TESTS FOR FM TRANSMITTERS

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I GENERAL INTRODUCTION TO STEREO

1. The Meaning of Stereo

Stereo reproduction has significant properties than mono reproduction, such as ambience, extensity, positionality and movement of sound, and can be defined in straightforward terms as a medium through which a spatial sound field can be created.

The main points of this definition can be classified into "the extensity of sound" and "the directionality of sound".

Approaching the matter from the viewpoint of process of sound mixing, we face with a number of questions: should we deal with the sound-source as a sound point; should we treat the extensity as a measure of wave-surface containing reverberation. We consider that an appropriate combination of these factors will be the key to stereo sound pickup.

If we review current trends in stereo recording, we find that there is a tendency of giving too much stress to the positionality of sound, and there is a general belief that stereo can be obtained just by emphasizng this feature. However, it is considered that in stereo, emphasis of extensity is of importance than stress of positionality, in means of quality and value.

2. Effect of Sound on Both Ears

The basic concept of stereo reproduction is derived from the effect of sound on both ears. Just like the effect

of seeing by both eyes, the two ears can discriminate, although roughly, the spatial arrival direction of the sound-waves, near and far of the sound source and other factors.

2-1 Special Effect of Sound on Both Ears

When a person uses both ears for listening, the faculty of hearing is enhanced than when using only one ear.

2-2 Perception of Distance

A person cannot perceive distances in great accuracy, but can perceive things near him quite accurately.

2-3 Perception of Direction

The ability of a person to perceive something in a vertical direction is totally unreliable, compared with the ability to perceive something in a horizontal direction.

The perception of sound in a horizontal direction is judged by the difference in sound pressure, the difference in time and phase of the sound reaching the left and right ear from an ordinary sound-source. It is also judged by the diffence in tone-color caused by the diffraction effect of the head.

2-4 Effect of Sound on Both Ears and Time Difference (Fig. 1)

In considering the difference in arrival time of a sound-source of plane-wave, to reach both ears, the difference in time for a sound-source stationed in front will be zero and increase as it is shifted towards bothsides.

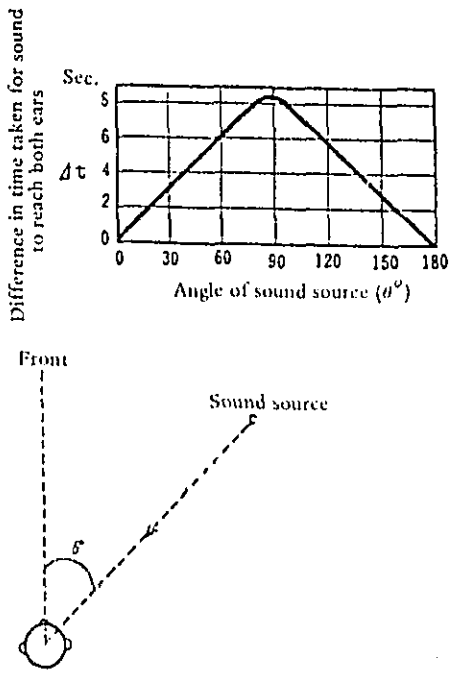


Figure 1 Relationship between direction of sound-source to both ears and difference in arrival time.

2-5 Difference in Sound Pressure and its Effect on Both Ears (Fig. 2, Fig. 3)

The difference in sound pressure between both ears varies greatly according to the direction of the sound waves and frequency, due to the diffraction effect around the head.

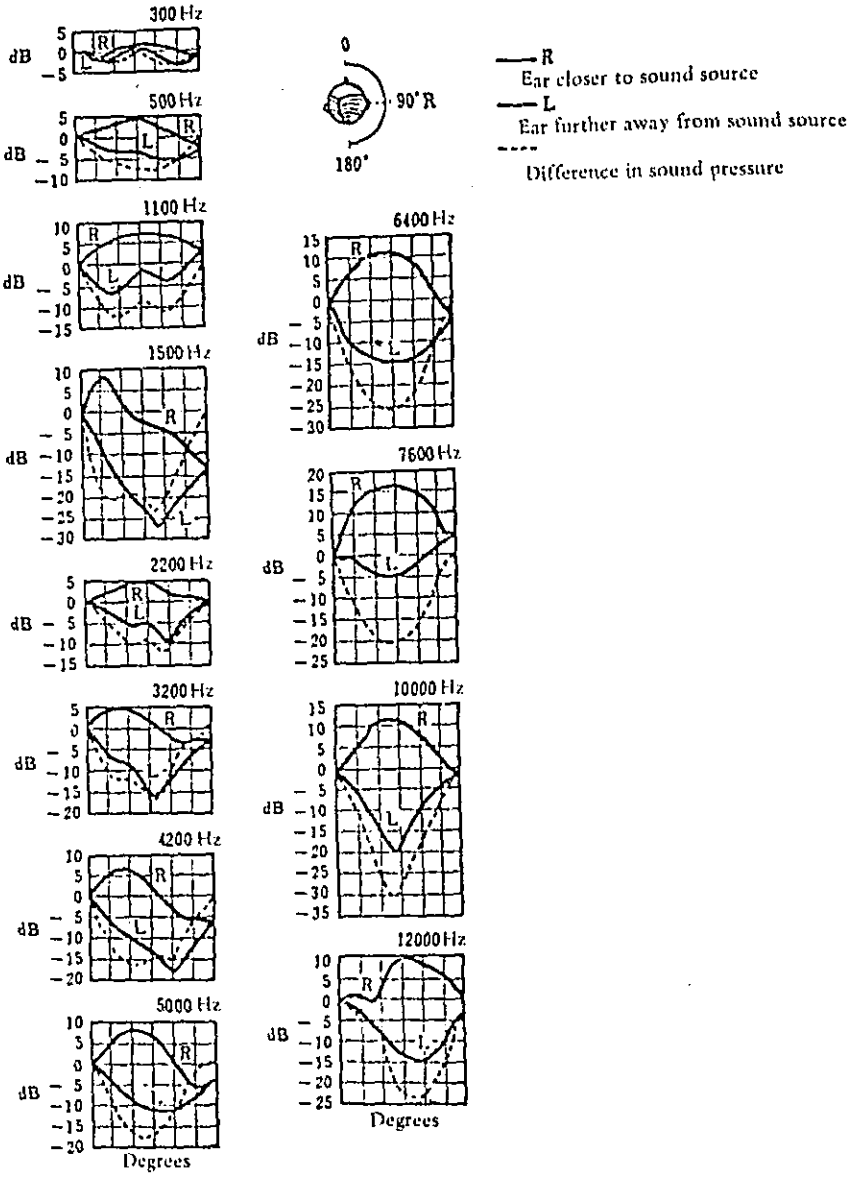


Figure 2 Difference in sound pressure of sine-wave on both ears in horizontal direction

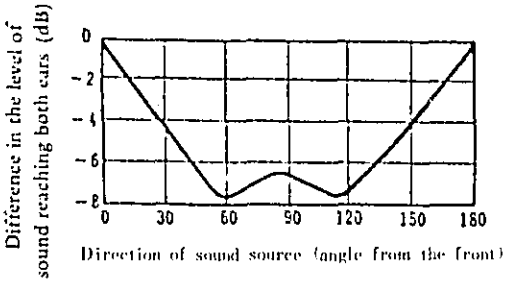


Figure 3 Difference in sound pressure on both ears in direction of person talking

2-6 Accuracy of Directionality and its Effect on Both Ears (Fig. 4, Fig. 5)

When the sound-source is positioned in front, the perception of direction is most accurate. However, the ability deteriorates as the source is moved sideways and it also varies according to frequencies.

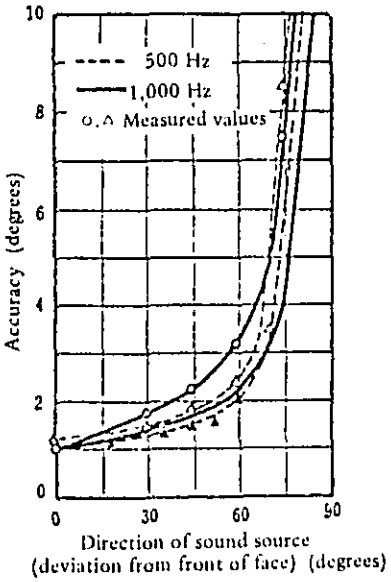


Figure 4 Accuracy in perception of sound positioned in a horizontal direction

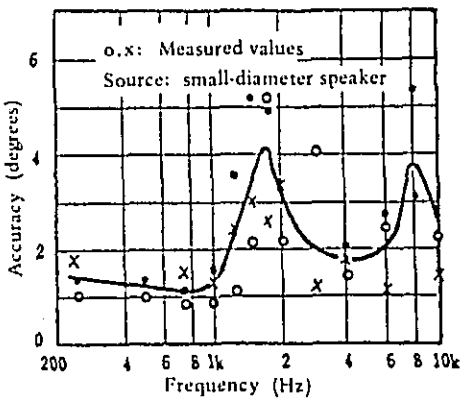


Figure 5 Accuracy in perception of sound positioned in a horizontal direction

3. Natural Sound Field and Stereo Sound Field (Fig. 6)

The sound wave in a natural sound field proceeds to the direction of the listener, describing a curve, and passes through from the right ear to the left ear in a transient state. The direction of the wave surfaces at the ears are not related to the frequency of the sound-source, but determined by the position of the sound-source.

On the other hand, in a stereo sound field where the sound is produced by two speakers, phase difference will occur if there is any time difference in the compound wave surface at the listening position, due to wave-length shift, and phase rotation will occur in accodance to the sound-source frequency.

What sets stereo reproduction apart from all other forms of reproduction is the fact that the direction of the sound changes according to the variation of the sound-source frequency, and the direction of the compound surface-waves is a function of frequency.

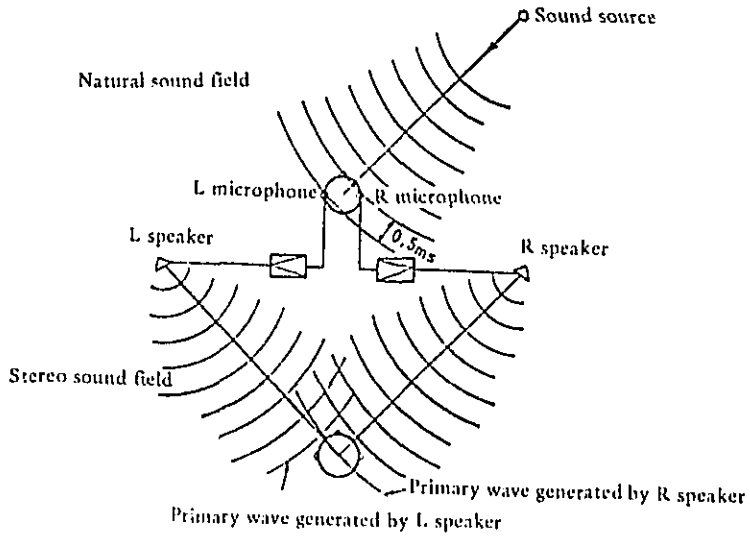
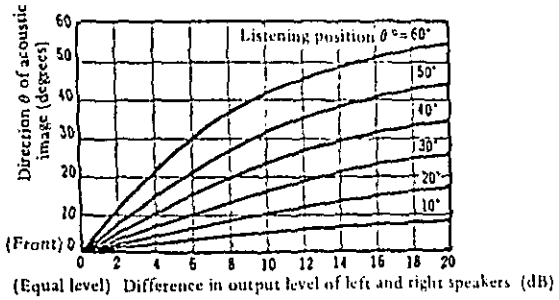


Figure 6 Natural sound field and stereo sound field

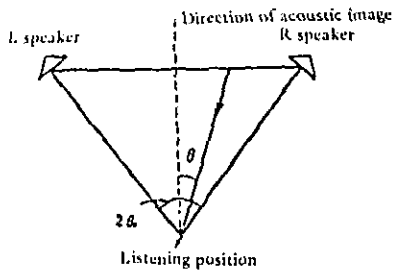
4. Parameters in Stereo Transmission

4-1 Problems Related to Level Difference in Stereo Transmission (Fig. 7 a, b)

The position (directionality) of an acoustic image can be moved freely by varying the output level of the left and right speakers, and in addition, the angle at which this acoustic image will be expected, differs to the listening position.



(a) Difference in output level of left and right speakers



(b) Direction of acoustic image

Figure 7

4-2 Problems related to Phase Difference in Stereo Transmission (Fig. 8, Fig. 9, Fig. 10)

If there is any phase difference, the difference in the output level of the left and right speakers as well as the direction of the acoustic image will markedly change if the phase difference changes. This is true even if the difference in the output level is fixed.

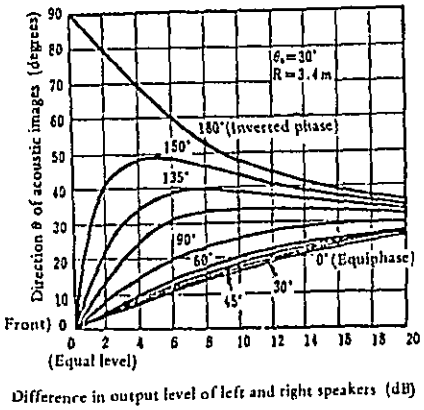


Figure 8 Relationship between difference in the output level of left and right speaker and variation of acoustic image direction, according to phase difference

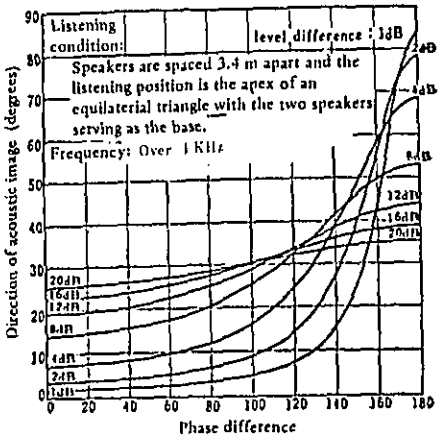


Figure 9 Relationship between phase difference and variation of acoustic image direction, according to level difference

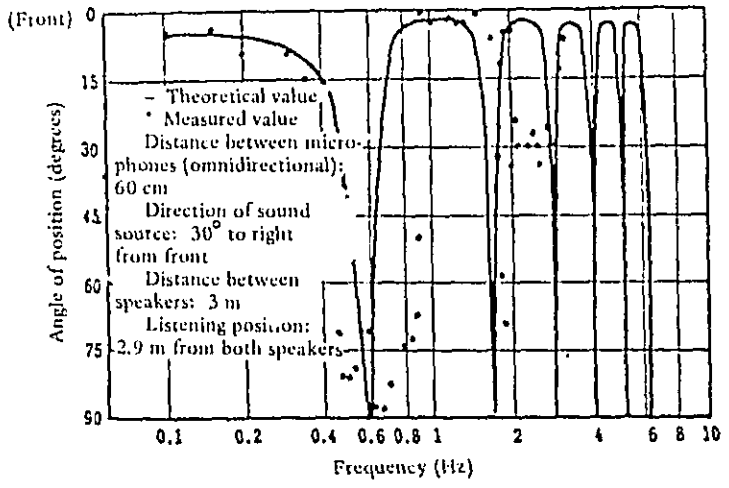


Figure 10 The direction-position varies in accordance with the sound-source frequency

There is little effect on the direction of the acoustic image when the phase difference is minimal. However, when this phase difference increases, the direction of the reproduced compound wave becomes a function of the frequency, and the direction changes in accordance with the frequency of the sound-source.

4-3 Problems related to Time Difference in Stereo Transmission (Fig. 11, Fig. 12)

It is extremely difficult to theoretically study the relationship between the difference of the sound arrival time and the direction of the acoustic image.

Especially with speaker reproduction, if there is time difference, phase difference will occur and the problem is still not resolved. Nevertheless, it is known that the transient condition of sound caused by direction of sound and difference in arrival time has a considerable effect.

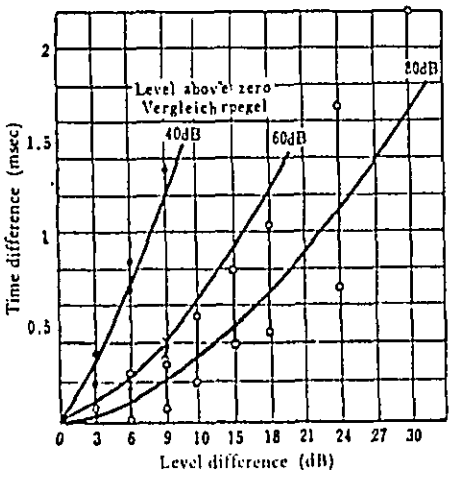


Figure 11 Equivalent relationship between the time difference and level difference perceived by human ear at various listening levels (using a click-equipped receiver)

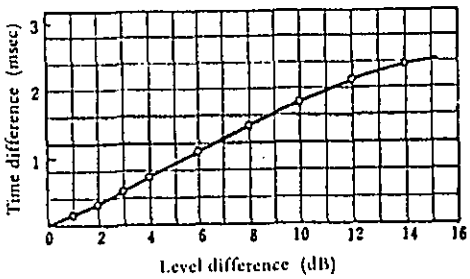


Figure 12 Equivalent relationship between the time difference and level difference of speech listened at apex of equilateral triangle with speakers set 3.5 m apart (using human voice)

II STEREO SOUND COLLECTION

1. "Extensity" and "Positionality"

In a natural sound field, the sound from the sound source heard at the listening position can be divided into "direct sound" and "reverberated sound".

In contrast to direct sound the reverberated sound is accompanied by a time-difference and phase-difference, and this sound evokes us the feeling of extensity and richness of the original sound field.

The effects of a stereo sound field are roughly divided into "extensity" and "positionality". If we remember that the level difference is of great significance to "positionality" and that time difference and phase difference are of great significance to "extensity", it then becomes a somewhat easy task to draw up a mixing plan and to understand what a stereo sound field is all about.

2. Methods of Stereo Sound Collection

There are many basic methods of sound collection, but they can be divided into the level/phase difference method, level-difference method and the branching method, according to the position of microphones and properties of left and right signals transmitted to the speakers. These methods can be further sub-divided according to the directionality of microphones and angle of directionality.

In normal circumstances, these methods are combined according to the acoustics of studios and the contents of programs.

2-1 Level/phase Difference Method (Fig. 13, Fig. 14)

This method of sound collection is sometimes known as the dual microphone method, but basically it stems from the idea of obtaining a sound effect on both ears using a dummy head which substitutes for the two microphones.

Normally, two unidirectional microphones with identical specifications are used at a distance. "Level difference" and "time difference" are produced by the difference in the relative distance between the two microphones, and also by the difference between the microphones' directionality. In addition, "phase difference" is produced by the "time difference".

There is also another method involving a pair of identical microphones for when the microphones are spaced far apart. Another microphone is stationed between the two to compensate for the weak acoustic image distibution in the center (hole-in-the-center effect),

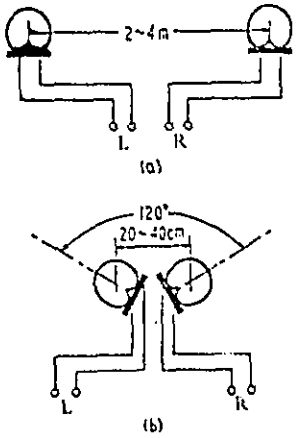


Figure 13 Level/phase difference method

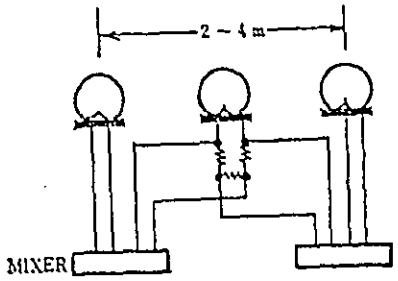


Figure 14 Three-channel method

and the sound is branched off to the two channels at the same level. This is commonly called the "three-channel method".

2-2 Branching Method (Fig. 15)

With this method of sound collection, a single directional microphone is employed instead of two identical microphones, and its output is branched to provide a suitable level difference between the two channels to obtain positionality.

This method is quite different from the basic concept of stereo reproduction whereby the acoustic image is naturally distributed over the whole sound field area between the two speakers.

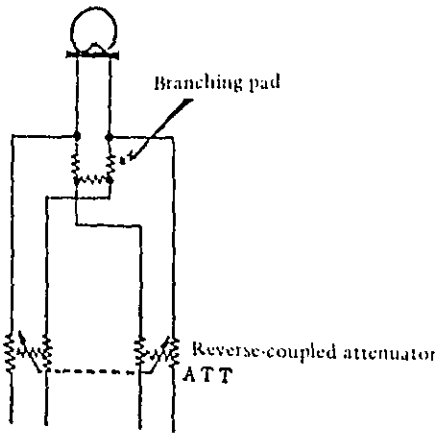
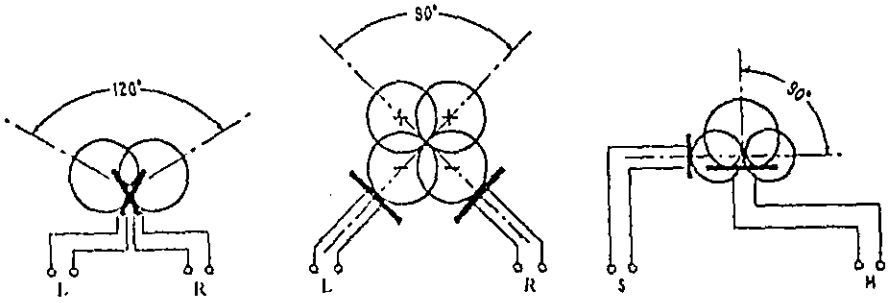


Figure 15 Branching method

2-3 Level Difference Method (Fig. 16 a, b, c)

This method of sound collection can be divided into the MS system and the XY system. Basically, however, it is a method of placing the distance between two microphones along the same axis.

With this method, as there is no difference in distance between the left and right microphone and the sound-source, there is no difference in sound pressure and time difference of the arrival sound. In other words, there is only a difference in level caused by difference of directionality of the microphone between the left and right signal sources. There exists no phase difference.



(a) X - Y system (b) (c) M - S system

Figure 16 Level difference method

With the MS system, the "M" stands for "middle" and the "S" for "side". The "M" denotes the main signal, and the "S" the direction signal. By passing the output of both signals through a sum and difference control circuit, the left (L) and right (R) signals can be obtained.

Normally, a unidirectional microphone and a bidirectional microphone are positioned so that the direction of their axis is mutually at right angles. (Fig. 17, Fig. 18)

This system is characterized by the fact that the side microphone gain varies the directionality pattern and the maximum sensitivity direction of the combined (M + S) and (M - S).

On the other hand, with the XY system, it is necessary to vary the relative angles of the microphones themselves in order to change the positionality of the acoustic image and extensity. This contrasts with the MS system whereby it is easy to adjust the width of the acoustic image and extensity electrically. (Fig. 19, Fig. 20)

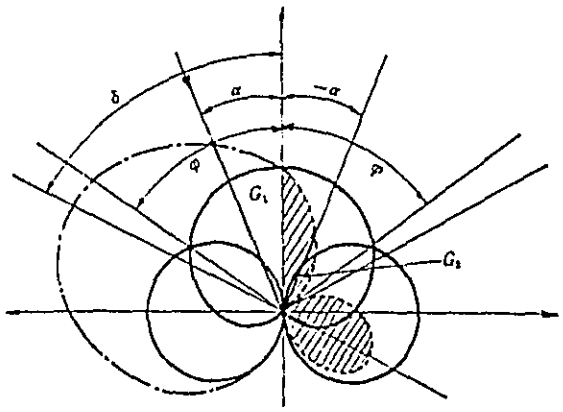


Figure 17 This figure is a vector diagram with respect to the left direction α° incidence angle under the MS system. The distribution after the signals passing through the sum and difference control circuit is represented by the dot-and-dash line for the left channel output and with the dotted lines for the right channel output.

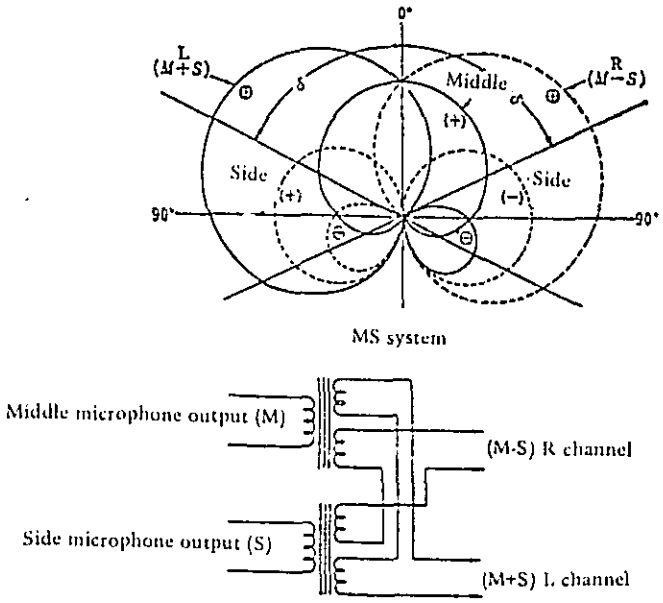


Figure 18 Sum and difference circuit for M and S microphone output signals

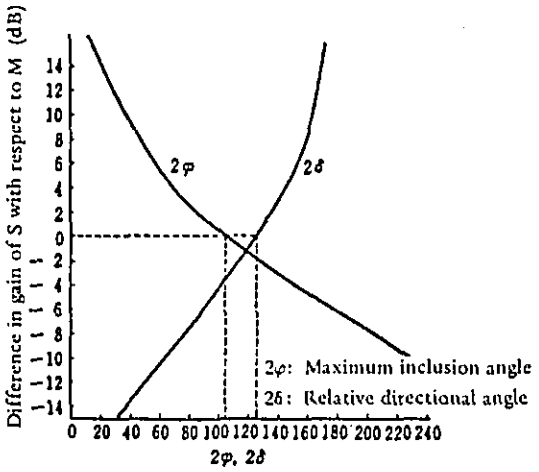
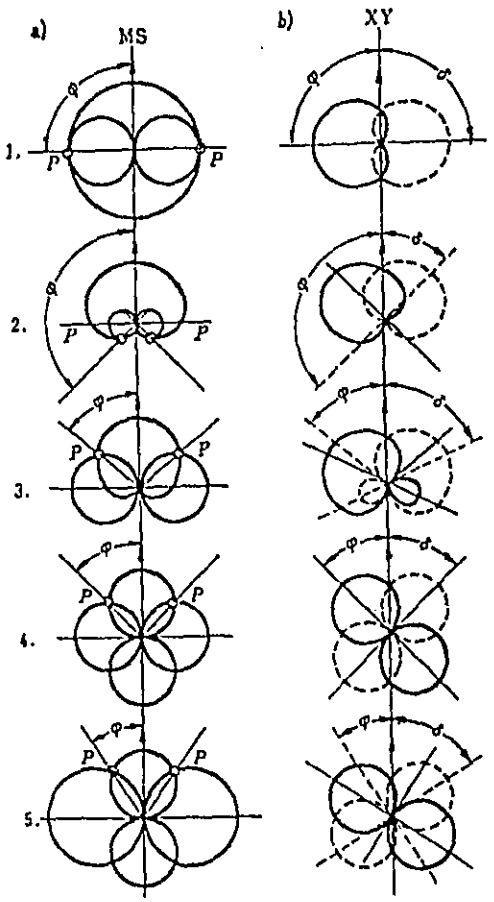


Figure 19 Relationship between maximum inclusion angle and relative directional angle of hypothetical microphone when the difference in the sensitivity of middle and side microphones is varied.



2δ: Relative directioned Angle

2φ: Inclusion angle

Figure 20 Relationship between MS system and XY system

3. Stereo Effects of Sound Collection Method

There is no general concept existing in effects of stereo reproduction, but what may be considered as common is the directionality, extensity, separation and sound volume.

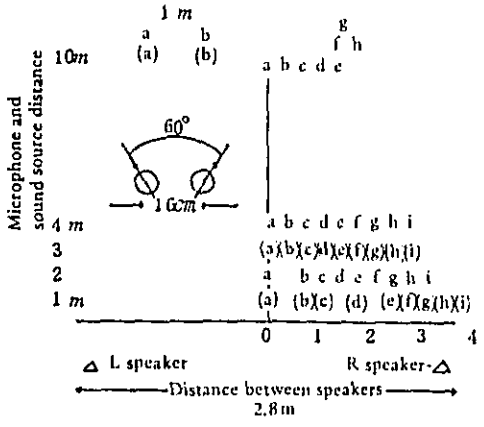


Figure 21 Speaker sound field distribution using two identical microphones (microphones are set 16 cm apart at a mutual angle of 60°)

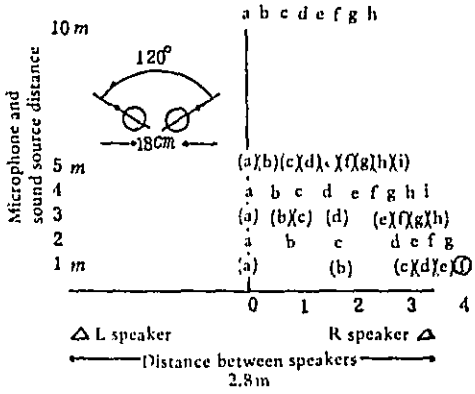


Figure 22 Speaker sound field distribution using two identical microphones (microphones are set 18 cm apart at a mutual angle of 120°)

3-1 Stereo Effects of the Level/phase Difference Method (Fig. 21, Fig. 22, Fig. 23)

This particular method is characterized by its effectiveness in providing a superior sense of extensity, a rich tone color and feeling of the dynamic.

When the microphones are placed close together, the time difference and the phase difference have very little effect. The positionality is clear but the extensity is lacking. Conversely, if the microphones are placed far apart, there is a good feeling of extensity but the positionality is unclear.

The drawback of this system is the effect of time difference and phase difference. With pure sound the positionality will vary, according to the direction and frequency of the sound-source. (Fig. 24)

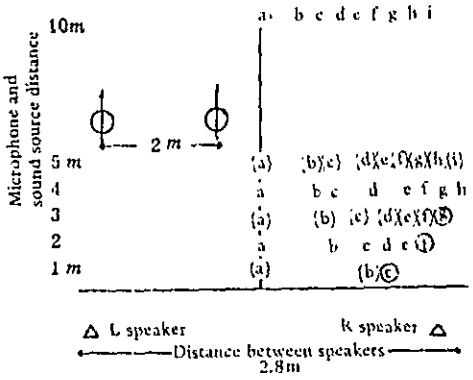


Figure 23 Speaker sound field distribution using two identical microphones (microphones are set 2 m apart at a mutual angle of 0°)

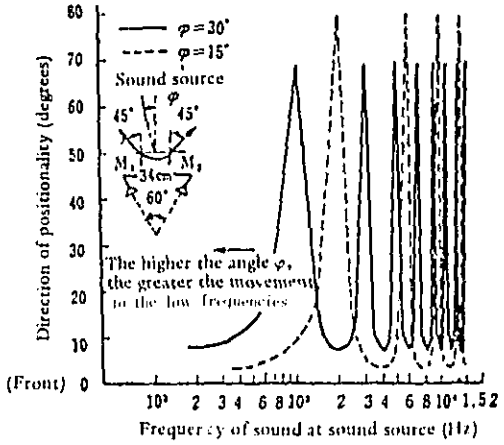


Figure 24 Fluctuations in positionality with two identical microphones

3-2 Stereo Effects of the Branching Method (Fig. 25)

The branching system features excellent separation and sharp direction positionality. However, the reproduced acoustic image is not distributed and it becomes positioned as a sound point in line with the difference in the left and right levels.

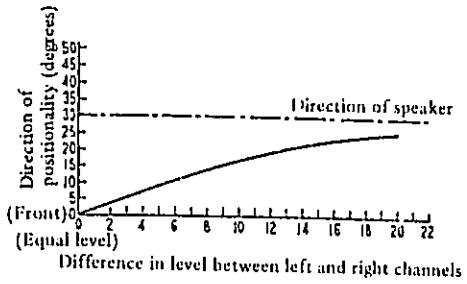


Figure 25 Relationship between the difference in level between the left and right channels, and the direction of the sound positionality

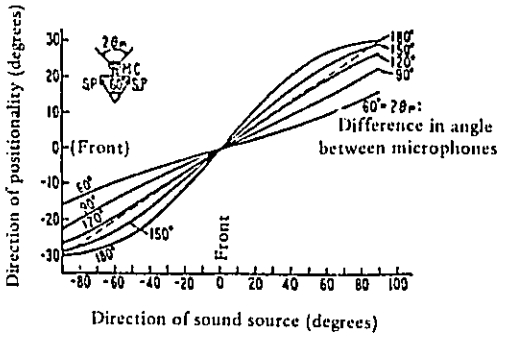


Figure 26 Relationship between the sound source direction and the direction of the sound positionality when sound is collected with two unidirectional microphones positioned along the same axis

The acoustic images can be freely arranged in order if the level difference is varied, and they do not move even if the sound source is moved.

However, if there is a great deal of interference between the microphones, numerous interference signals with level difference and phase difference will affect the main signal, and as the reproduced acoustic image properties and tone color will very, the sound source is usually set apart so as not to cause any interference.

3-3 Stereo Effects of the Level Difference Method (Fig. 26, Fig. 27)

This method is characterized by the fact that an acoustic image, faithful to the direction positionality of the original sound source can be aligned.

The direction of the acoustic images will be only positioned in line with the level difference produced by the difference in microphone directionality with respect to sound source, and will have no relation to the frequency.

Furthermore, as there is no time difference, there will be no phenomena occuring such as in the level/phase difference method.

In other words, even if the sound source is a compound sound, the rendered indistinct.

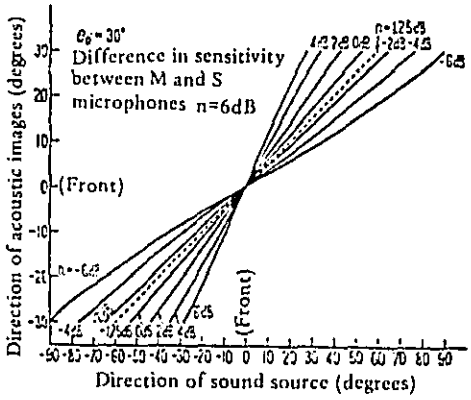


Figure 27 Relationship between direction of sound and positionality in direction of sound-source under MS system

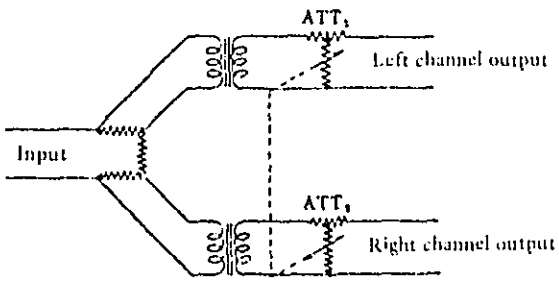
III SPECIAL DEVICES FOR STEREO APPLICATIONS

1. Pan-Pot Circuit (Fig. 28, Fig. 29)

Pan-Pot is an abbreviation for panometeric potentiometer and it is a circuit to produces artificially movement and positionality on a sound stage composed of two speakers.

In this circuit, two attenuators are coupled in reverse to vary the difference in the relative level between the left and right channels.

The attenuation curves is chosen so that a constant loudness will be perceived on the sound stage during operation.



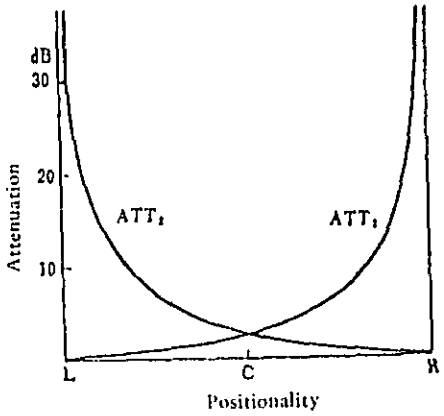


Figure 28 Pan-Pot circuit

Figure 29 Pan-Pot attenuation curve

2. Cross-mixing Circuit (Fig. 30)

This circuit is to adjust the amplitude of the extensity by increasing and decreasing the amount of crosstalk between the two channels.

The pan-pot attenuation curve can be applied to show the relationship between the amplitude of the extensity and the amount of crosstalk.

3. Sum and Difference Control Circuit (Fig. 31)

Attenuators are inserted between the two sum and difference control circuits, and the L and R signals are converted into M and S signals. By varying the ratio of M, S signals, the amplitude of the extensity is adjusted.

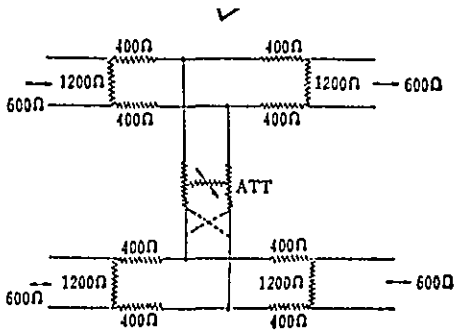


Figure 30 Cross-mixing circuit

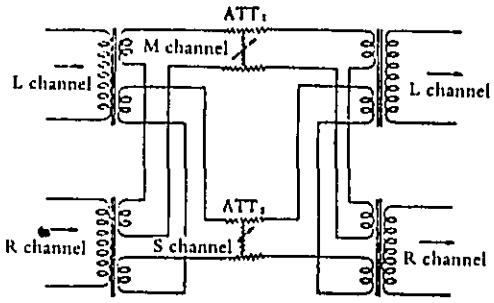


Figure 31 Sum and difference control circuit

4. Stereophonic Fading Circuit (Fib. 32, Fig. 33)

To obtain stereo fade-in effect, it is necessary to synchronize the amplitude of the extensity with the increase or decrease of volume.

This is to accomplish the so-called zoom effect as the amplitude of the extensity gradually increases along with

the increase of the acoustic images volume, it will fill the whole sound stage at maximum volume.

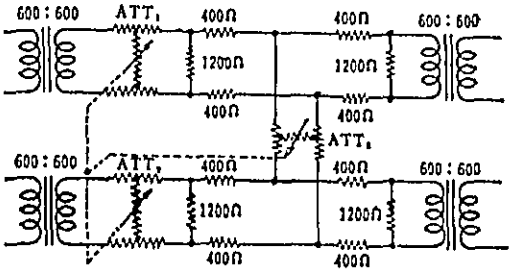


Figure 32 Stereophonic fading circuit

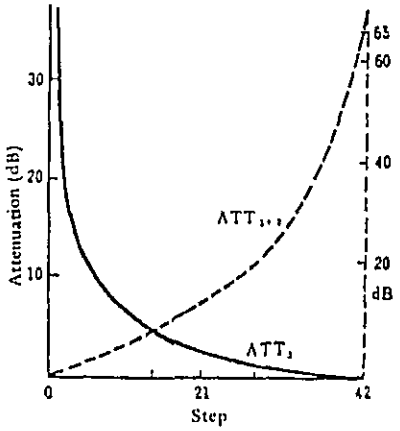


Figure 33 Attenuation curves of stereophonic fading circuit

5. Over Cross Changing Circuit (Fig. 34)

This circuit is designed to convert the positionality on the sound stage through 180 degrees, and it is used for changeover of drama scenes.

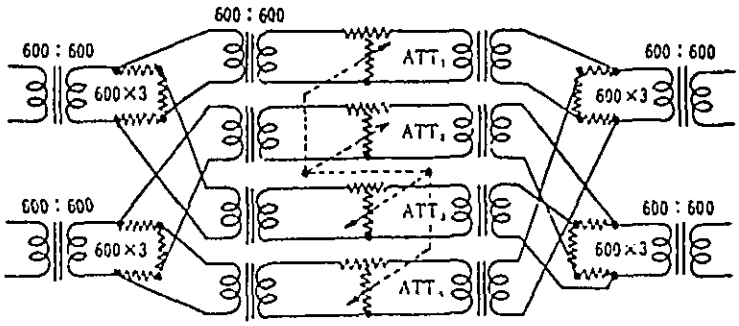


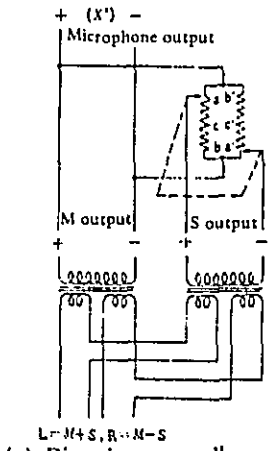
Figure 34 Over cross changing circuit

6. Direction Controller (Fig. 35 a, b)

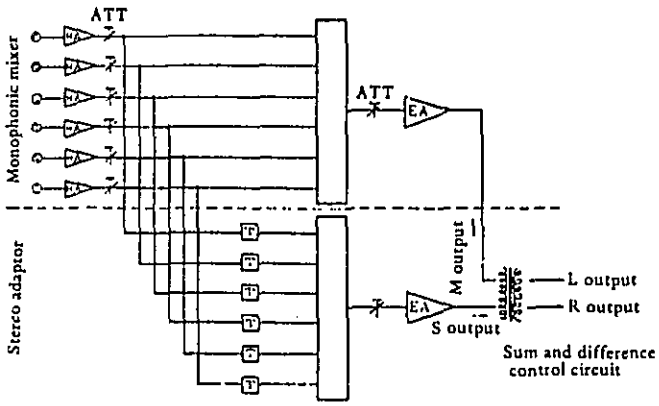
The effect of this circuit is similar to that of the pan-pot circuit although its configuration is somewhat different.

The signal output of one microphon is taken out in parallel and a reverse-coupled potentiometer is inserted in the other, and its output is turned into the S signal.

This circuit can be applied to convert a monophonic mixer easily to a stereophonic unit by incorporating it in a stereo adaptor.



(a) Direction controller



(b) Stereo adaptor using a direction controller (it is necessary to provide a shunt for impedance matching)

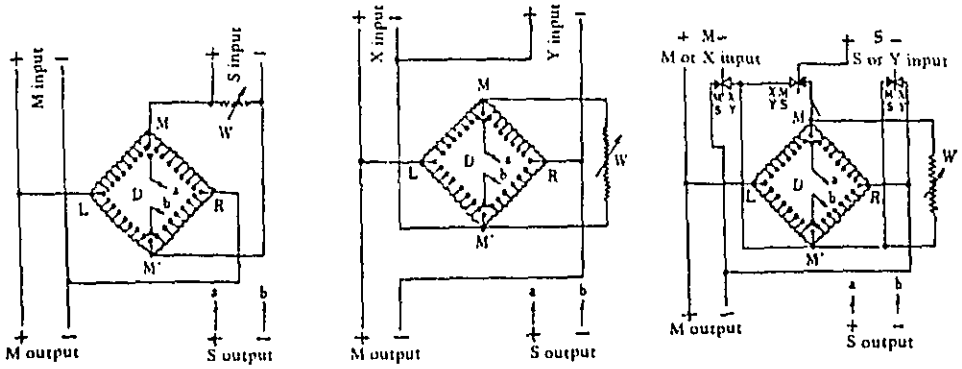
Figure 35

7. Direction mixer (Fig. 36 a, b, c)

This circuit is designed to apply the S input to the direction controller, to enable the adjustment of the positionality and amplitude of extensity.

The direction mixer allows the positionality and the amplitude of the acoustic images to be freely adjusted without varying the volume balance in the program, and it can be used to provide the same effect for programs which have been prerecorded.

It is also easy to provide rotation of acoustic images, reversal of left and right channels and panning movement, and the adjustment and operation can be executed simply. (Fib. 37)



(a) MS input circuit of direction mixer

(b) XY input circuit of direction mixer

(c) Simplified figure of direction mixer

Figure 36

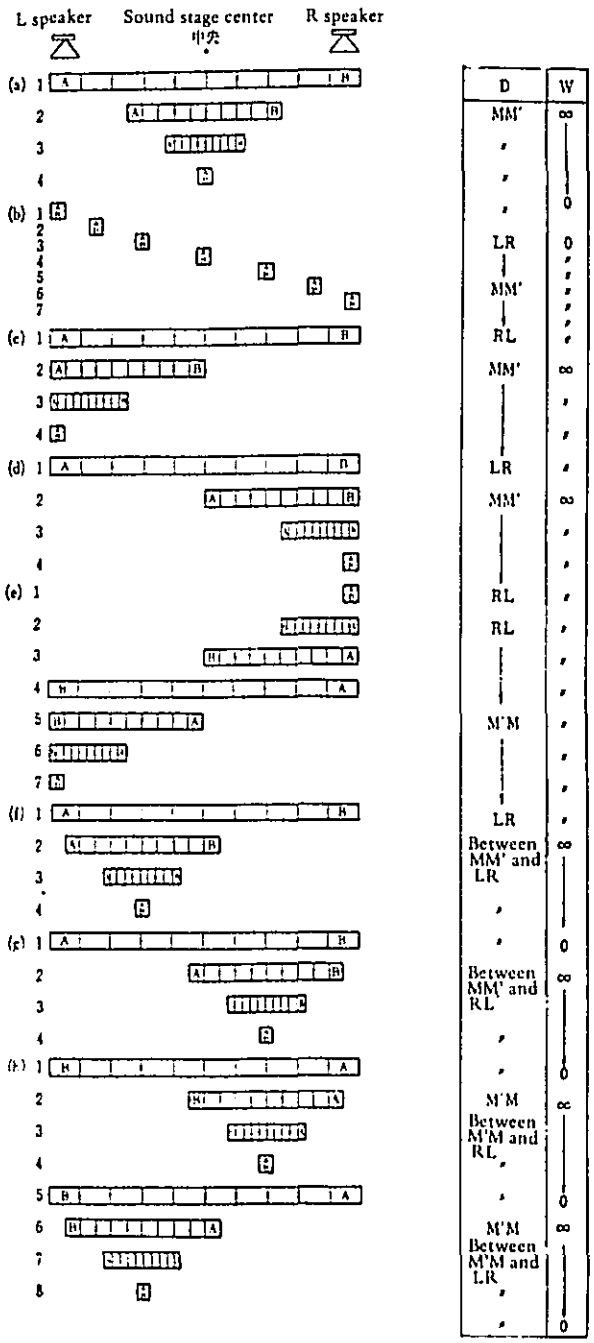


Figure 37 Positionality of direction mixer

8. Module Unit for Console (Fig. 38)

It is no exaggeration to state that recent mixing positively creates sound by fully using the functions of the console, and the qualitative conditions of the programs depends on the function of the console.

The mixing console for stereo of which the Japan Broadcasting Corporation (NHK) is currently using is of the model 440 total module unit, and its functions, performance, construction and design conform to tentative standards.

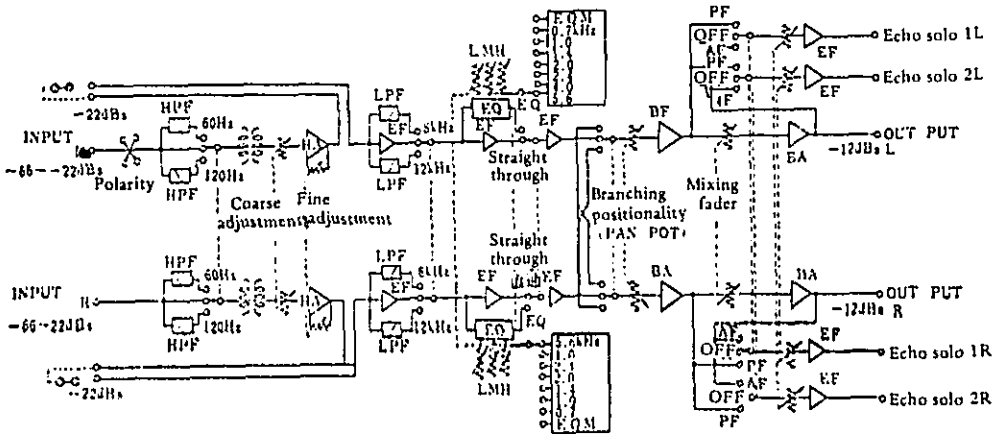


Figure 38 Input module system

IV MONOPHONIC ACOUSTICAL QUALITY OF SUMMING SIGNAL

It is necessary to give full consideration to the problem of the monophonic acoustical quality of the summing signal in FM stereo from the viewpoint of monophonic and stereophonic compatibility.

In actual program sound collection, various basic methods are combined, and this process renders the monophonic acoustical quality of the summing signal even more complex.

In stereo programmes, the deterioration of monophonic acoustical quality of summing signals is inevitable because the stress is placed on stereo effects. But, indeed, the quality deteriorates if compared with the same programme collected in mono. The reason is considered because the positioning of microphone (especially the distance between the sound source and microphone) is fundamentally different.

1. Summing Signal Quality under Level/Phase Difference Method (Fig. 39 a, b)

Differences in both level and phase will occur according to the direction of the sound from the sound-source between the left and right signals. When these differences aer added together and a summing signal is provided, abnormalities will appear in the oscillation waveforms of the amplitude-frequency response of the signal.

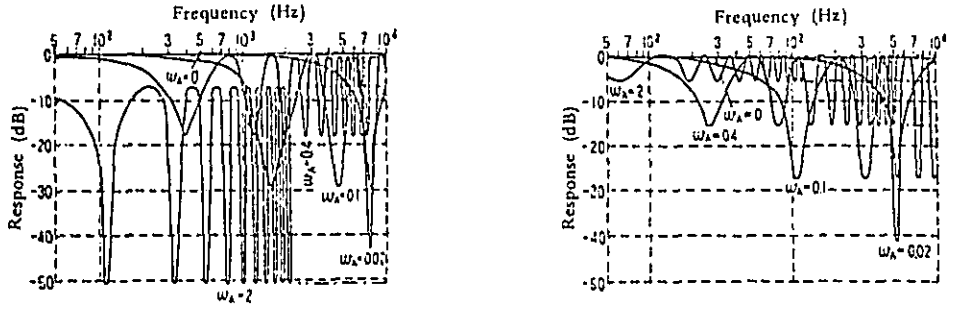
Moreover, in accordance with the sound emanating from an outer source, the summing signal output tends to drop compared with the output of the center sound source.

If this kind of phenomenon exists, the balance of the volume to direction of the sound-source will deteriorate.

In addition, the sound from outer source will tend to cause noticeable variations in tone-color according to its frequency.

2. Summing Signal Quality under Branching Method

When one microphone is positioned at each sound-source and the sound is branched to form a stereo sound field, there is only level difference in the left and right signals and no phase difference. This means that there is no special phenomena in the summing signal, in respect to the amplitude -frequency response and power difference in direction of sound.



(a) With the microphones placed 2 m apart

(b) With the microphones placed 4 m apart

W_A : distance (in meters) from middle of sound source (between both microphones)

Figure 39 Amplitude-frequency response of level/phase difference sound collection method

3. Summing Signal Quality under Level Difference Method (Fig. 40)

As there is only level difference existing between left and right signals, there is no phase difference. There are no abnormal phenomena occuring in the summing signal, and the frequency response is flat. However, a difference in output occurs according to the direction of the sound.

As the S signal in the summing signal under the M-S system is cancelled out, the output will be of the unidirectional microphone facing toward the front. Therefore, there is no deterioration in the monophonic acoustical quality, this system is superior in means of compatibility.

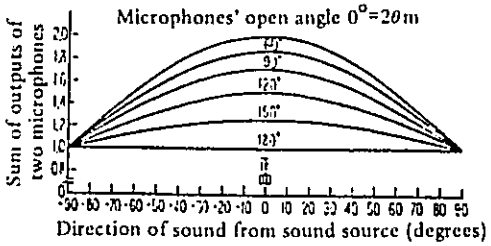
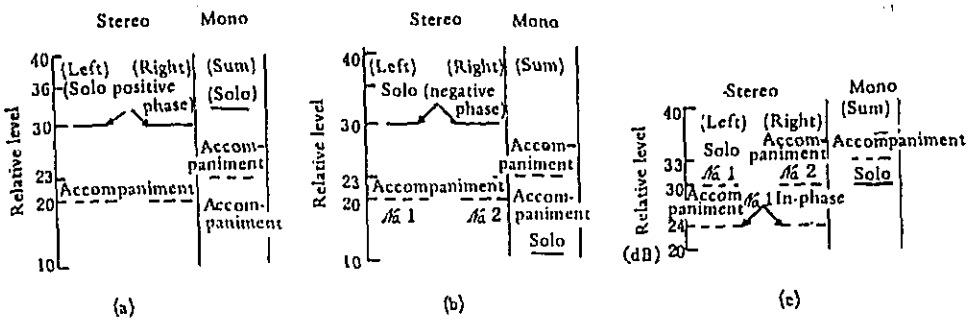


Figure 40 Output of Summing Signal under Level Difference Sound Collection Method



a) When the solo acoustic images have a positive phase between the left and right channels and when they are branched at the same level, the positionality is in the center. However, the sound pressure doubles with the center solo under left and right mixing summing conditions, and a rise of about 6 dB is registered with regard to the left accompaniment. The sum of the left and right accompaniments marks a rise of about 3 dB in the sound pressure. As a result, the center solo rises about 3 dB with respect to the left and right accompaniments.

b) When the solo acoustic images have a negative phase between the left and right channels, and when they are branched at the same level, the L + R is canceled out, leaving only the accompaniment (at the outset, we came across many records like this).

c) When the solo is on the left, and the accompaniments on the right and at the center, the accompaniments increase with respect to the solo under L + R conditions.

Figure 41 Differences in balance with LR mixing summing

Stereo mixing has been explained in general and technical problems related to reproduction of sound field of various sound collection methods, stereo effects and monophonic acoustical quality of the summing signal have been considerably resolved. In the future, it will be necessary to tackle with problems of how to apply stereo effects in individual programmes and how to produce top-class stereo programmes.