Microphone Arrays for Natural Multiphony

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Michael Williams
Paris, France

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MICROPHONE ARRAYS FOR NATURAL MULTIPHONY

by Michael WILLIAMS, Paris, France.

Abstract

The sound field surrounding a multiphony microphone array can be considered as a set of individual segments in the reference plane. The particular characteristics of the microphone array covering a given set of segments, must be determined from the intersection of the physics of the microphone array with the psychoacoustics of the listening configuration, reproduction being on a one to one microphone/loudspeaker relationship.

INTRODUCTION

For many years, we have seen the existance side by side of Natural Stereophony and "Directed Monophony" (translation of the French term "Monophony dirigé"). There has always been a place for "Natural Stereophony" in studio recordings, whether generated by a pair of microphones (spaced or coincident) or by acoustic obstacle techniques (Dummy Head, Jecklin Plate, Spherical Pressure Zone Microphone system, etc.), even though the majority of commercial recordings are made by intensity variations created by a "pan pot" (Directed Monophony) or other artificial effects.

The cinema industry, on the other hand, has managed to restrict almost completely sound recording techniques to "Directed Monophony" or to what one can only call "effects stereophony". Any experiments in natural stereophonic sound recording for the screen are doomed to failure by the reproduction configuration used in cinemas, the associated matrixing arrangements and, of course, the need for a large stereo listening area.

The advent of multichannel sound facilities for television with the possibility of reproducing a sound field for a relatively small number of viewers, again opens up the possibility of developing natural sound recording techniques for certain types of programme, even though the majority of programme materiel will, of necessity, be "effects" multiphony stemming from the cinema industry or using techniques applicable to the cinema industry.

There have been many attempts to create a continuous surround field using different microphone and loudspeaker systems, with however not very satisfactory results concerning accurate localisation, even though the "effect" can be quite spectacular.

This paper describes the method that can be used to determine different microphone arrays, which will reproduce a vitual continuous surround sound field, with accurate localisation, minimum geometric distortion, good early reflection and reverberant field reproduction.

BASIC LOUDSPEAKER AND MICROPHONE ARRAY CONFIGURATION.

It is a quite legitimate approach to the reproduction of the sound field, to divide the surrounding 360° in the horizontal or reference plane, into individual sectors both in relation to the recording system and to the loudspeaker reproduction system, maintaining a one to one relationship between the constituent elements of the microphone array and those of the loudspeaker system.

However, in order to reproduce a continuous sound field with a minimum of geometrique distortion, it is absolutely necessary to have a clear idea of the relationship between the physics of the microphone system and the psychoacoustics of the reproduction system. Each segment can be treated as an individual stereophonic system, having a specific Stereophonic Recording Angle (SRA) according to the angle and distance between the pair of microphones (ref.1).

The Standard Stereophonic Listening Configuration is shown, in Figure 1, by listening position "A". The listener is placed at the summit of an equilateral triangle with the loudspeakers positioned at each extremity of the base of the triangle and directed towards the listener. However, if the listener is placed at the summit of an isosceles triangle with relation to the loudspeaker base, the stereophonic localisation will still be acceptable, as long as the position of the listener is not too far from the standard listening position.

Listening position "A" in Figure 1 is equivalent to one segment of a six segment array (Figure 2), the angle subtended by the louspeakers being 60°. One segment of a five segment array (Figure 3) is equivalent to listening position "B" in Figure 1, the louspeakers forming an angle of 72° in relation to the listener. Whilst position "C" in Figure 1 corresponds to a four segment array (Figure 4), where the loudspeakers are at 90°.

Listening positions "B" and "C" in Figure 1 will have approximately the same SRA limits as position "A", but Angular Distortion will however be slightly more pronounced. Realiable psychoacoustical information for listening positions "B" and "C" is unfortunately not, at present, available. However, if we consider that the SRA is approximately the same in each listening position (A, B and C), we can determine the combinations of Distance/Angle for microphone arrays covering 4 or 5 segments as well as for 6 segments.

It is evident from Figures 2, 3 and 4, that the Stereophonic Recording Angle of an individual segment of the microphone array, must be equal to the angle covered by that segment, which is necessarily the same as the angle between the microphones.

Stereophonic Recording Angle Diagrammes (Figures 5, 6 and 7) have been reproduced from Reference (1) with specific SRA values corresponding to segment angles of 4, 5 and 6 segment systems. Each diagramme is related to a specific microphone directivity:

Figure 5 for Cardioid Micophones
Figure 6 for Hypercardioid Microphones
Figure 7 for Hypocardioid Microphones

With this information, we can now determine the exact specification of a specific microphone array.

<u>Six Segment Array</u>

If we take as an example, a six segment array using cardioid microphones:

- the SRA will be +/- 30° (a total of 60°),

- the angle between the microphones must also be 60°.

The only possible combination of distance/angle that can be determined from Figure 5 that satifies this situation is 53cms/60°.

If Hypercardioid microphones (Figure 6) are used the combination distance/angle becomes 46cms/60°.

And for Hypocardiod microphones(Figure 7) - 61cms/60°

<u>Five Segment Array</u>

With the microphone array shown in Figure 3, the segment angle is 72°, the angle between the microphones being also 72°. The SRA must therefore be +/- 36°, giving the following combinations:

Hypercardioid microphones (Figure 6) - 31cms/72°
Cardioid microphones (Figure 5) - 39cms/72°
Hypocardioid microphones (Figure 7) - 48cms/72°

<u>Four Segment Array</u>

With the microphone array shown in Figure 4, the segment angle is 90°. The angle between the microphones is therefore 90° and the SRA is +/-45°. This gives the following combinations:

Hypercardioid microphones (Figure 6) - 11cms/90°
Cardioid microphones (Figure 5) - 25cms/90°
Hypocardioid microphones (Figure 7) - 35cms/90°

CROSSTALK AND MATRIXING.

In choosing Hypercardioid or Hypocardioid microphones care must be taken to choose back lobe values which do not interfer with the main front lobe pickup of the corresponding opposite pair. Back attenuation must be at least 8dB to be acceptable.

It would be an interesting extrapolation of this method to produce a COINCIDENT microphone array that satisfies the basic condition that the SRA of each segment should be equal to the the segment angle. This would facilitate all kinds of manipulation of the signal by matrixing, including, for instance interpolation between the segment signals to change the one to one microphone/loudspeaker relationship - the number of segments in the microphone array would not have to correspond to the number of segments in the loudspeaker array.

It is an unfortunate restriction to this type of system that coincident microphones with first order directivities, CANNOT satisfy the basic conditions for this type of microphone array. Use of microphones with hypercardioid directivity patterns and 3.7dB back attenuation (Figure 8) seem to satisfy the basic requirements (SRA = Segment Angle), unfortunately the crosstalk interference, created by the back lobes in relation the opposite segment front lobes, is unacceptable. A spaced microphone array is therefore the only viable solution, thus excluding all matrixing techniques.

However, in certain circumstances, the subjective quality of this type of spaced microphone array, producing natural multiphonic sound reproduction, is an advantage that should considerably outweigh the disadvantage of not being able to manipulate the signal by matrixing.

Conclusion:

It is to be hoped that futur research and development of surround sound for television will be able to use the multichannel audio facilty for productions using this type of natural multiphony.

References:

(1) M. WILLIAMS A.E.S. 82nd Convention, 1987, London, Preprint 2466(H6), "Unified Theory of Microphone Systems for Stereophonic Sound Recording".

FIGURE 1 - ISOCELES TRIANGLE LISTENING CONFIGURATION

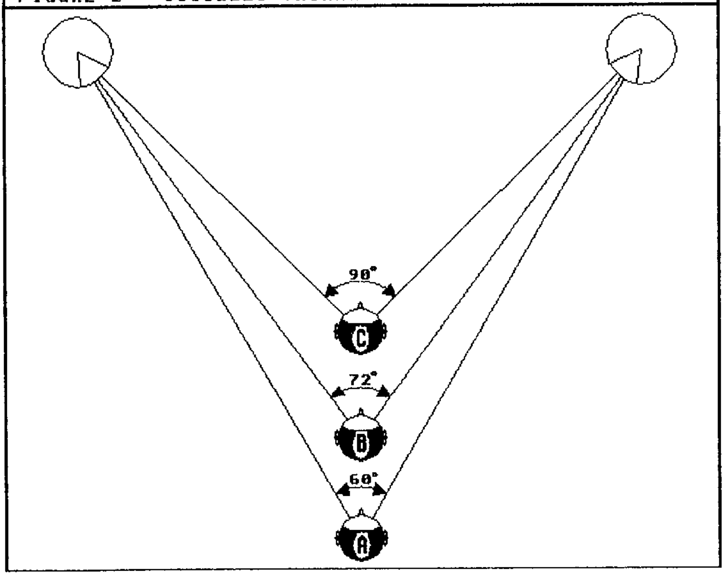


FIGURE 2 - SIX SEGMENTS of 60°

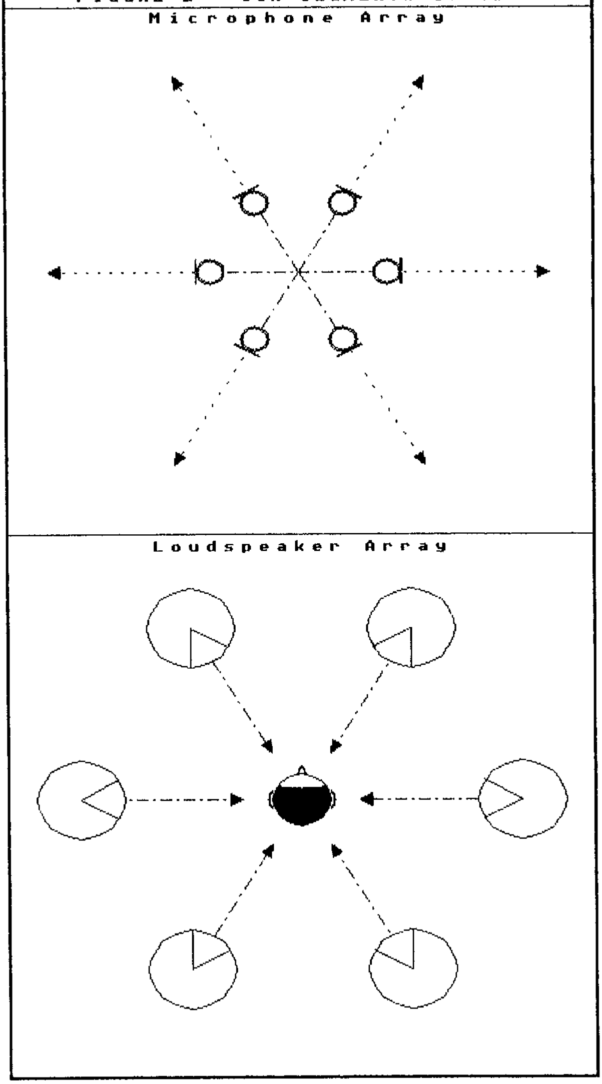


FIGURE 3 - FIVE SEGMENTS of 72°

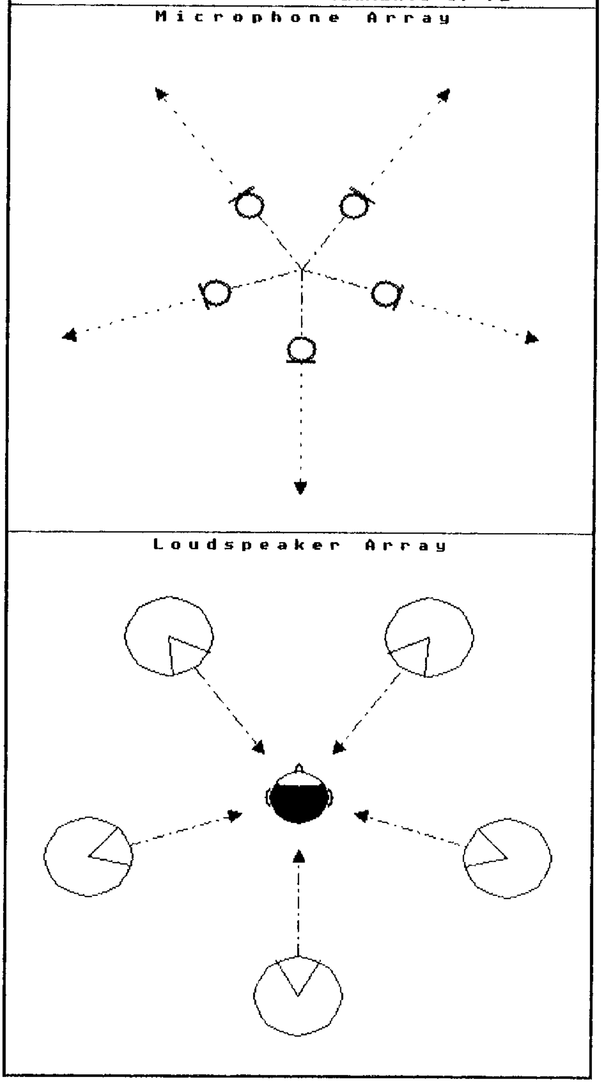
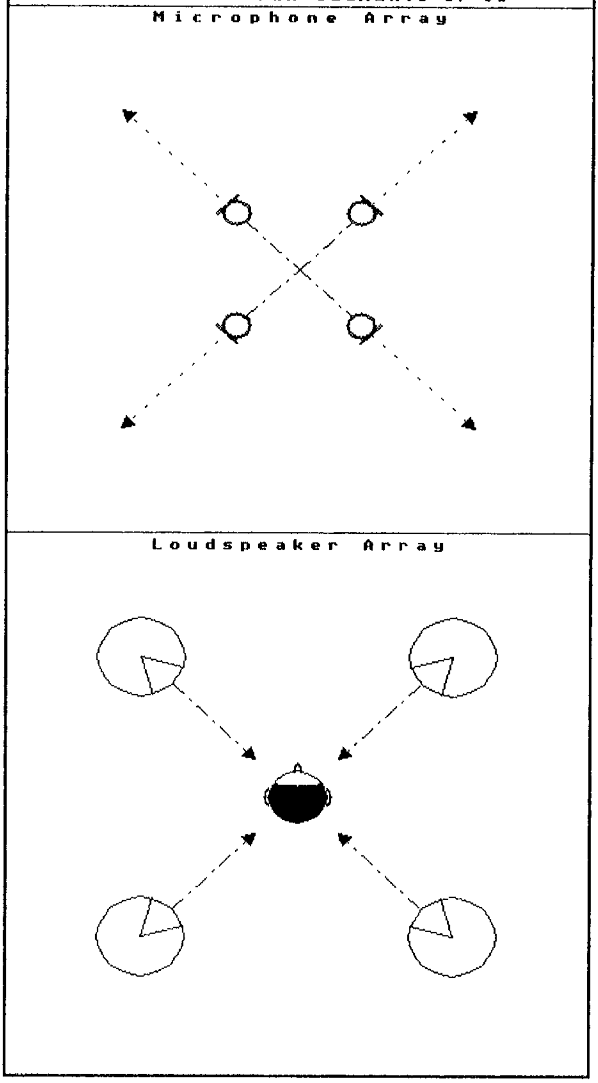


FIGURE 4 - FOUR SEGMENTS of 90°



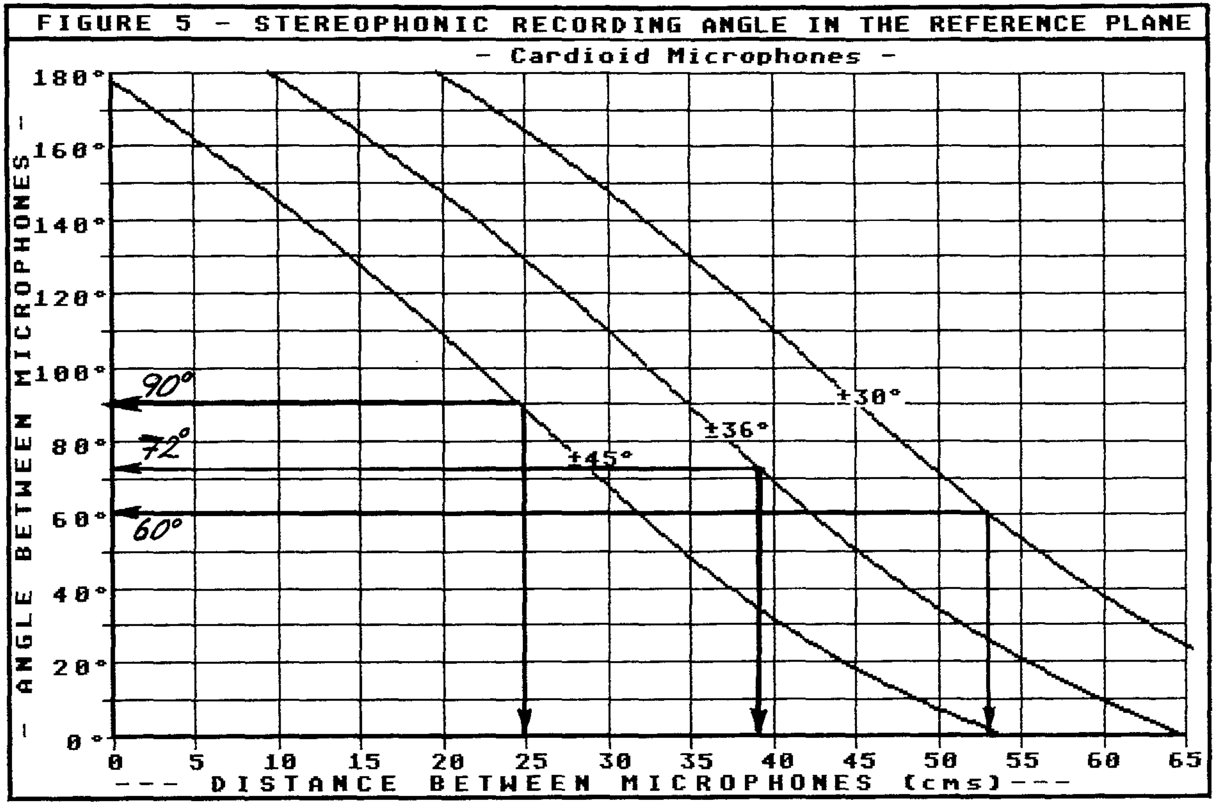


FIGURE 5 - STEREOPHONIC RECORDING ANGLE IN THE REFERENCE PLANE
- Cardioid Microphones -
ANGLE BETWEEN MICROPHONES
180°
160°
140°
120°
100°
80°
60°
40°
20°
0°
90°
72°
60°
±30°
±36°
±45°
0 5 10 15 20 25 30 35 40 45 50 55 60 65
--- DISTANCE BETWEEN MICROPHONES (cms)---

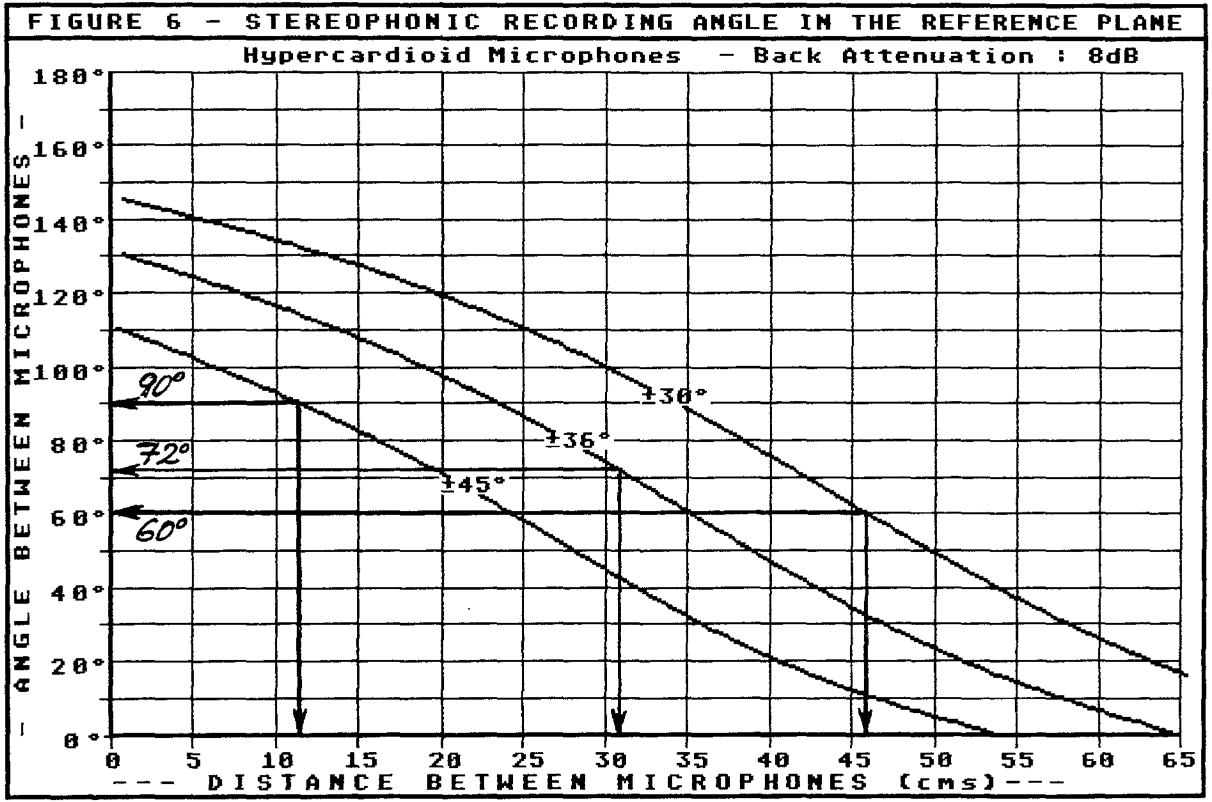


FIGURE 6 - STEREOPHONIC RECORDING ANGLE IN THE REFERENCE PLANE
Hypercardioid Microphones - Back Attenuation : 8dB
180°
160°
140°
120°
100°
80°
60°
40°
20°
0°
- ANGLE BETWEEN MICROPHONES -
90°
72°
60°
±30°
±36°
±45°
0
5
10
15
20
25
30
35
40
45
50
55
60
65
--- DISTANCE BETWEEN MICROPHONES (cms) ---

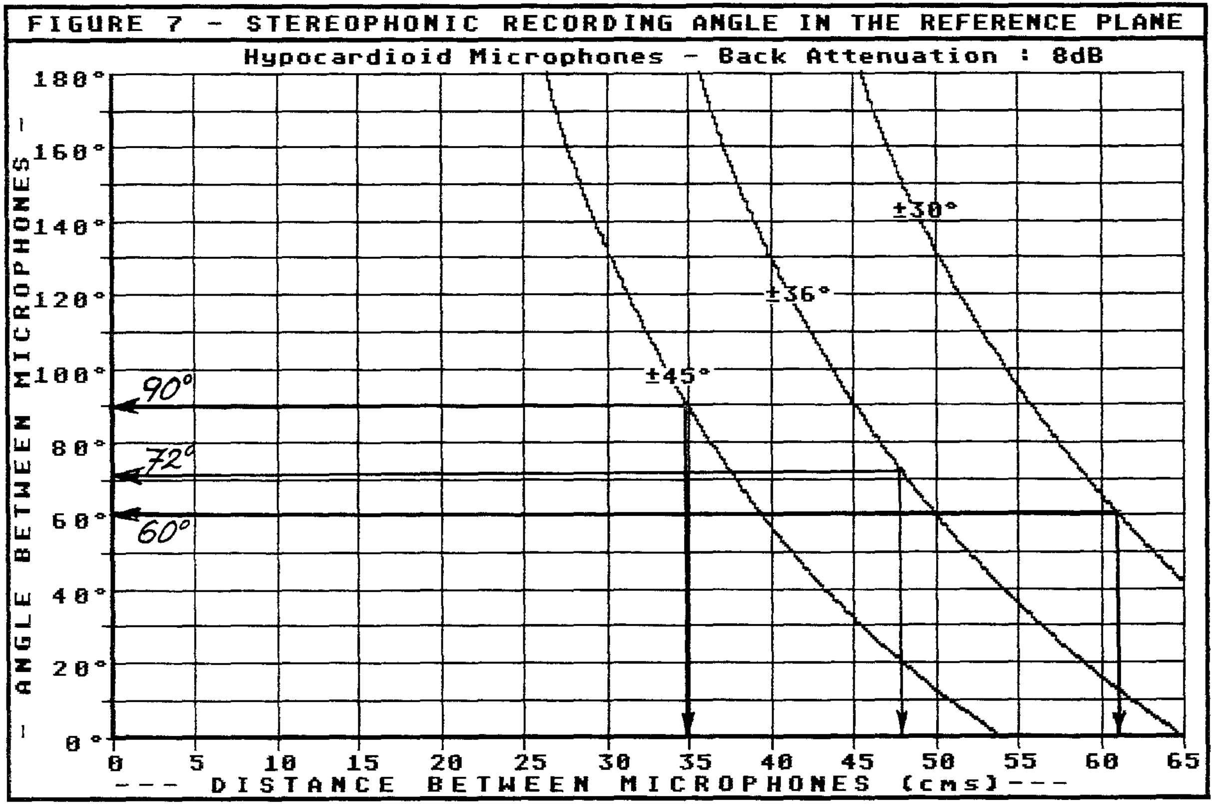


FIGURE 7 - STEREOPHONIC RECORDING ANGLE IN THE REFERENCE PLANE
Hypocardioid Microphones - Back Attenuation : 8dB
ANGLE BETWEEN MICROPHONES
180°
160°
140°
120°
100°
80°
60°
40°
20°
0°
±30°
±36°
±45°
90°
72°
60°
0
5
10
15
20
25
30
35
40
45
50
55
60
65
--- DISTANCE BETWEEN MICROPHONES (cms)---

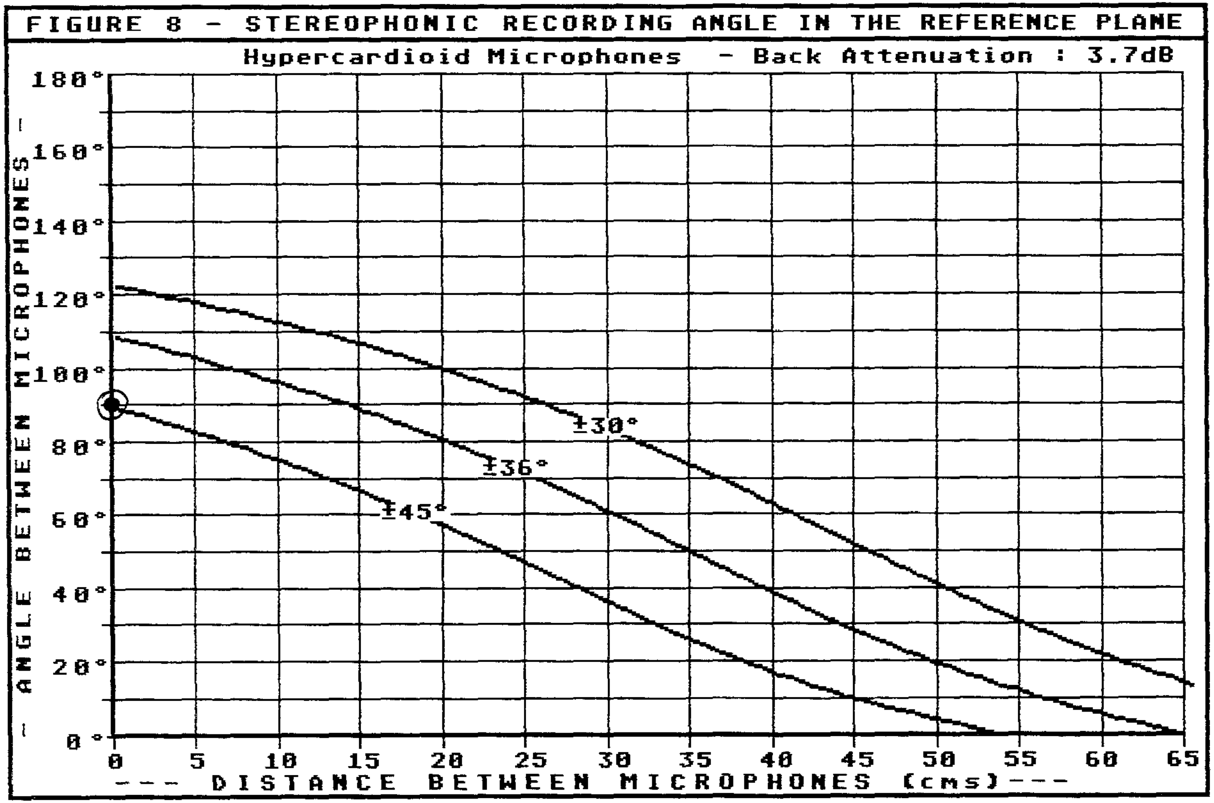


FIGURE 8 - STEREOPHONIC RECORDING ANGLE IN THE REFERENCE PLANE
Hypercardioid Microphones - Back Attenuation : 3.7dB
180°
160°
140°
120°
100°
80°
60°
40°
20°
0°
--- ANGLE BETWEEN MICROPHONES ---
±30°
±36°
±45°
0
5
10
15
20
25
30
35
40
45
50
55
60
65
--- DISTANCE BETWEEN MICROPHONES (cms) ---