REPORT 300-7

STEREOPHONIC OR MULTI-DIMENSIONAL SOUND IN FREQUENCY-MODULATION SOUND BROADCASTING

(Question 46/10, Study Programme 46D/10)

(1963-1966-1970-1974-1978-1982-1986-1990)

1. Stereophonic sound in frequency-modulation sound broadcasting

Since the XIth Plenary Assembly of the CCIR, Oslo, 1966, certain administrations and broadcasting organizations have conducted theoretical and experimental work relating to stereophonic broadcasting.

As a result of this work, stereophonic transmissions intended for the public, using single frequency-modulation transmitters, were introduced in a large number of countries.

Specifications for stereophonic broadcasting systems already in use, i.e. the pilot-tone system and the polar-modulation system, are given in Recommendations 450 and 412.

A variant of the pilot-tone system has been investigated in the Netherlands using a single-sideband modulation of the sub-carrier, having a vector amplitude twice that of the sidebands generated in the case of normal sub-carrier modulation, making it compatible for stereophonic receivers having a synchronous type of decoder. The variant could offer interesting applications in certain circumstances, while maintaining the normal receiving and decoding principles.

2. Multi-dimensional sound-broadcasting systems

2.1 *Desirable basic characteristics*

The principal desirable characteristics of any system providing 3 or more output sound signals from a single radio-frequency channel, are as follows:

- the system should be compatible: that is to say, it should be possible to obtain both stereophonic and monophonic reception of a multi-dimensional sound transmission without reduction of quality in comparison with the reception of normal stereophonic or monophonic transmissions;
- the system should provide high-quality multi-dimensional sound reproduction;
- it should be possible to construct multi-dimensional sound receivers at reasonably economic prices;
- the introduction of multi-dimensional sound transmissions at an existing stereophonic broadcasting station, should not significantly reduce the coverage area of the station for stereophonic or monophonic reception;
- the coverage area of the broadcasting station for multi-dimensional sound reception should be substantially equal to that required for stereophonic reception;
- the protection against interference required for multi-dimensional sound reception should not be significantly greater than that required for stereophonic reception;
- the introduction of multi-dimensional sound transmissions should not necessitate extensive changes to existing frequency assignment plans;
- any system adopted should, as far as possible, acknowledge the existence of non-ideal receivers in the market and be so designed as to minimize the effect of any resulting cross-modulation on their monophonic and stereophonic performance.

2.2 *Results of tests on multi-dimensional sound systems*

[CCIR, 1970-74a] describes a variant of the pilot-tone system in which quadrature modulation is used for an additional sound channel *C* combined with the two stereophonic channels *A* and *B*. By so doing, the system is capable of transmitting three separate sound signals which can be demodulated in the same way as the pilot-tone system. With a baseband width the same as that required for stereophony and by a correct choice of signal levels, the radio-frequency bandwidth remains unchanged and hence, also, the radio-frequency protection ratios. This system is in accordance with Recommendation 450.

Subjective tests have shown that with three separate channels and matrixing signals *A*, *B* and *C* corresponding with the positions of the studio microphones feeding four loudspeakers, no significant subjective differences occur when compared with reproduction in four separate channels.

A third variant of the pilot-tone system is described in [CCIR, 1970-74b], in which four separate channels are transmitted by one transmitter. The system uses quadrature modulation of the normal suppressed sub-carrier of 38 kHz but additionally modulates a fourth audio-frequency signal onto a second suppressed sub-carrier of 76 kHz. Two possibilities of dividing the four signals into the different sub-carrier channels are given and with a sub-carrier frequency of 76 kHz, either double-sideband or single (lower) sideband modulation may be used.

[CCIR, 1974-78] outlines the work that has been carried out involving the study of some of the fundamental properties of hearing involved in the subjective aspects of multi-dimensional sound systems. It includes a proposal for a quadraphonic broadcasting system known as Matrix H, which encodes the incoming audio signals into two audio channels for distribution and transmission. At the receiver these signals can be reproduced directly as stereophony (or monophony) and can be decoded to give quadraphony. A considerable number of tests and calculations carried out in the United Kingdom have shown that Matrix H meets the basic characteristics as listed in § 2.1.

[CCIR, 1978-82a] describes surround-sound systems used experimentally in the United Kingdom for broadcasting. It is acknowledged that while all systems require an artistic compromise to be made between surround-sound and stereophonic balances, a broad distinction can be made between hierarchical and non-hierarchical systems. In hierarchical systems surround-sound decoding is possible with two or two and a half channels, and it achieves a similar coverage area to the stereophonic service at the expense of reducing the sharpness of sound images because of phase differences occurring in the audio band. In non-hierarchical three channel systems the stereophonic sound image can be excellent, but with the penalty of a reduced surround-sound coverage area.

[CCIR, 1978-82b] describes the stereophonic and monophonic compatibility of various multi-dimensional sound systems which utilize an N-2-N matrix format. This describes five such systems: SQ (CBS), HJ (BBC/NRDC), H (an earlier BBC system), BMX (Cooper/Nippon Columbia) and QS (Sansui). As described in this document, these characteristics differ significantly under conditions of ordinary stereophonic and monophonic reception.

3. Compandor applications

3.1 *The FM-FM system using a compressor/expander in the S-channel*

In the Documents mentioned in the Note to this Report, results are given of tests on a number of systems using a compressor for the *S*-channel in the transmitter and a corresponding expander in the receiver. These tests were carried out with an FM-AM system, a pilot-tone system and an FM-FM system. The results obtained have shown that noise in the *S*-channel is considerably suppressed by the compressor/expander. Recent tests have shown furthermore that, when transmitting two independent monophonic programmes, only the FM-FM system can give sufficiently low cross-talk from the *S*-channel, into the *M*-channel. The FM-FM system is defined by the following specifications:

- a compatible signal *M* produces a deviation of the main carrier of not more than 80% of the maximum frequency deviation for monophonic transmissions; in the case of two-programme transmission, the deviation is equal to that of the first programme signal. In the case of stereophonic transmissions, it is equal to one half the sum of the left-hand signal *A* and the right-hand signal *B*;
- a signal *S* produces frequency-modulation of a sub-carrier; in the case of two-programme transmissions equal to the second programme signal and, in the case of stereophonic transmissions, equal to one half the difference between the left-hand signal *A* and the right-hand signal *B*;
- the frequency of the sub-carrier is 33.3 kHz ± 100 Hz;
- the maximum frequency deviation of the sub-carrier is ± 10 kHz;
- the sub-carrier produces a deviation of the main carrier of between 18% and 20% of the maximum frequency deviation for monophonic transmissions;

- the pre-emphasis of the *S*-signal is identical to that of the compatible *M*-signal;
- a compressor with transfer ratio 2/1 (in dB) is inserted in the *S*-channel of the transmitter before the pre-emphasis network. This compressor has time-constants respectively equal to 2 ms for the rise-time and 20 ms for the decay-time;
- an expander with characteristics reciprocal to those of the compressor, is inserted in the *S*-channel of the receiver after the de-emphasis network;
- in stereophonic transmissions, an *A*-signal produces a frequency deviation in the same direction for the sub-carrier and the main carrier.

3.2 *Compatible companding in the pilot-tone system*

Broadcast tests [CCIR, 1986-90] in the United States of America have demonstrated the feasibility of providing improved stereo reproduction in fixed and mobile reception. A new technique uses an additional stereophonic sub-carrier in quadrature at 38 kHz for transmission of a compressed audio difference (L-R) signal. In new receivers, an adaptive expander utilizing the uncompressed difference signal as a decoding reference, provides accurate decoding over a range of compression characteristics. With this system, the size of the original stereophonic coverage area has been increased while maintaining compatibility with properly aligned receivers. The system has the following specifications:

- all existing characteristics of the pilot-tone composite signal are maintained;
- the *S'* signal, which is a compressed version of the regular *S* signal, amplitude modulates a second stereophonic sub-carrier;
- the frequency of the second stereophonic sub-carrier is also 38 kHz. It is transmitted in phase quadrature with respect to the first (regular) stereophonic sub-carrier;
- the polarity of the S' signal is reversed with respect to the S signal;
- complimentary transmitter and receiver low-frequency equalization with time constants of 200 and 1000 μs is employed in the S' signal;
- an identification signal at approximately 10 Hz, for automatic actuation of receivers, is included in the quadrature channel, at a level which produces 1% deviation of the main carrier. The identification signal is frequency-locked to the pilot sub-carrier divided by 1920 (approximately 10 Hz);
- the compression function for the S signal is characterized at low input levels by a 14 dB gain. For input levels greater than -22dB with respect to the level providing maximum modulation of the sub-carrier, the output is gradually attenuated in order to reduce possible over-modulation of the main carrier. With the exception of the 14 dB fixed gain, this compression characteristic is only approximate, and, for the reason stated below, may be modified somewhat by a broadcaster without concern about rendering obsolete receivers already using the new service;
- in receivers, a unique expander processing the sum of the *S* and *S'* signals and using the *S* signal alone as a decoding reference produces a new signal equivalent to the *S* signal, but with an improved signal-to-noise ratio at low programme levels.

Note. – A complete list of CCIR documents on stereophonic broadcasting from the periods between 1963 and 1970 is to be found in Volume X of the XIIIth Plenary Assembly, Geneva 1974, pages 124 and 125.

REFERENCES

CCIR Documents

[1970-74]: **a.** 10/52 (Netherlands); **b.** 10/44 (USA).

[1974-78]: 10/266 (United Kingdom).

[1978-82]: **a.** 10/20 (United Kingdom); **b.** 10/27 (USA).

[1986-90]: 10/104 (USA).

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GRAVEREAUX, D. W., STEBBINGS, D. W., CUGNINI, A. G. and KADIN, J. B. [December, 1985] Re-entrant compression and adaptive expansion for optimized noise reduction. *J. Audio Eng. Soc.*, Vol. 33, **12**.

MIDDLEKAMP, L. C., *et al.* [August, 1977] A subjective evaluation of FM quadraphonic reproduction systems – listening tests. United States Federal Communications Commission, Lab. Div., Project No. 2710-1.

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