THE WIDE IMAGING STEREO - ONE YEAR ON

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1. INTRODUCTION

The abandoned land to either side of the stereo 'hot spot' was brought to attention by a previous paper presented at Reproduced Sound 4 Conference in November 1988. Since then, efforts have been made to cultivate the abandoned land into 'sweet area', but it is too vast to explore in one year.

The WIS Hypothesis, which contains four parts, was put forward last year as follows:

The WIS H-P1: Haas Effect in Stereophony
The WIS H-P2: Optical Theory in Audio
The WIS H-P3: Viva Human Sonar!!
The WIS H-P4: Hologram-like Sound Image

Now it is time to report on one year's progress.

2. THE WIS H-P1: HAAS EFFECT IN STEREOPHONY

"Initial time delay between left and right source could be compensated by initial sound pressure difference. Conversion factor between 'milli-second' and 'dB' is to be determined by further psycho-acoustical study."

As this is the starting point for WIS Hypothesis, it is quite natural that efforts were made to uncover the conversion factor between 'millisecond' and 'dB'. The typical case is to keep the centre image as it is.

According to Haas et al, it is anticipated that the conversion factor will not be linear and influenced by type of stimuli and subjects.

In the case of stereophony, reproduced sound could be anything and recording methods are another dimension which influences stereo image reproduction. Moreover, the arrival time difference is not simply decided by two speakers' relative angles, but by difference of distance to subject.

All these factors imply that there is no simple solution to compensate arrival time difference by amplitude.

Actually psycho-acoustical (phase 1) study found that the benefit of WIS approach lies in other areas than amplitude compensation for time delay differences. This means that as can be assessed from our demonstration, it is still performing comfortably well

to provide 'sweet area' around 'hot spot'. Though the sound image in sweet area is not as sharp as hot spot, it is not pulled towards the nearer speaker.

It is assumed that the human brain identifies sound images by given clues which vary from time to time, averaging them so that the sharpness of image is reduced to a certain degree.

Further study would be required to reveal optimal trade off factors between arrival time difference and augumentation of amplitude by frequencies.

3. WIS H-P2: OPTICAL THEORY IN AUDIO

"Meaningful frequencies for stereo image perception are reflected according to off-centred audio mirror and initial sound pressure at angle is determined by geometrical reflection, which is well known in optical theory."

3.1 Hard to analyse the data, difficult to simulate in computer.

Qualitatively, it is quite understandable that sound will behave like light as both are wave form, but quantitatively their behaviour is different because of their wave length relative to mirror size and our measurement order.

Since audio mirror size (10-30cm effectively) is in the middle of sound wave length (17mm-17m), wave longer than mirror seems to slip away, and as the wave becomes shorter, audio mirror starts to work.

Diagram 1. is one of the typical results from measurement.

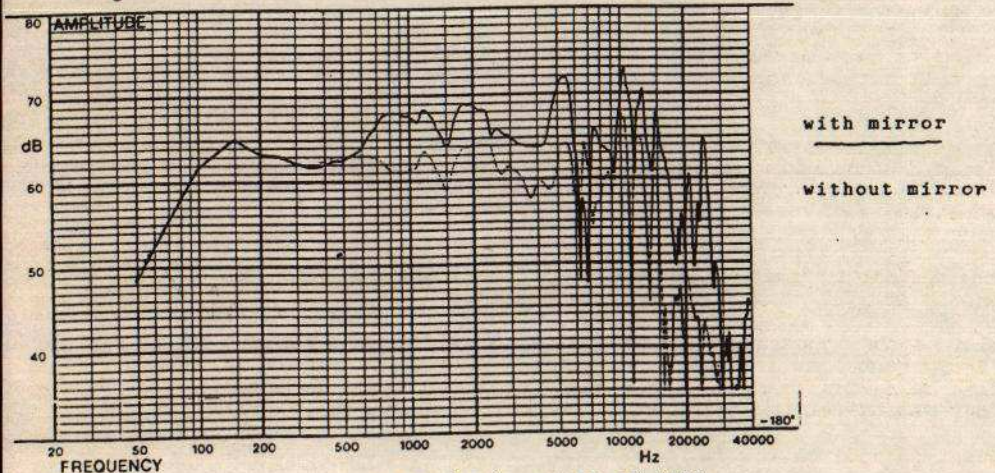

Diagram 1. (courtesy of KEF)

Difficulty lies in computer simulation for the sound wave reflection.

Boundary element method et al were proposed but none of them were substantiated yet. Further studies are awaited.

Second part of H-P2 was off-centred conical audio mirror.In theory, polar pattern should be a simple curve whereas measured patterns are very different.

Immediate assumption is interference due to different wave path. Since WIS relies on wave front of initial arrival through the mirror, it is quite important to measure separately. Phase 2. should address the wave front analysis.

3.2 Coincident sources vs. separate sources

One of the intriguing questions is whether coincident sources could provide WIS effect or not. In WIS theory, the driver should propagate sound wave from all over the diaphragm, therefore Mark II/III employed planer diaphragms known as pistonic motion in given frequency range.

There was a challenge from the coincident camp since one of the criticisms to Mark II was the vertical movement of sound source by pitch because of its vertically deployed drivers/mirrors.

The results, Mark IV.3 and Mark V, are shown here for your audition.

In theory, coincident source should have an apparent disadvantage in WIS effect because of its wider polar distribution in mid frequency, but in reality, the difference between separate sources and coincident source in terms of the WIS effect is minimal. Rather than sound quality in general prevails the preference between two camps.

4. THE WIS H-P3: VIVA HUMAN SONAR!!

"Human perception for stereo image in stereophony relies on initially arriving sound wave from both speakers for their arrival times and pressures. Any delayed arrival via a longer path, even within loudspeakers, appears to be meaningless for sound location but important for its timbre."

ISVR study revealed that even 1 ms difference between left and right speakers has an apparent effect for image localization and, to a certain extent, sound pressure could compensate the effect. It is one point of strong support for the first part of the WIS H-P3.

The second part, any delayed arrival via longer path such as early reflections, has been simulated as follows:

4.1 Early reflections in the anechoic room

4.1.1 1 ms delay only by introducing wall

Early reflections were introduced in the anechoic room by using two sheets of 12mm chipboard to line the walls between the listener and the loudspeakers. The reflections achieved in this way were received about 1 ms after the direct sound. The result of subjective listening carried out by experienced psycho-acoustitian was albeit fairly boxy-sounding due to delay time, but others remain similar in perceived quality compared to the anechoic condition.

4.1.2 Additional loudspeakers with digital delay lines

The precise effects of early reflections on stereophonic listening were then investigated by creating a simulation using digital delay lines and a pair of additional loudspeakers.

i) Simulating reflection from side wall

A pair of KEF 101 loudspeakers powered by a Quad 306 power amplifier were set up for typical stereo listening in the small anechoic room. Lateral reflections were simulated by splitting the signal and creating a delayed version via a pair of Yamaha SPX 900 professional Multi-Effect processors, a Quad 303 power amplifier and a secondary pair of KEF 101 loudspeakers placed to the side of the listening chair.

Compact disc source material was played through this system and the sound was judged to be subjectively better as the strength of the simulated lateral reflections was increased. The signal still appeared to emanate from the frontal loudspeakers, as a result of the precedence effect mentioned earlier, while the time delay was in the region of 1-30 ms, corresponding to a path difference between direct and reflected signals of 0.3-10m.

ii) Simulating reflection from frontal/rear wall

The secondary loudspeakers used for the simulation of side lateral reflections were then placed symmetrically between, and on the same plane as, the main frontal loudspeakers. Reflections emmanating from the surface to the rear of the loudspeakers were simulated.

As the strength of the signal from those secondary loudspeakers was increased, the sound was judged to be subjectively more pleasant without the stereo image being affected, although the overall increase in subjective improvement was not as startling as for the simulated side lateral reflections.

The above findings seem to support the second part of WIS H-P3 in a positive manner and in addition, early reflections provide subjectively pleasant sound.

4.2 Smooth roll off of off-axis response ... Extra benefit of WIS

The previous section has already indicated the importance of early reflections which is dependant on off-axis radiations from two loudspeakers. It is also known that a conventional loudspeaker is directional in mid/high frequencies, but in the case of WIS loudspeakers, off-axis response rolls off smoothly by its very configuration.

To assess the influence of off-axis response several tests have been carried out.

4.2.1. Additional loudspeakers with digital delay lines

In Section 4.1.2., simulated early reflections did have the same frequency balance as main signals and gave subjectively more pleasant sound without the stereo image being affected. But the frequency response of the additional loudspeakers was changed to simulate typical off-axis colouration, the improvement of perceived sound quality was reduced.

The above findings suggest that WIS loudspeaker, which provides a large amount of and less coloured off-axis radiation, could create more pleasant sound, whereas conventional loudspeakers, which have less in quantity and spectrally distorted off-axis frequency response, could not.

This observation also supports the merit of omni-directional loudspeakers which have by nature uncoloured off-axis response. However our previous experience has already shown that omni-directional stereo loudspeakers provided a loss in focus, a serious dilution of the WIS effect, and excess rear and side wall reflection.

4.2.2. Microstructure of directivity

The previous section has studied large angle off-axis responses but even within small angle, stereo WIS loudspeakers seem to have extra benefit.

Anechoic measurement has been made at microphone locations corresponding to the two ear positions for typical stereophonic listening described in Diagram 2. The results are shown in Diagram 3. and 4. for direct (= conventional) and reflector (= WIS) modes respectively.

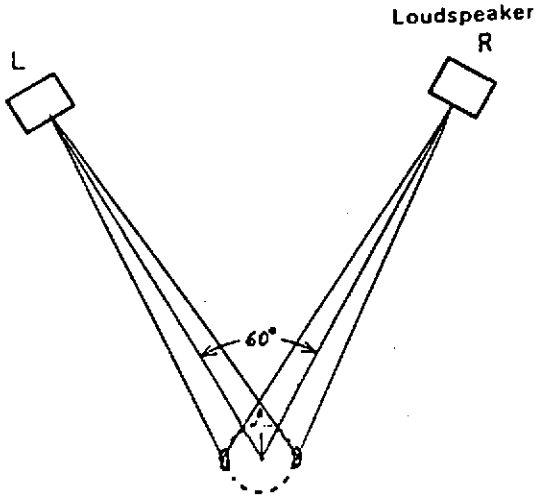

Diagram 2.

The difference between the outputs of left and right ear listening positions is much smaller for the reflector mode than the direct mode.

Careful critical listening in the anechoic room revealed a more stable stereo image in the WIS mode. The position of the virtual images were less critical of precise head position making for far more comfortable listening.

4.2.3. Multi-mode room excitations

i) Impulse response measurements

The loudspeaker situated in the typical listening room in a typical position for stereophonic listening were fed with impulses for the measurements. The reflector listening mode is shown to generate early reflections which are about twice the size of those found for the direct listening mode relative to the strength of the direct sound. Needless to say, the quasi-omnidirectional nature of reflector mode will trigger various mode of room excitations, which is confirmed by the following section.

ii) Coherence measurement

The coherence between measurements made at two positions is a measure of the linear relation between them. The arrangement is the same as Diagram 2. in typical listening room. The results for the direct and reflector listening modes show a more clearly defined pattern for the coherence function when the loudspeakers are in the direct listening mode, than in the reflector mode

WIS - one year on

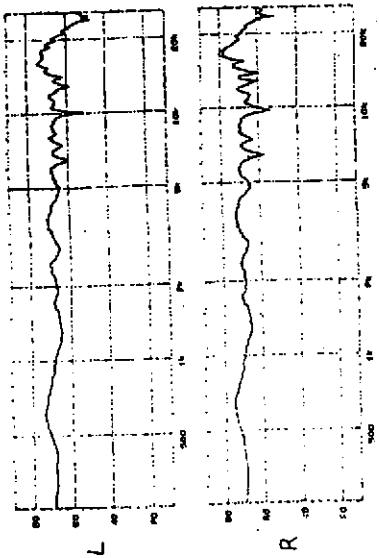

Diagram 4.

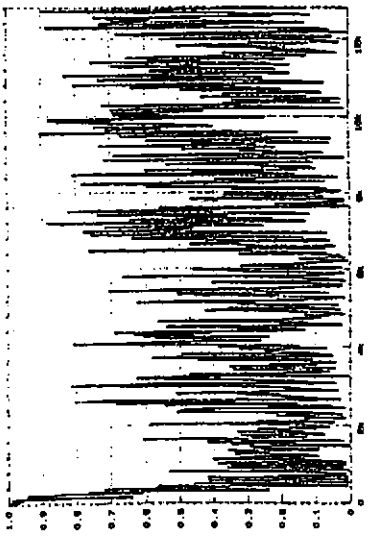

Diagram 6.

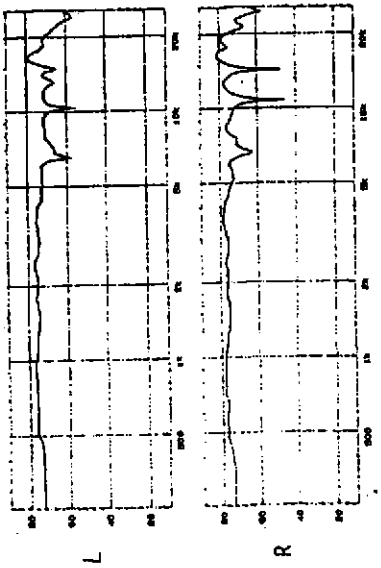

Diagram 3.

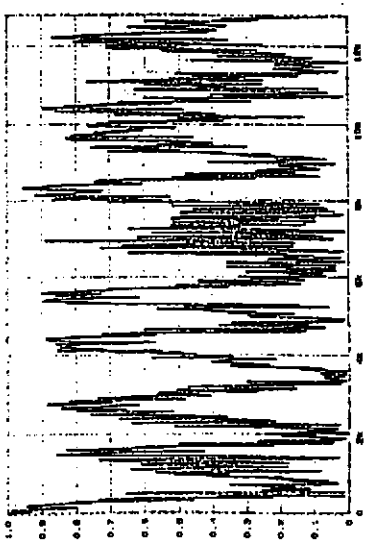

Diagram 5.

when the coherence is lower for all frequencies, and exhibits a fairly random pattern. This is largely due to the way the loudspeakers excite the various room modes. Diagrams 5. & 6. respectively explain this.

For direct listening, the room is only excited in a limited number of modes. For reflector listening, however, many more modes are excited. This is consistent with the result of the impulse measurement mentioned previously. It also suggests that the conventional loudspeaker is far more critical of the listening room, whereas WIS loudspeakers are much less sensitive.

5. WIS H-P4 HOLOGRAM-LIKE SOUND IMAGE

"Like image of three-dimensional hologram, stereo image varies from different angles. Human sonar can reproduce stereo image from an angle, providing consistent sound signals arrive from two loudspeakers. The WIS supplies much better sound signal to non hot-spot area."

In Section 2., it is evident that different stimuli need different time/intensity trade. Music is obviously a mixture of various stimuli therefore off-"hot-spot" listening positions receive inconsistent information for localizing sound image. Like optical lens system, inconsistent imaging information reduces the sharpness of the image, but on average, it will bring obscure image of sounds in between two loudspeakers. It is quite understandable and should be pointed out that amplitude compensation between the loudspeakers can recreate an overall spread of sound between them, but it cannot restore the original stereophonic images heard in the hot spot.

Another aspect of holographic image will be strongly connected to recording technology.

Since early arrival of uncoloured signal does enhance pleasure of sound, rather than confusing it, reassessment of recording technologies might help to improve stereophony/multi-channel reproductions.

6. CHARACTERIZATION OF WIS LOUDSPEAKERS

Since WIS loudspeakers concern controlling polar directivity, the following analysis has been made to clarify the difference from others.

6.1 Three fundamentals in anechoic condition

As mentioned in 4.2.2. smooth microstruture of polar directivity around main axis gives stability of stereo image as well as less critical head position.

In a much wider context, extreme listening position such as outside of one speaker, inter-loudspeaker balancing is difficult. It is easy to understand that 'beaming' loudspeaker could give better balancing than omni-directional.

However, if emphasis is given to provide inter-loudspeaker balancing, main axis of 'beaming' loudspeaker has to be directed inward as in the Hugh Brittain arrangement (45°-45° inward) resulting in inadequate hot spot sound quality. On the other hand, WIS loudspeakers could provide for better balanced solo/group listening condition by Hugh Brittain arrangement.

The three underlined above seem to be fundamental characters of stereophonic loudspeakers from polar directivity without any room interaction.

6.2 Three derivatives in listening room

Normally, listening stereophony takes place in an ordinary room resulting in room interaction. Without any reflection, stereo image is highest in its clarity, but when a lot of reflections exist, clarity is low. Thus clarity of stereo image is dependant on the type of loudspeaker as well as liveliness of the room.

Other aspects of reflection are its strength, timbre and timing. As discussed already in 4.2.3., the strength of balanced early reflection is an important psycho-acoustical factor for pleasant sound.

Lastly, the loudspeaker should be placed in a room to perform stereophony anyway and many factors have to be balanced.

Setting flexibility of loudspeaker is influenced by main axis/off-axis balance and both extreme cases have poor flexibility.

The three derivatives, underlined above, in the listening room are also important to characterise stereo loudspeakers together with three fundamentals. Diagram 7. tries to illustrate these six factors as six axes and gives our scores for typical loudspeakers in order. Outside position represents superior character to the inside.

WIS - one year on

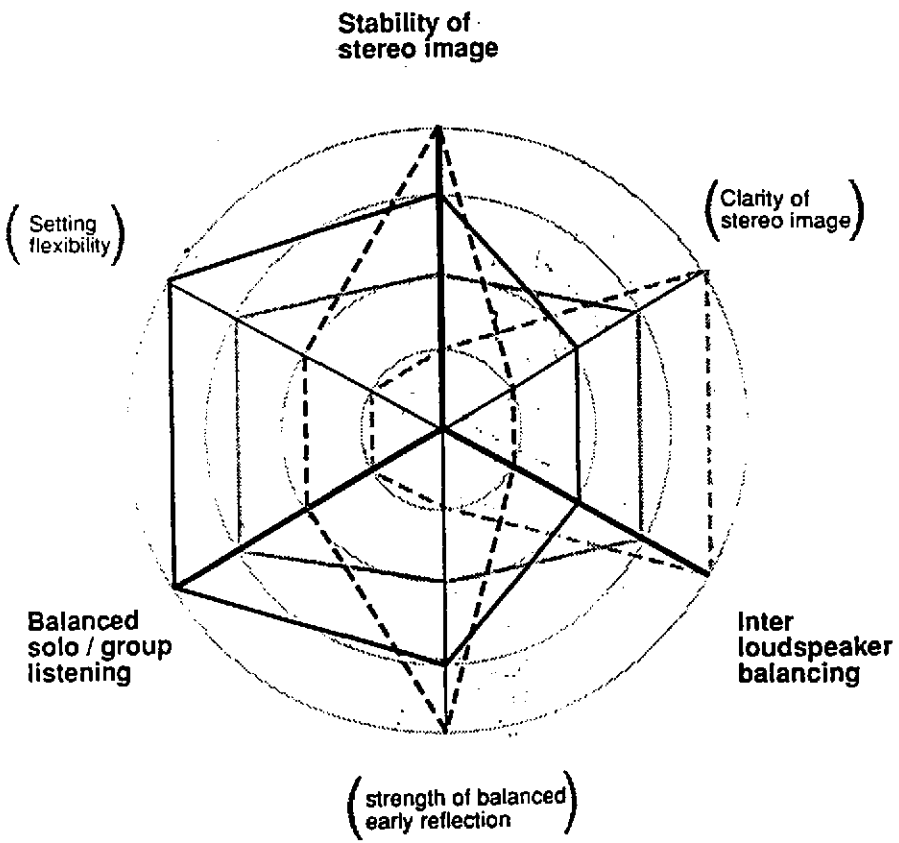

Diagram 7.

6.3 Characterisation of typical loudspeakers

6.3.1. Two extremes: 'Beaming' vs 'Omni'

'Beaming' is best in clarity of stereo image and that is what it is all about. Because of lack of stereo image stability, slight head movement gives the change of stereo image which triggers awareness for stereo image up to conscious level, otherwise awareness remains in sub-conscious level. This built-in reminder of stereo image might help 'Beaming' as hi-fi buffs' favourite as well. Though it is also good at inter-loudspeaker balancing, very few hi-fi-buffs will care about group listening.

'Omni' on the other hand provides well-balanced and pleasant sound all over, but clarity of stereo image is masked by its excessive room reflections, despite its stable stereo image.

Both show low scores for balanced solo/group listening as well as setting flexibility, for very different reasons. 'Beaming' has no way to satisfy the group listener nor does 'Omni' provide solo satisfaction.

'Beaming' is most demanding for setting whereas 'Omni' has no main axis to control loudspeaker direction.

6.3.2. WIS-Wide, Non-beaming/WIS-Narrow

Unlike the two extremes mentioned above, 'WIS' and 'Non-beaming' are moderate. Additional flexibility for WIS is controlling its off-axis radiation by applying absorbent. Hereafter 'WIS-W' represents no absorbent mode whereas 'WIS-N' means with absorbent to reduce rear radiation which is similar to 'Non-beaming'.

'WIS-W' is best at balanced solo/group listening as well as setting flexibility. It is quite in line with the original design purpose to provide sweet area around hot spot. Setting flexibility is partly benefited by strength of balanced early reflection which is second to 'Omni', and partly by smooth roll-off at off-axis. Stability of stereo image is also second to 'Omni' which is suitable for easy listening too.

'Non-beaming' and 'WIS-N' could achieve balance between 'Beaming' and 'WIS-W'. Those who appreciate clarity more than pleasant sound may prefer this intermediate, however it was interesting that many experienced listeners recommended 'WIS-W' after listening to both conditions simply by on/off of polyurethane absorbent at the rear of mirrors. It is also possible to adjust to any intermediate state which might help the listening condition to the taste of the listener.

7. CONCLUSION

Though further studies are awaited, WIS seems to provide extra benefits to stereophonic reproduction, namely:

* More stable stereo image due to similar signal for two ears.
* More pleasant sound because of less coloured early reflections. (Though trade-off for purity/pleasure necessary.)
* Less sensitive to room/loudspeaker interaction.

8. ACKNOWLEDGEMENTS

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