The EBU's multichannel Audio activities

EBU Project Group P/MCA (Multichannel Audio) was set up to support the introduction of the 5.1 multichannel audio system for radio and television. The group has now reported and the results of its work are presented here.

Introduction

At the present time, the audio reproduction and transmission systems used in television and sound broadcasting are typically monophonic or two-channel stereophonic. However, as the two-channel stereo system has serious limitations, an improved sound system – **multichannel audio** – is needed for TV and radio broadcasting, particularly in view of the other media formats, such as DVD, that have recently become available to the consumer for reproduction at home.

Over the past 12 years, the consumer has been able to receive a form of multichannel surround sound via two analogue transmission channels. These surround signals were originally encoded for cinema and TV application using a phase/amplitude matrix to create two-channel stereo-like signals. On reaching the home, the matrixed signals can be decoded by a special decoder (for instance, a Pro-Logic® decoder for "Dolby Surround®") to recreate and reproduce the surround sound signal(s) in a 3.1 format.

Now the introduction of new digital broadcasting systems in Europe such as Digital Television (DVB-T) or Digital Audio Broadcasting (DAB) provides the potential to improve not only the transmitted audio quality in general, but also to allow the use of new, discrete multichannel audio formats, such as the standardized 3/2 (5.1) format.

There are a number of international standards from ITU-R and ISO/IEC, as well as related documents from the SMPTE and EBU, which define the requirements and conditions for the coding, transmission and reproduction of multichannel sound in different signal and channel formats. Furthermore, the new storage medium DVD supports the use of multichannel audio in the home.

Terminology

The term "**stereophony**" derives from Greek (stereo = spatial, solid, and phonos = tone, sound). It was originally a generic term used for all sound transmission methods using *two* or *more* channels and was defined in such a way by Snow et al., in 1953. In fact, "stereophony" does *not* mean merely "two-channel technology" but today it is widely used in this sense.

In this context, the term **"multichannel audio"** is used to design multichannel sound formats for the origination, recording, reproduction or transmission of sound events using more than two transmission or reproduction channels – in order to achieve additional imaging (rendering) of directional information and spatial information which are primarily designed for reproduction by loudspeakers. A multichannel audio format may be used with or without accompanying pictures.

The term **"surround sound"** is commonly used in the framework of multichannel audio to characterize the acoustical atmosphere or "enveloping effect" of a sound – which gives the listener a mental image of the relevant room size. Today, the terms "surround sound" or "surround signals" are sometimes used to describe the ambience channels only.

Basics of the universal 3/2 (5.1) multichannel audio signal format

The new universal multichannel audio format called "3/2" or "5.1" is based on the generic international broadcasting standard given in ITU-R Recommendation BS.775-1 [1] and other related EBU and SMPTE documents [2][3][4].

BS.775-1 [1] defines the following source and reproduction signals/channels as "Format 3/2", which means three signals for the left (L), right (R) and centre (C) channels (to the front), plus two signals for the left surround (LS) and right surround (RS) channels (to the rear).

As an option – because it is common in the film industry – the reference 3/2 format can be supplemented by an additional low-frequency extension (LFE) channel which carries signals intended for driving bass extension loudspeakers (sub-woofers). This channel is used for special effects in motion pictures. It has a restricted bandwidth of 20 - 120 Hz and provides up to 10 dB higher reproduction levels.

These "5.1" channels are summarized in the table below:

Code	Signal / channel
L	Left
R	Right
C	Centre
LS	Left Surround
RS	Right Surround
LFE	Low Frequency Extension (optional)

Compatibility with existing audio systems

An important requirement for the new multichannel system is to provide backward compatibility with existing audio formats that use a lower number of channels/signals. This leads to a hierarchy of compatible sound systems *(see Table 1)*, ranging from mono (1/0) via two-channel stereo (2/0) up to the new universal multichannel audio system (3/2).

Table 1
Hierarchy of compatible multichannel sound systems for broadcasting and recording *(according to [1])*

System	Channels	Code	Application
Mono	M	1/0	Radio/TV
2-channel stereo **2-channel + 1 surround** **2-channel + 2 surround**	L/R L/R/MS L/R/LS/RS	2/0 2/1 2/2	Radio/TV, CD/MC recording *(not used in practice)* (so called Quadraphonic)
3-channel stereo **3-channel + 1 surround**	L/C/R L/C/R/MS	3/0 3/1	*(not used in practice)* Matrixed surround (Dolby, etc.)
3-channel + 2 surround	L/C/R/LS/RS	3/2	Universal multichannel system for film, TV, radio, recording (DVD) etc. – otherwise known as "5.1"

In this hierarchy, up- and down-mixing of multichannel sound – that was originated for broadcasting, cinema or recording – is possible, as well as programme exchange or broadcasting at different format levels. That means that a receiver can reproduce a 3/2 programme also in 2/0 format, at an appropriate quality depending on technical and other conditions at the receiver.

Is multichannel audio really affordable for radio and TV?

The increasing penetration of discrete multichannel audio systems into the consumer market, worldwide, means that broadcasters should not be left behind.

Multichannel sound reproduction was primarily developed for film sound and is still mostly used for this medium but, nowadays, for DVD recordings also. As feature films are an essential part of television schedules, it is necessary that television broadcasting can also provide the new audio formats (DVB-T uses MPEG-2 transport coding, which allows the transmission of multichannel audio signals either with MPEG-2 Audio or Dolby AC-3 source coding).

Pure multichannel audio programmes can also be transmitted by radio, as the revised coding scheme for DAB (Digital Audio Broadcasting) now allows the use of MPEG-2 Layer II multichannel audio. Although there are some limitations for the maximum bandwidth (bit-rate) that can be used in a DAB multiplex (1.5 Mbit/s per block), recent tests made by EBU Project Group B/CASE [5] have shown that a bit-rate between 512 and 640 kbit/s is sufficient to provide reasonable quality for a 5.1 multichannel audio programme.

The provision of multichannel audio via TV or radio can be an argument for the user to replace his/her conventional reception device by new receivers for DVB and/or DAB.

In addition, the digital coding system MPEG-2 – which is recommended for DVB-T [6] and DAB [7] – supports further multichannel applications which can be implemented along with, or instead of, the described 3/2 format. Examples are:

- multi-lingual services (with up to 8 different languages);
- commentary services;
- auxiliary audio services for visually- or hearing-impaired people.

This emphasizes the importance that broadcasting organizations should give to this new step in audio quality for the consumer, which can be compared to the great leap forward from mono to two-channel stereo. Therefore, the programme and technical staff of broadcasting organizations need to be aware of the implications of multichannel audio technology and be informed about the use of studio production facilities and their limitations.

What has the EBU done so far?

After the preliminary activities of the former EBU Expert Group V3/HTF, the EBU Technical Committee duly took into account this international trend and committed Project Group **P/MCA** (Multichannel Audio) to collect and evaluate the existing proposals and to carry out some basic investigations in order to support the introduction of multichannel audio in the production process of their member organizations. P/MCA dealt with multichannel audio formats, listening conditions and methods for subjective assessment, sound production problems etc. It comprised experts from the BBC, Deutsche Telekom, DR, IRT/ARD/ZDF, MR, NOB/NOS, SVT, TRT and YLE.

In addition to P/MCA, other groups were also active on these aspects:

- Project Group **P/AFT** (Audio File Technology) which – among other things and together with P/MCA – dealt with the track allocation for multichannel recordings and the extension of the Broadcast Wave Format (BWF) to multichannel audio.

- Project group **B/CASE** (Compressed Audio Systems Evaluation) which – among other things and together with P/MCA – dealt with comparison tests on existing digital coding systems for multichannel audio.

Since then, several EBU Recommendations and related documents have been approved by the PMC and BMC and are available to the EBU member organizations. Some further questions are still under consideration, for example in Project Group **P/AGA** (Advisory Group on Audio).

System format aspects

Some basic audio format requirements have been recommended on the basis of an analysis of several existing reproduction and delivery formats available on the market:

- EBU Technical Recommendation R 96–1999: **Formats for production and delivery of multichannel audio programmes** [3].
- EBU Technical Report BPN 021 (1999): **Multichannel Audio: Report on different reproduction and delivery formats available on the market** [4].

Henceforth, the use of the 3/2 multichannel audio format, according to ITU-R Recommendation BS.775-1, is recommended for the production, delivery and interchange of radio and TV programmes within the EBU, taking into account its backward compatibility with other existing audio formats used in broadcasting.

In addition, BPN 021 gives an overview of the many reproduction and delivery formats available on the market worldwide and shows the current status of the international standardization of the most important aspects of multichannel audio systems.

The recording and film industries have already produced a large amount of multichannel audio material and will continue to do so in the future. Due to differences in formats, levelling and other characteristics *(see* [4]*)*, it will be necessary in many cases to adapt this material to suit the needs of radio and TV production.

Some guidance to converting multichannel audio programme material from an existing format to the new standard used for broadcasting is provided in:

- EBU Technical Report BPN 042 (2002): **Report on conversion techniques for multichannel audio formats** [8]

Conversion may involve changing the signal format, the coding format, or aligning other characteristics which may be different to those of the target 5.1 format. The document also gives advice on how to deal with compatibility between multichannel audio formats and other existing formats (such as two-channel stereophonic or Dolby Surround).

Listening conditions

Basic requirements for the acoustical and geometrical conditions in listening rooms and other operational rooms, valid for two-channel and multichannel reproduction, are given in

- EBU Technical Recommendation R22–1999: **Listening conditions for the assessment of sound programme material** [9].
- Supplement 1 (1999) to EBU document Tech 3276–1998 (second edition): **Listening conditions for the assessment of sound programme material: multichannel sound** [10].

These documents list a number of recommendations and special requirements for critical listening to sound recordings, with and without accompanying pictures, in the 3/2 and 2/0 formats. They also describe:

- the requirements for the reference sound field in a listening room:
- the geometrical conditions required for a multichannel listening arrangement;
- the electro-acoustical requirements of monitoring loudspeakers.

These recommendations are in line with the corresponding requirements of the ITU-R [11], the SMPTE [2] and are referred to in related documents of the AES [12].

In order to verify the requirements given in [9][13], and to show that several organizations already have listening rooms available which meet those requirements, some detailed acoustic measurements have been done in different places, such as at BBC Research & Development (Kingswood Warren), Deutsche Telekom Berkom (Berlin), the IRT (Munich), MR (Magyar Radio, Budapest) and YLE (Finnish Broadcasting Corporation, Helsinki).

These results have been compiled as an internal document of the EBU:

- EBU Technical Report BPN 014: **Acoustic measurements of listening rooms made to EBU Tech 3276-1998 – "Listening conditions for the assessment of sound programme material: monophonic and two-channel stereophonic**" [14].

It reports that the listening conditions specified in Tech 3276-1998 are quite realistic and could be achieved in several existing listening rooms at different locations.

A typical layout for a five-channel listening arrangement for critical listening, as used in the EBU, is shown in *Fig. 1* (taken from [10]).

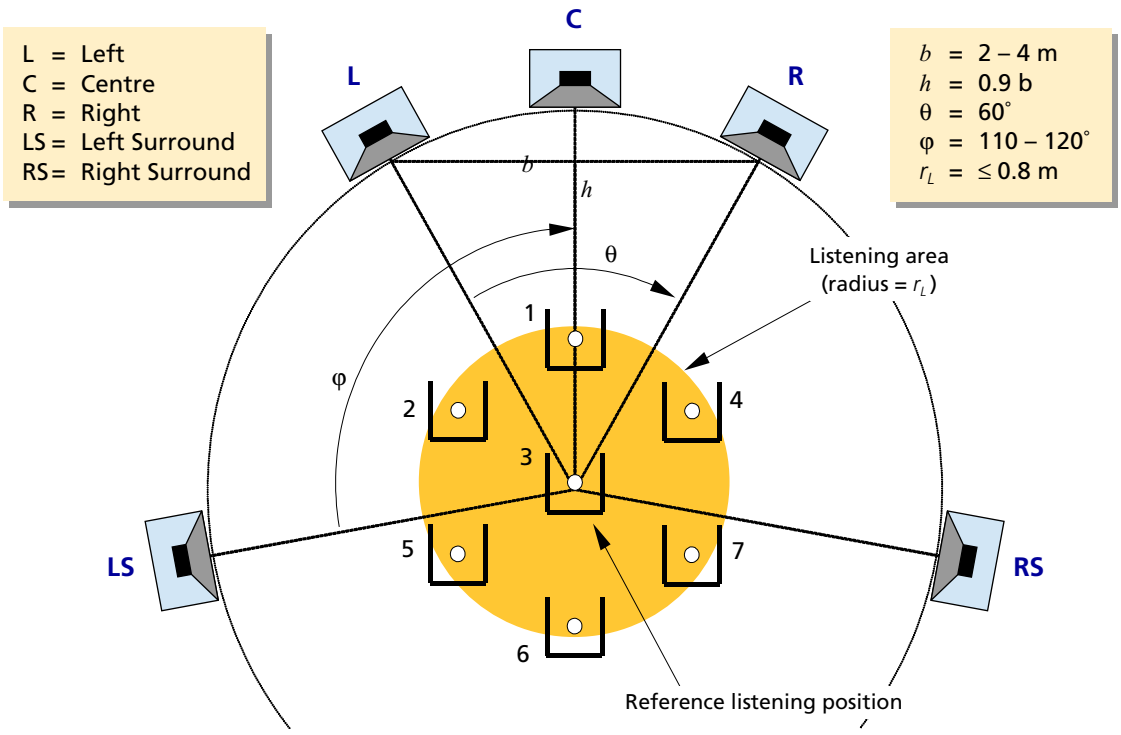

Figure 1
Typical layout of the five-channel listening arrangement

The Left (L) and Right (R) front loudspeakers are placed at the extremities of an arc subtending 60° at the reference listening point, so that the arrangement is compatible in this respect with the listening arrangement for conventional two-channel stereophony.

Quality assessment

The existing EBU methods for the subjective quality assessment of sound programmes [13][15] were supplemented by special requirements for multichannel audio as an important control instrument, especially during the introductory phase.

- EBU Technical Recommendation R90–2000: **The subjective evaluation of the quality of sound programme material** [16].

❍ Supplement 1 (2000) to EBU document Tech 3286–1997: **Assessment methods for the subjective evaluation of the quality of sound programme material – Multichannel** [15][17].

As an important part of the method described, *Table 2* shows the recommended quality parameters for the subjective evaluation of classical music.

These parameters were developed for use with classical music, but they may also be suitable for any live acoustical performance taking place in a real space.

Table 2
Main parameters, sub-parameters and examples of common descriptive terms

Main parameter	Sub-parameter	Common descriptive terms
1. Front image quality The front sound image appears to have the correct and appropriate directional distribution.	Directional balance. Directional stability. Sound image width. Location accuracy.	Wide / narrow. Precise / imprecise Stable / unstable Localizable / unlocalizable
2. Side and rear sound quality The side and rear sounds appear to have the correct and appropriate balance.	Directional balance. Directional stability. Location accuracy. Homogeneity of spatial sound	Stable / unstable Localizable / unlocalizable
3. Spatial impression The performance appears to take place in an appropriate spatial environment.	Spatial reality Reverberance. Acoustical balance. Apparent room size. Depth perspective.	Room reverberate / dry. Direct / indirect. Large room / small room.
4. Transparency The details of the performance can be clearly perceived.	Sound source definition. Time definition. Intelligibility.	Clear / muddy.
5. Balance The individual sound sources appear to be properly balanced in the general sound image.	Front/rear loudnessk balance. Direct/indirect loudness balance. Dynamic range.	Sound source too loud / too weak Sound compressed / natural.
6. Sound colour The accurate presentation of the characteristic sound of the source(s).	Timbre Sound colour (frontal / side & rear) Sound colour of reverberation. Sound built-up:	Boomy / sharp. Neutral / dull / bright. Dark / light. Warm / cold.
7. Freedom from noise and distortions Absence of various perceptible disturbances	Noise Distortion Coding artefacts.	Bit errors Electrical noise Acoustical noise: Public noise Distortions Coding artefacts
8. Main impression A subjective weighted average of the other parameters.		

Quality of transmission systems

Another point is to evaluate the quality of the transmission (coding) system itself. EBU Project group B/CASE, supported by project group P/MCA, carried out careful comparison tests on existing audio codecs for multichannel audio:

- EBU Technical Report BPN 019 (1998): **Report of the EBU subjective listening tests of multichannel audio codecs (MPEG-2-Audio vs. AC-3)** [5].

This report describes in detail the results of the tests (made according to ITU-R BS.1116-1 [11]) between two real-time implementations of multichannel audio codecs: MPEG-2 Layer II (in the backward compatible "Matrix Mode") and Dolby Digital® (AC-3) at several bit-rates.

Fig. 2 shows selected scores, taken from [5].

Recording and programme interchange

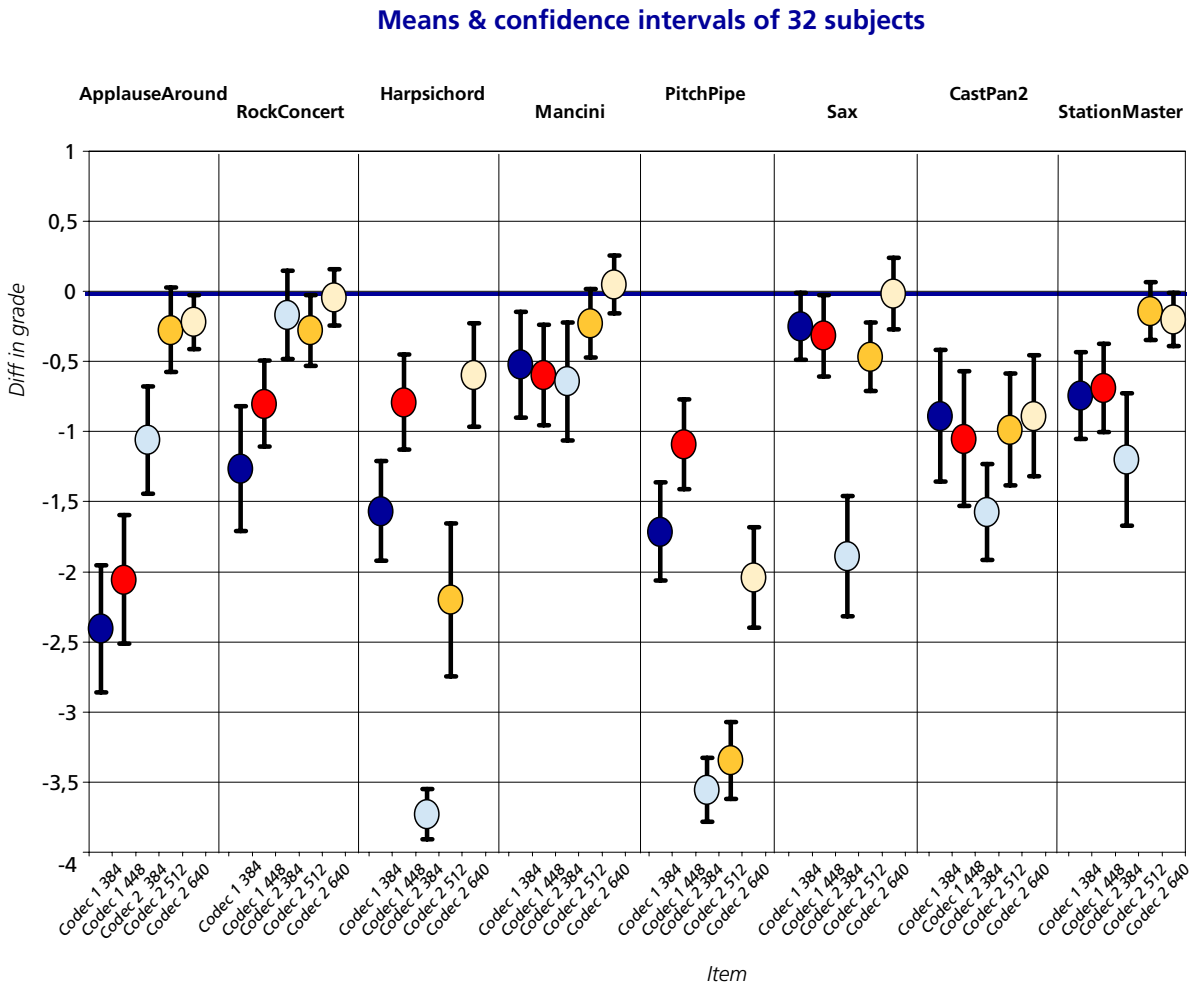

Figure 2
Selected scores obtained during comparative listening tests on audio codecs

Programme exchange is an essential task of the EBU. This will be particularly true for multichannel audio in the future because there are not so many programmes in the archives, yet. The basic requirements for recording multichannel signals on conventional audio media are given in an EBU recommendation elaborated by Project group P/AFT, and supported by project group P/MCA, which is consistent with those issued later by the ITU-R [18] and the SMPTE [19].

- EBU Technical Recommendation R91–1998: **Track allocations and recording levels for the exchange of multichannel audio signals** [20].

This document describes track/channel allocations for 8-track recordings of multichannel audio formats, together with related compatible two-channel signals, as shown in *Table 3*.

Table 3
Allocation of signals to the eight tracks

Track/channel	1	2	3	4	5	6	7	8
Signal	L	R	C	LFE [a]	LS	RS	A [a]	B [a]
					or both MS (-3dB)			

a. Optional

Conclusions

Most of the conclusions given below, for the introduction of multichannel audio services in broadcasting, have already been published in EBU Recommendation R96-1999 [3]:

- The 3/2 (5.1) format according to ITU-R Recommendation BS.775-1 [1] is recommended for the production, broadcasting and interchange of multichannel audio programmes, with or without accompanying pictures.
- The track allocation given in EBU Recommendation R91-1998 [20] should be used for the recording and interchange of multichannel audio programmes.
- For critical listening to (subjective assessment of) multichannel audio material in the production process, the listening conditions defined in EBU Recommendation R22–1999 should be used *(for details: see Supplement 1 (1999) to EBU Tech 3276-1998)* [9][10][13].
- Suitable assessment methods are given in (revised) EBU Recommendation R90 *(for details: see Supplement 1 to EBU Tech 3286)* [15][16][17].
- Special emphasis has to be given to the compatibility between multichannel audio formats and the existing two-channel systems: A transmitted or recorded multichannel audio programme should be backward compatible with two-channel reproduction [4].
- Compatibility should also be provided between the discrete 3/2 multichannel format and the existing two-channel surround sound systems already widely used (for example, the Dolby Surround® 3/1 format) [8].
- The implementation of multichannel audio features in DVB-T or DAB can provide value-added services in order to make these new digital systems more attractive than the existing analogue broadcasting services. Also, other new features of multichannel transmission systems, such as Multi-lingual Services, should be used [7].

Outlook (further studying)

The successful introduction of multichannel audio into the production process of radio and television will require some further studies covering, for example:

- the extension of the BWF (Broadcast Wave Format) to include multichannel audio (already foreseen in P/AGA);

- a method of conversion from 5.0 or 5.1 to normally-available formats such as 2x2-channels, for the recording of multichannel audio programmes with accompanying pictures – for production, delivery and exchange;
- methods for the visual control of multichannel audio signals, such as ppm-metering, graphic displays (multichannel goniometer), loudness control etc. (partly foreseen in P/AGA);
- production technologies for multilingual services, audio services for hearing-impaired people etc.;
- methods of transcoding between different multichannel audio coding schemes.

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Abbreviations

AES	Audio Engineering Society	**ITU**	International Telecommunication Union
BWF	(EBU) Broadcast Wave Format	**ITU-R**	ITU - Radiocommunication Sector
DAB	Digital Audio Broadcasting (Eureka-147)	**LFE**	(5.1) Low-Frequency Extension
DVB	Digital Video Broadcasting	**LS**	(5.1) Left Surround
DVB-T	DVB - Terrestrial	**MPEG**	Moving Picture Experts Group
DVD	Digital Versatile Disc	**PPM**	Peak Programme Meter
IEC	International Electrotechnical Commission	**RS**	(5.1) Right Surround
ISO	International Organization for Standardization	**SMPTE**	Society of Motion Picture and Television Engineers (USA)

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