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THE ACOUSTICS OF DOMESTIC LISTENING ROOMS AND THEIR INFLUENCE ON SOUND REPRODUCTION

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Summary and Introduction

The listening room is the final link in the sound reproduction chain and whilst over the past decade or so, and more notably over the past 2-3 years, major improvements have occurred to both the electronic and electro-acoustical aspects of the signal chain (e.g.introduction of the compact digital disc), the listening room and the effect it can have on sound reproduction has tended to be forgotton or ignored.
Although major improvements have taken place over the last few years in the field of studio and control room design, little is know about the conditions under which most rcords, discs or tapes are heard - although frequently the domestic reproduction equipment may be of superior qualify to that found in the recording studios - particularly where monitor loudspeakers are concerned.
A pilot research project has been carried out by the author into the acoustic conditions of typical domestic listenin rooms, the way in which loudspeakers interact with such environments and methods of controlling or overcoming such effects. The aim of this brief paper is to highlight some of the more interesting effects observed to date and raise for discussion a number of the more fundamental aspects which have arisen from the investigation. The concept, measurement and meaningfullness of reverberation time in typical domestic rooms in particular is raised, as is the need for some suitable objective method of measurement and assessment of such rooms.

There is a wealth of evidence showing that the listening room very much affects our subjective assessment and appraisal of reproduced sound quality. Indeed it has been shown that a given listening room can alter a listener's preference of one loudspeaker over that of another, whilst a second room may reverse this (Moller 1975).

It is well known, particularly in the more expensive echelons of hi-fi, that a loudspeaker system once installed in the home can give a very different quality of reproduction to that heard in the dealer's demonstration room or studio.

Based on research to date, it is the author's belief that few listeners actually achieve optimal performance from their loudspeaker systems. When it is considered that today £250 to £1500 is typically spent on a good pair of hi-fi loudspeakers and that the total value of a typical good quality sound reproduction system may cost anything from £750 up to several thousand pounds, it seems illogical not to take the listening room into account and realise the full potential of such a system.

Many people do not realise, or believe, that the listening room can and does fundamentally alter the sound they hear. Yet a typical domestic listening room will affect the frequency of tonal balance of the reproduced sound, introduce colouration and loss of definition and affect and degrade the stereo image.

Before discussing in detail some of the measured data and observed effects, it is worth noting that a modern high quality 'hi-fi' or monitor loudspeaker may be achieving a frequency response performance within +/- 2dB or even +/- 1.5 dB over the range 60Hz to 20KHz and loudspeaker pair matching within 0.5dB. These targets are not lightly set (or achieved), but are required in order to achieve accuracy of reproduction and subjective approval.

Taking such a loudspeaker and repeating the frequency response measurement in a typical listening room would be likely to reveal a response result of +10, -15dB - a variation of 25 dB over the above frequency range. A 1/3rd octave analysis, although perhaps more akin to human frequency balance/spectral assessment, would still reveal at least a 15 dB variation impulse or tone burst measurements would reveal comparable orders of magnitude of 'distortion' in the time domain.

It is not unreasonable to assume that such gross distortions of the frequency and time responses go some substantial way to explaining observed subjective assessment.

Although 'in-room' frequency response graph looks, and is, highly complex, it is possible to strip away the unnecassary detail and gain an understanding of what is going on. It is, however, easier to build up the pattern from known interactions and extrapolate. To facilitate this, it is useful to divide the problem into three separate regimes.

THE ACOUSTICS OF DOMESTIC LISTENING ROOMS

1 The acoustics of the listening room as characterised by its reverberation time and standing wave pattern etc.
2 Loudpeaker-room interactions - boundary enhancement, standing waves and early reflection effects.
3 Listener- loudspeaker- room effects.

Domestic Room Acoustics

Little data is available regarding the acoustics of domestic rooms, the author being aware of only two references where reverberation time data is given. (Jackson 1971 and Gilford 1959/1972). But even the data here is in poor agreement. Although a reverberation time of 0.5s is often referred to, e.g. in BS testing procedures, this is for the unoccupied condition. A survey has therefore been undertaken to provide further data. Although still in its early stages, a rather different pattern of reverberation time characteristics is emerging. Gilford's data, for example, shows a reverberation time characteristic varying from around 0.5s at 63Hz to 0.3s at 8KHz. The more recent data indicates much poorer control, being typically 0.9s at 63HZ falling sharply to around 0.3s at 8KHz. The increase in reverberation time at low frequencies is due to the presence of strong standing waves found to be typical of all rooms investigated to date. Several strong, isolated modes generally occur, often with maximum subjective coloration in the regions of 60 and 120Hz. A survey or room size shows by far the most common dimensions to be 12 x 15 x 7.5 feet. In rooms of such comparatively small dimension, theory suggests (e.g. Schroeder), that bass frequency problems will exist up to around 450 Hz when a continuous spectrum is formed. This would certainly seem to be the case. 'In room' sound pressure level variations of 10-15 dB occur within a given 1/3 octave band up to at least 250 Hz in practice.
Measuring low frequency reverberation or decay curve characteristics in such rooms posed a number of problems which are only really exposed when an electronically rather than mechanically produced decay curve recording is employed. Examination of low frequency decay curve data often shows there to be a considerable 'overhang' or time delay after the cessation of the excitation sound; before the decay begins to develop. Delays of 100 to 20 mS are common - though are not observed when using a pen level recorder in

conjunction with random noise excitation. Energy storage for this period of time is of significant importance and is likely to substantially affect subjective assessment of bass response and loudness - particularly when the integration time/loudness weighting characteristics of our hearing mechanism are considered. Essentially, it may be said that the size (and to an extent the physical construction) of the listening room determines the low frequency acoustic performance, whilst the furnishings determine the mid- and high-frequency response.

Flutter echoes were found to occur in many of the rooms surveyed - large patches of hard reflecting upper wall surface or window areas being responsible. In many instances it was found that such flutter echoes added little to the overall slope of the reverberation decay curve, but again, affected the pre-decay response and had considerable subjective impact.