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Operational Limits of the Variable M/S Stereophonic Microphone System

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VARIABLE M/S STEREOPHONIC MICROPHONE SYSTEM
by

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ABSTRACT

The Variable M/S stereophonic microphone system seems to be a neat solution to modifying the stereophonic recording angle, either during recording or in the post production process. This paper shows that angular distortion and the ratio of direct to reverberant sound can vary throughout the range of stereophonic recording angles created by different matrixing values, thus restricting considerably the operational range available.

INTRODUCTION

In 1987 at the AES Convention in London, I presented a paper(1) entitled "Unified Theory of Microphone Systems for Stereophonic Sound Recording". This paper described the basic characteristics of the microphone system and the reproduced stereophonic sound field, using various distances and angles between the microphone pair. The standard microphone directivities considered were omnidirectional, hypocardioïde, cardioïde, hypercardioïde and figure of eight.

Using coincident microphones (distance = 0) and various angles between the microphones, the Stereophonic Recording Angle and Maximum Angular Distortion can easily be determined from the graphs presented. However, the coincident microphone system called "M/S" was almost impossible to analyse with the information given.

The aim of this paper is to analyse the variable M/S microphone system using the same criteria as in my 1987 paper - showing the basic characteristics for any matrixing value, and to determine certain operational limits to the systems at present available.

TERMINOLOGY

1) Stereophonic Recording Angle (SRA)

There is an unfortunate confusion between my use of the term "Recording Angle" in the 1987 paper and the German definition of this term (Aufnahmebereich).

The German definition is derived purely from the physics of the microphone system and is defined as the angle between the centre axis of symetry (towards the front) and the direction where the Intensity Ration L/R is a maximum.

My use of this term is a combination of the physical characteristics of Time Difference/Intensity Difference AND the psychoacoustic characteristics of the standard listening configuration (Figure 1). I use the term "Recording Angle" to signify the sector of the sound field in front and to the right (+ve, clockwise) and to the left (-ve, anticlockwise) of the axis of the microphone system, which will produce a virtual sound image between the two loudspeakers. I now propose to call this sector of the sound field the "Stereophonic Recording Angle" in order, I hope, to avoid confusion.

It is interesting to note that the "Stereophonic Recording Angle" is inversely porportional to BOTH the distance and the angle between the microphones and is in general, smaller than the Recording Angle as defined in Germany and, in some cases, much smaller.

2) Maximum Angular Distortion

The term "Standard Deviation" was used in my 1987 paper to represent the geometric or angular distortion of the reproduced sound field. This term, although a good analogy with its nautical usage, has quite rightly been "shot down" by the mathematicians working in the field of statistics. I therefore propose to use the term "Maximum Angular Distortion" in its place.

Figure 2 and 3 will help to understand the significance of this term. The elements B and D of the sound field ABCDE (Figure 2), will be translated or compressed towards the extremities of the reproduced sound image (Figure 3). The difference between the linear reproduction of B and D at 15° in relation to the centre of the stereophonic reproduction base and the actual reproduced position is the numerical value called "Maximum Angular Distortion".

3) Reverberation Limits

The ratio of direct to reverberant sound should normally remain reasonably constant throughout the range of the Stereophonic Recording Angle. This is not however always the case. This ratio can in fact vary considerably with certain combinations of distance and/or angle between the microphones. There are two situations that can occur :

a) the ratio of direct to reverberant sound degenerates towards the extremities of the reproduced SRA,
b) the ratio is in fact worst in the middle of the reproduced SRA.

The reasons for this effect are clearly explained in my 1987 paper. These reverberation limits can be considered as the main operational limits to any variable stereophonic microphone system. However, with a good understanding of the effect, it can in certain situations be used to one's advantage.

VARIABLE M/S

The front facing microphone (M) can have almost any directivity characteristics desired, whilst the side facing microphone (S) is generally a bidirectional (figure of eight) directivity pattern.

The matrixing of the M & S signals produces the relevant left and right stereo channel information.

$$\text{Left} = M + S \qquad\qquad \text{Right} = M - S$$

Variable M/S matrixing modifies the proportion of the M to the S signal as follows :

$$\text{Left} = K.M + (1 - K).S \qquad \text{Right} = K.M - (1 - K).S$$

Coefficient K is less than 1 and greater than 0

If we now consider the standard (1st order) directivity patterns for the M signal, we can express its directivity by the following formula:

$$Cf + (1 - Cf).\cos(\theta)$$

θ is the incident sound angle
Coefficient Cf is less than 1 and greater than 0
(if Cf = 0.3 directivity is hypercardioïde
Cf = 0.5 directivity is cardioïde
Cf = 0.7 directivity is hypocardioïde)

After matrixing we obtain the following relationships :

$$\text{Left} = K.Cf + (1 - Cf).\cos(\theta) + (1 - K).\cos(\theta - 90^\circ)$$

$$\text{Right} = K.Cf + (1 - Cf).\cos(\theta) - (1 - K).\cos(\theta - 90^\circ)$$

It is a simple matter now to determine the Intensity Difference in decibels from the intensity ratio of the left to right signals :

$$\text{Intensity Difference (db)} = 20 \times \text{LOG}_{10}\left(\frac{\text{left}}{\text{right}}\right)$$

The psychoacoustical characteristics (figure 4) of the standard listening configuration have been determined with "natural" wide band sound sources by G. Simonsen (2). The intersection between the physical intensity difference and the psychoacoustical characteristics of reproduction enable us to determine the Stereophonic Recording Angle of each system under consideration, that is for each value of the coefficients K and Cf. Figure 5 is a graphical representation of SRA for various values of the matrixing coefficents (K) and the directivity coefficient (Cf).

ANGULAR DISTORTION

The psychoacoustical information given by G. Simonsen (2) include not only the outside limits of stereophonic reproduction, but also values of dI/dt for intermediate positions of localisation (10° & 20°) on the base line of the equilateral triangle formed by the listener and the loudspeakers. This enables us to determine the geometric linearity of the reproduced sound image, again by intersection of physical with psychoacoustical parameters. This information is shown in Figure 6 as numbers within boxes at relevant points on each curve. Detailed information concerning its calculation is again given in my 1987 paper.

REVERBERATION LIMITS

When both left and right directivities fall below an approximate limit of about - 2.5db in relation to the microphone axis response, the degeneration of the ratio of direct to reverberant sound becomes apparent. It is therefore possible to indicate by shading as in Figure 6, the areas where this effect become a problem.

OPERATIONAL LIMITS

We can now see clearly in Figure 6 the real pratical operational limits of any standard directivity variable M/S system. Values of matrixing below 0.5 to 0.6 (depending on M directivity) produce an unacceptable reverberation at the extremities of the S.R.A., whilst values above 0.75 produce unacceptable reverberation at the extremities of the S.R.A.

Geometric or angular linearity is also not constant throughout different values of K & Cf. If the M directivity tends towards hypocardioïde or omnidirectional, the angular distortion increases. Use of M directivities with lower values of Cf have of course the opposite effect - angular distortion being improved.

There is however another operational consideration which has to be taken into account. In general one can say that base response improves as the coefficent Cf increases (the directivity becomes more omnidirectional), but unfortunately angular distortion also increases. It is again a question of swings and roundabouts.

VARIABLE M/S STEREOPHONIC SHOTGUN SYSTEM

The use of the term Shotgun to describe this type of system is a misnomer, the interference tube is generally less than half the length of a standard shotgun microphone. The directivity pattern is in fact very near to a hypercardioïde directivity with Cf = 0.28; the back lobe being however slightly more attenuated.

Consequently the recording characteristics can be determined also from Figure 6 using Cf = 0.3 for various matrixing values.

The following table will help to determine the relationship between matrixing coefficients of M & S signals used in figures 5 & 6 and the "Recording Angle" and also to see the equivalent value of Stereophonic Recording Angle".

MATRIXING COEFFICIENTS		CARDIOIDE Cf = 0.5		HYPERCARDIOIDE Cf = 0.3	
M	S	R.A.	S.R.A.	R.A.	S.R.A.
0.9	0.1	155	145	106	102
0.8	0.2	127	109	94	86
0.7	0.3	98	79	80	77
0.6	0.4	73	56	64	51
0.5	0.5	53	39	49	37
0.4	0.6	37	32	35	26
0.3	0.7	24	18	24	17
0.2	0.8	14	10	14	10
0.1	0.9	2	5	2	5

CONCLUSION

There are a considerable number of parameters that can be varied by the sound engineer to improve gradually the quality of the sound image, but by critical listening alone it is almost impossible to have a clear idea of the variation of each of these parameters.

The matrixing technique, used in the variable M/S stereophonic microphone system, produces a series of virtuel microphone directivity patterns and microphone orientations, that are generally difficult to interpret in operational terms.

It has been shown that Angular Distortion becomes quite pronounced in parts of the variable matrixing range and also that the ratio of direct to reverberant sound can be a severe limitation to the range of stereophonic recording angles available.

In the process of matrixing, the adjustement of this type of system must be made with full knowledge of the variation of the various stereophonic parameters. I hope that this paper will help the sound recording engineer to use the Variable M/S Stereophonic Microphone Systemto to better advantage.

References:

(1) M. WILLIAMS, A.E.S. Convention 1987, London, preprint 2466(H-6), "Unified Theory of Micropnone Systems for Stereophonic Sound Recording".

(2) G. SIMONSEN, Master's Thesis, October 1984, Lyngby, Denmark.

FIGURE 1 - STANDARD LISTENING CONFIGURATION

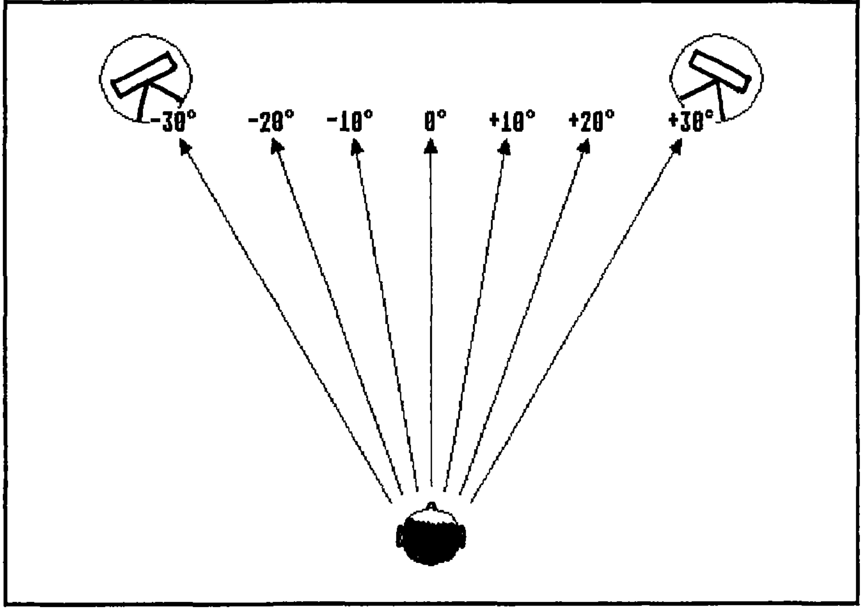

FIGURE 2 - SOUND SOURCE

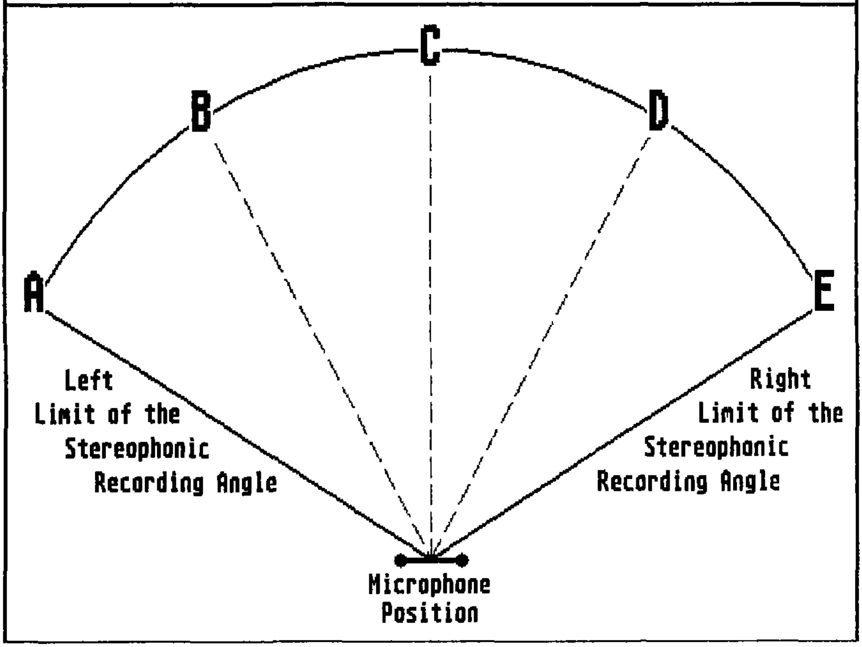

FIGURE 3 - REPRODUCTION WITH ANGULAR DISTORTION

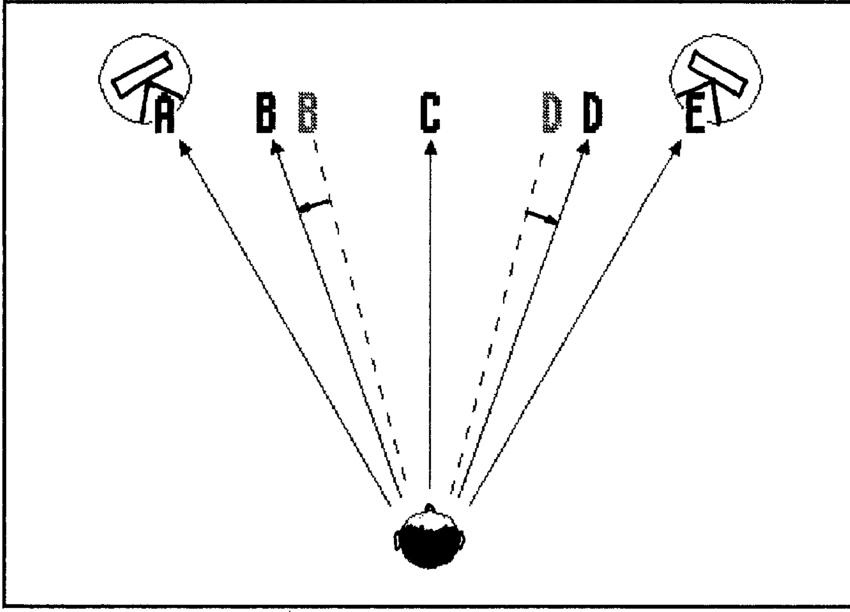

FIG 4 - PSYCHOACOUSTIC CHARACTERISTICS OF STEREOPHONIC LOCALISATION

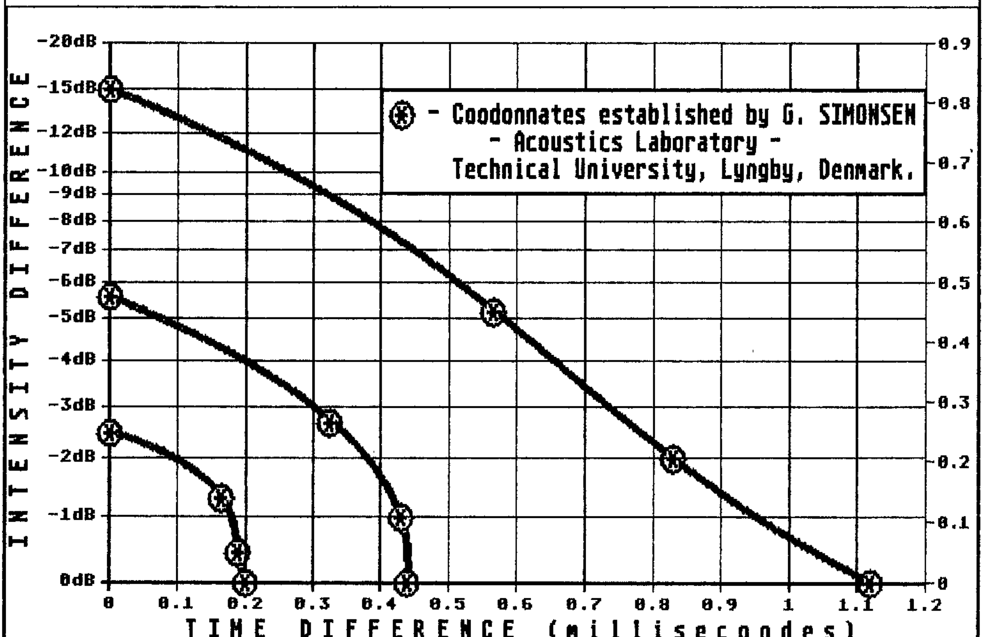

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FIGURE 5

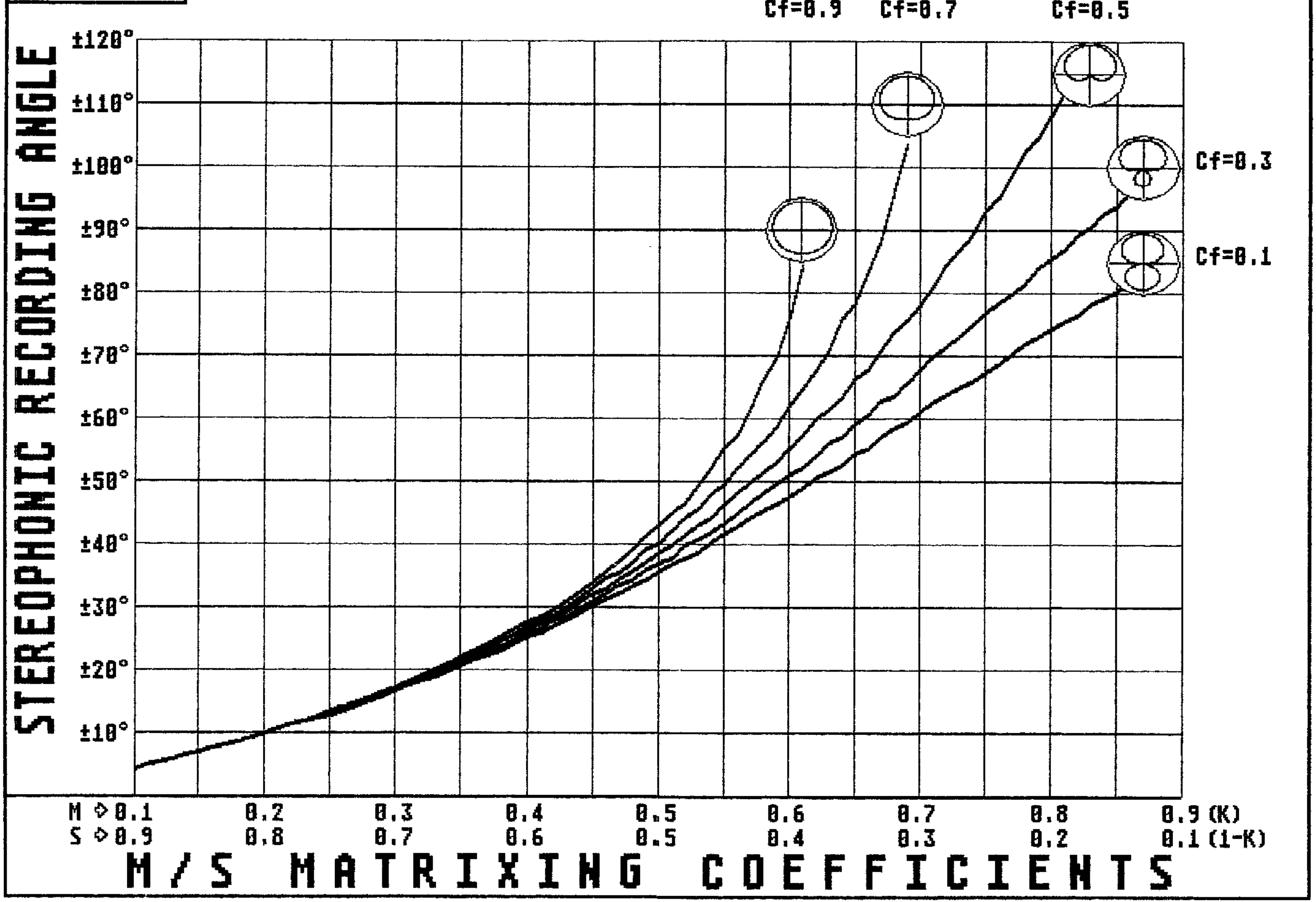
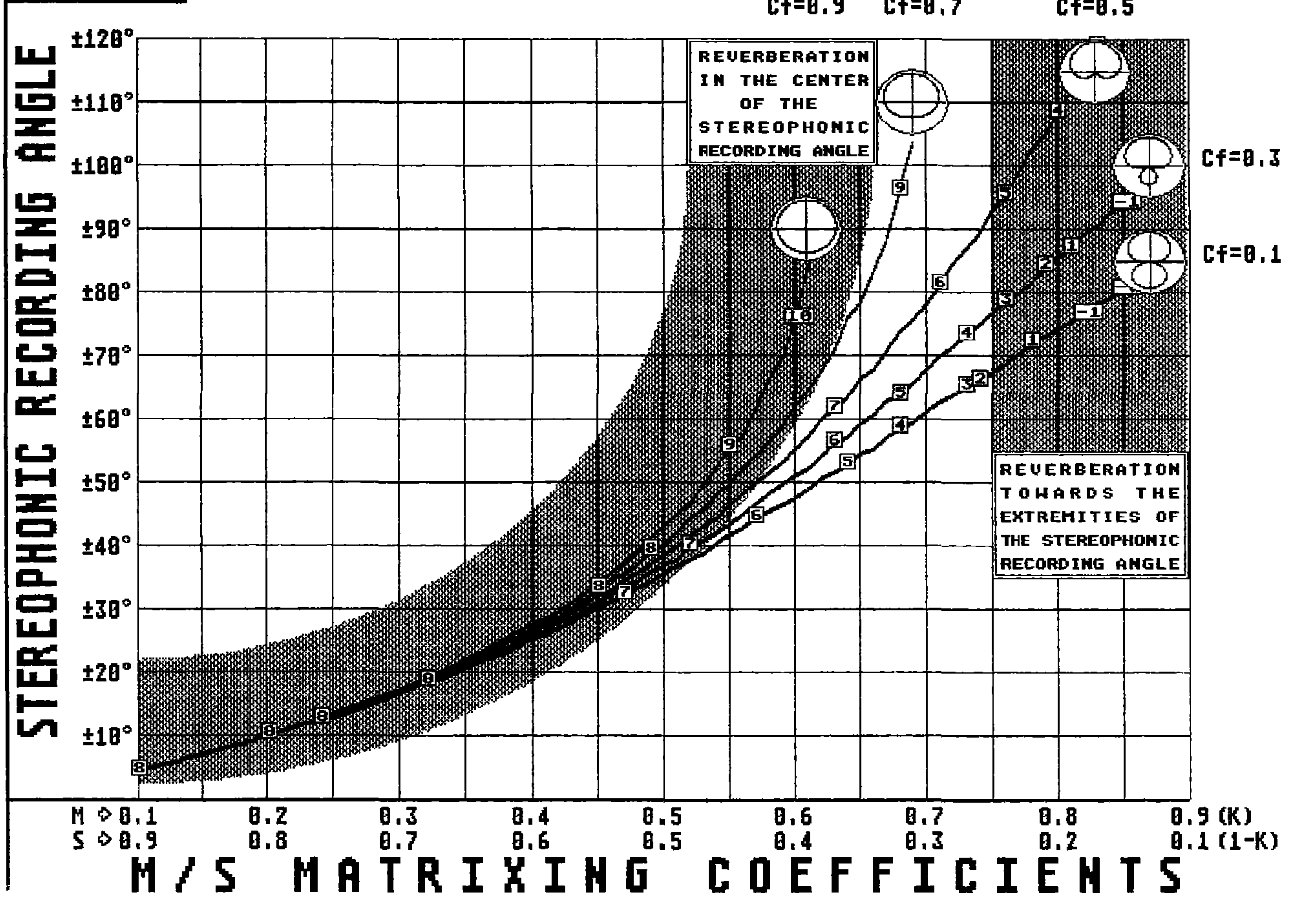

STEREOPHONIC RECORDING ANGLE
Cf=0.9
Cf=0.7
Cf=0.5
Cf=0.3
Cf=0.1
±120°
±110°
±100°
±90°
±80°
±70°
±60°
±50°
±40°
±30°
±20°
±10°
M ⇨ 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 (K)
S ⇨ 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 (1-K)
M/S MATRIXING COEFFICIENTS

FIGURE 6



STEREOPHONIC RECORDING ANGLE
±120°
±110°
±100°
±90°
±80°
±70°
±60°
±50°
±40°
±30°
±20°
±10°
Cf=0.9
Cf=0.7
Cf=0.5
Cf=0.3
Cf=0.1
REVERBERATION IN THE CENTER OF THE STEREOPHONIC RECORDING ANGLE
REVERBERATION TOWARDS THE EXTREMITIES OF THE STEREOPHONIC RECORDING ANGLE
M ⇨ 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 (K)
S ⇨ 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 (1-K)
M/S MATRIXING COEFFICIENTS