the reproduction chain. The idea of this system was to re-introduce four narrow frequency bands of boosted signal into the music. As the four carefully chosen frequencies were "pleasingly" harmonically related, this gave a slight "chording" effect to the whole signal. When played in a room with bad acoustics, the boosted frequencies still had a tendency to predominate, especially as the lower levels of the sounds in between were unlikely to excite any room modes as strongly as they would otherwise have done. The result is, they claim, a loudspeaker system which to all intents and purposes, always sounds the same. It is also argued that by mixing on this system, the engineer is psychologically drawn into the chosen frequencies, producing a mix in which they would naturally predominate even when reproduced over a conventional radio or television. It is understood that certain American entertainment companies are already looking at the prospects for its use.

People often mention that recording of "Dire Straits" always seem to sound good, again irrespective of on what, or where they are played. By chance, having been looking at the E.P.Q., band splitting visual monitor, It was noticed just how strong the fundamentals appeared to be on the "Dire Straits" recordings. There was a great predominance of "clean" pseudosinusoidal waveforms. Once again, narrow band or sine wave orientated signals produce a distinctive fingerprint which is very difficult to upset. Whilst realising that Emile Ford's system is not what is meant by accurate monitoring, where rubbish in <u>must</u> give rubbish out, surely it will have its applications. It does also highlight the opposite extreme of the tendency for a more linear system to allow <u>differences</u> in response anomalies to predominate over the similarities.

The point to be made here is that the present conventions of using pink noise or swept sine waves is of little relevance beyond a certain point. That point is when very high quality drive units begin to produce very similar response graphs which have no bearing upon the humanly perceived discrepancies in their sonic character. From the work which we have done to date, we believe that the step function fingerprints do relate to perceived sonic performance, with the units which visually produce a recognisably more accurate output response, sounding more "natural" under representative listening conditions.

When given a highly linear monitor system, a room will dominate in the perception of the overall sonic performance, hence the reverberation time characteristics of the room will assume very great importance. The complication here, however is that the knowledge of the reverberation time of a room, when calculated from an omnidirectional source such as a starting pistol, is of little consequence unless the loudspeakers were to energise the room in a similar manner. Without any fixed standard of directivity, it is impossible to say precisely what would be the "best" reverberation time (Rt) characteristic for any given room. Only when considered as part and parcel of the monitor system can any rooms' Rt requirements be specified or judged.

Impulse testing of the loudspeaker/room combination can, by Fast Fourier Transform, give a graphic representation of the actual, overall steady state response of the whole monitor combination. Only when the steady state response and the gated, on-axis impulse response produce one and the same, overall, linear response graph, can the response then be deemed to be "accurate". Tailoring of the response may then be possible to suit individual requirements based on average listening levels, fatigue problems, or other considerations, but at least any adjustments will enable the overall responses to "track" those adjustments.

Where an off axis response becomes irregular or lobed, excitement of the room modes will not be uniform with positions. By impulse testing, the tendency of any loudspeaker to drive the room reverberation, can be related to overall directivity patterns and room reverberation times can be adjusted to take into account the on-axis and off-axis responses of the loudspeakers. Nonetheless, the off-axis impulse response should still be representative of the on-axis response in order that any reflexions produced should continue to be phase coherent when they eventually reach the listener. Whilst many people have put forward proposals for omni-directional loudspeakers to mimic more closely the characteristics of the original recording space, such polar distribution would cause an inordinately high direct to reflected ratio in the listening room, blurring the stereo imaging. About 60° would seem optimum for the horizontal directivity of a monitor system. Having said this however, the impulse/step function fingerprint at a 30° off axis position should be as close as possible to the on-axis fingerprint. Furthermore, one can never <u>truly</u> reproduce the sound field of an instrument, as only in the loudspeaker is the sound source distribution dependant entirely upon frequency due to the spacing of the high and low frequency drivers. It appears that we are, in the foreseeable future, always going to be looking at compromise in loudspeaker design. Without common goals and standard specifications however, it will prove very difficult to approach the most realistic compromise as manufacturers pull in widely disparate directions and merely try to promote the strongest assets of their own products.

We would strongly recommend that step function fingerprints and their Fast Fourier Transform derived phase and frequency/amplitude graphs should become the accepted reference standard for all loudspeaker and loudspeaker/room combinations which are intended for accurate studio monitoring. The general drift of technological advance should be towards more faithful reproduction of such step functions, after which everything else should fall into line.

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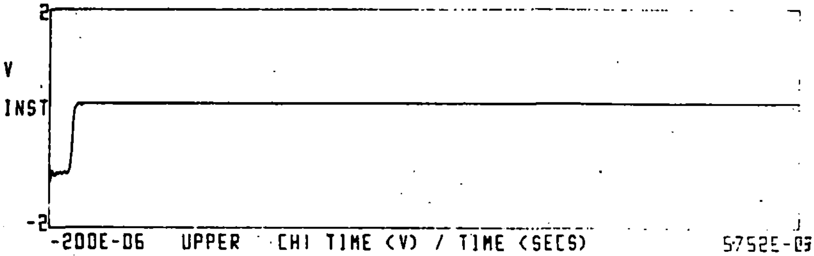
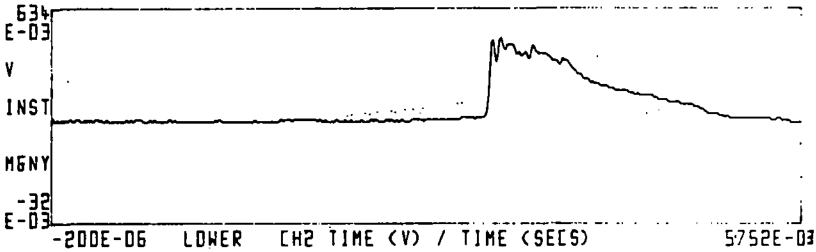
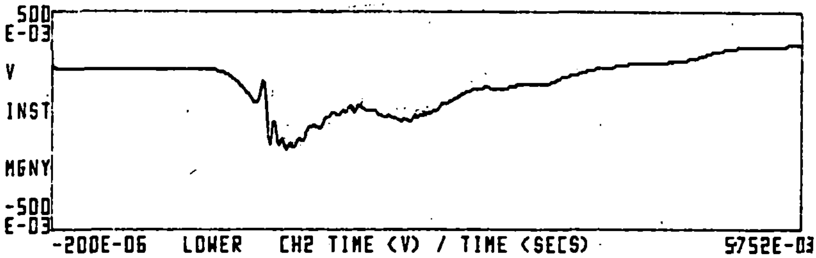


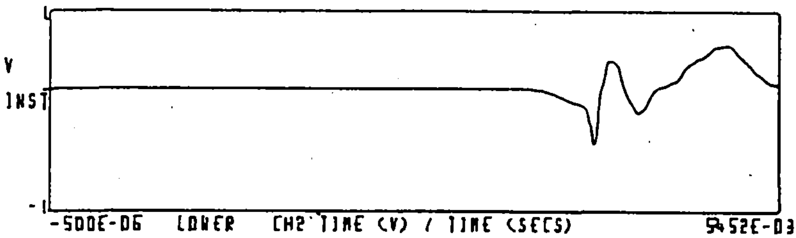
INPUT STEP



RESPONSE OF ELECTROSTATIC LOUDSPEAKER - TAIL OFF DUE TO LIMITED LOW FREQUENCY RESPONSE



RESPONSE OF WELL KNOWN DUAL-CONCENTRIC - IGNORE PHASE REVERSE



RESPONSE OF LARGE, WIDLEY USED, 2-WAY STUDIO MONITORING SYSTEM