Multichannel audio

— a review of the work of EBU Focus Team B/MCAT

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Over the years many EBU Members have experimented with multichannel audio (MCA) within radio and television services. In more recent times, since the advent of DVB digital broadcasting, multichannel audio has become an integral part of Members' transmissions, improving the quality and user enjoyment of many different types of programming.

The Focus Team B/MCAT (MultiChannel Audio Transmission) was formed to allow EBU Members to share their experiences of multichannel audio broadcasting and to address any transmission issues arising. The final output of the group is EBU Tech doc. 3311, *EBU Guidelines for Multichannel Audio in DVB* [1]. This article describes the efforts and studies that lay behind the creation of this document.

EBU Focus Team B/MCAT

One of the key findings early in the life of the B/MCAT Focus Team was members' experiences that many of the set-top boxes (STBs) currently available in European markets do not perform according to broadcasters' and consumers' expectations and may not fully comply with existing ETSI specifications such as TS 101 154 [3]. As a result, viewers and listeners may experience difficulties in accessing multichannel audio services in a consistent and reliable manner.

The EBU, through B/MCAT, agreed to act as a facilitator to help broadcasters and manufacturers to remove bugs and deficiencies relating to multichannel audio from both the broadcast chain and the STBs available on the market. The objective was to ensure that the millions of users Europe-wide who are already able to experience multichannel audio transmissions, would be more satisfied with the quality of the broadcast services they receive today, and be better prepared for those that will be available in the future.

The work plan of the group followed four distinct steps:

- Collation of existing broadcasters' experiences;
- Definition of test vectors that could be used to quantify these experiences;
- Creation of the test vectors and testing of a representative population of STBs;
- Drafting of the guidelines based on the test results.

This article provides an overview of these four steps, leading to the creation of the guidelines document [1].

Broadcasters' experiences

The first output from B/MCAT was BPN 065 [2]. This document is based on the collective knowledge and experiences of various European broadcasters, after conducting trials and pilots, and after launching permanent services with 5.1 multichannel audio transmissions using DVB digital broadcasts.

Currently, EBU Members are providing multichannel audio in a variety of ways including DVB-S, DVB-C or DVB-T as well as internet downloads. The choice of delivery method varies from country to country, based on platform availability and transmission bandwidth. Members are also providing multichannel audio services on both radio (audio-only) and standard-definition television broadcasts (in 2004/5 when BPN 065 was written, Members were yet to launch high-definition services [4]).

Testing of commercial STBs

A number of areas of concern for B/MCAT to investigate were identified during the collation of Members' experiences. A set of test bit-streams was created in discussion with B/MCAT Members, to validate and quantify these concerns. To date, these tests have been predominantly conducted on Dolby Digital services and STBs ... but broadcast trials have also included DTS and MPEG services. The range of test bit-streams is illustrated in *Appendix A*.

Areas of concern:

1) Ability of the STBs to tune, select and correctly identify multichannel-audio radio and television services, irrespective of the ordering of the PID values [5] and the presence of video and/or stereo MPEG-1 Layer 2 (L2) audio. *Some Members had experience of certain STBs not tuning properly to multichannel audio services; this was especially true of radio services.*
2) What happens to the stereo analogue audio output when multichannel audio is selected. *Some STBs fall silent on the analogue outputs when multichannel audio is selected, which removes the ability to record the programming on an existing VCR.*
3) Ability to switch multichannel audio streams on or off within a service for individual programmes or groups of programmes. *Some Members transmit permanent multichannel audio services, whereas others only have sufficient transmission bandwidth to transmit MCA services on a programme-by-programme basis. Experiences with the latter method have shown multiple issues with STBs failing to recognize the presence or lack of multichannel audio.*
4) Ability to use a variety of data rates for the multichannel audio service and to dynamically change these data rates as the number of audio channels in the multichannel audio service changes. *Both of these capabilities provide the broadcaster with the means to maximize the transmission data rate.*

Abbreviations

A/V	Audio / Video (Visual)
DTS	Digital Theatre Systems
DVB	Digital Video Broadcasting http://www.dvb.org/
DVB-C	DVB - Cable
DVB-S	DVB - Satellite
DVB-T	DVB - Terrestrial
ETSI	European Telecommunication Standards Institute http://pda.etsi.org/pda/queryform.asp
IRT	*Institut für Rundfunktechnik GmbH* (German broadcast engineering research centre) http://www.irt.de/
MCA	Multi-Channel Audio
MPEG	Moving Picture Experts Group http://www.chiariglione.org/mpeg/
PID	(MPEG) Packet IDentification number
PVR	Personal Video Recorder
S/PDIF	Sony/Philips Digital InterFace
SI	(DVB) Service Information
STB	Set-Top Box
SVT	*Sveriges Television och Radio Grupp* (Sweden) http://svt.se/
VCR	Video Cassette Recorder
WDR	*Westdeutscher Rundfunk* (Germany) http://www.wdr.de/

5) Ability of the STBs to respond to errors within the transmission, both at the transport packet and the elementary stream levels. *Some STBs were believed to recover more gracefully than others.*

6) A/V synchronization of both stereo and multichannel audio on analogue and digital outputs. *This is a significant problem with some STBs on the market.*

7) Formatting of the S/PDIF and/or optical digital output [6].

The bit-stream tests *(see Appendix A)* have been conducted on a representative range of commercially available STBs (in total 25 STBs) produced by several manufacturers and used by EBU Members for their multichannel audio services. In some cases, obvious problems were corrected in collaboration with the manufacturers prior to the tests commencing.

These tests were conducted by Dolby Laboratories, the IRT, WDR and SVT under the auspices of the EBU B/MCAT Focus Team.

Test results

Identification of television and radio services

These tests were designed to show the ability of STBs to identify, tune and output multichannel audio for both radio and television services. The tests explored different configurations of the transport stream, SI tables and video content.

All STBs tested correctly identified TV services that contained video, MPEG-1 L2 audio and Dolby Digital audio, irrespective of the ordering of the PIDs.

In the absence of the MPEG-1 L2 signal, a minority of STBs either failed to tune to this TV service or failed to output the Dolby Digital audio.

For those bit-streams providing audio-only (radio) services, the following results were obtained:

- One STB failed to tune to any radio-only service, including services with dummy video PIDs.
- One STB failed to tune to services that did not contain MPEG-1 L2 audio.
- Three STBs tuned to the services but both the stereo and multichannel outputs suffered extensive drop-outs.
- In the case of one STB, such drop-outs could be corrected by reselecting the audio service.
- One STB detected the presence of Dolby Digital audio but did not output the multichannel audio.

Stereo analogue audio output

This test was designed to identify STBs that were able to maintain a stereo analogue audio output whenever the multichannel audio was selected. The test identifies STBs with multichannel audio decoders (with downmixing capabilities) or STBs that can demultiplex multiple audio streams.

With all the STBs, the stereo output fell silent once the Dolby Digital audio was selected [1]. ()

> **Comment:** *The expectation of broadcasters is that the stereo analogue audio output should be maintained whether or not Dolby Digital audio has been selected. It is further expected that if Dolby Digital is broadcast without a stereo elementary stream, then the STB should provide a downmixed and decoded stereo signal on the analogue output.*

1. NB: outside the range of STBs that were used for these specific tests, it is known that there are other STBs which maintain the stereo analogue audio output, even when the Dolby Digital audio is selected.

Switching audio streams on and off within a TV service

These tests were designed to evaluate the ability of STBs to handle services where the multichannel audio is used on a temporary basis. The test streams add and remove the presence of a multichannel audio stream.

In the case of switched streams with corresponding SI changes, when the Dolby Digital disappeared, each of the STBs correctly switched to the MPEG audio. However, very few STBs automatically switched back to the Dolby Digital stream when it reappeared.

> **Comment:** *This automatic re-acquisition of Dolby Digital is important for users in the context of PVRs. Even in the absence of a PVR, without this feature users would have to manually reselect Dolby Digital after each discontinuity.*

It was further noted that the disappearance and reappearance of Dolby Digital caused an audible glitch on both the MPEG audio (when selected), and on the analogue output.

When MPEG audio had been selected by the user and the MPEG audio service disappeared, most STBs went silent but one STB switched to Dolby Digital. In this latter case, when MPEG reappeared, the STB stayed switched to Dolby Digital when it should have switched back to the user-selected MPEG audio.

In the case where no corresponding SI changes were made (i.e. Dolby Digital was always signalled as an available service), the automatic behaviour of the STBs was the same as listed above. However, each of the STBs allowed the user to select Dolby Digital even if it was not really available, causing the user to hear silence.

> **Comment:** *The behaviour of the STBs in allowing users to select Dolby Digital when not there, but when signalled in the SI, is correct: this scenario demonstrates a fault at the point of transmission in allowing an illegal bit-stream / SI combination.*

Dynamic changes in Dolby Digital audio data rate

This test examined the ability of the STB to process the entire range of Dolby Digital data rates allowed in ETSI document TS 101 154.

Two types of test were conducted; firstly, sequencing through the full range of Dolby Digital data rates and, secondly, switching between the two most commonly used data rates of 192 and 384 kbit/s (stereo to 5.1).

The responses of the STBs were broadly correct.

Some STBs would not decode Dolby Digital at a higher bitrate than 512 kbit/s.

> **Comment:** *Bitrates up to 640 kbit/s are perfectly legal and could be used by broadcasters although, in practice, the maximum bitrate used is 448 kbit/s.*

Some STBs gave a short mute of the Dolby Digital output at the point of the data rate change.

> **Comment:** *As such changes are likely to take place at programme junctions, this behaviour is deemed acceptable under these circumstances but should be minimized*.

One STB would not output audio for bitrates between 32 and 56 kbit/s.

> **Comment:** *These data rates would not normally be used for Dolby Digital transmissions*.

Robustness to errors

The tests included damage to transport packages alone and elementary streams alone. In each case, the damage was applied either to video, to MPEG audio or to Dolby Digital audio in sequence. In such cases it is natural to expect some transient disruption on the output from any STB.

With some STBs there was no discernable disruption to audio or video services.

At no time did an error on one of the audio services cause problems with either the other audio service or the video service.

In the case of one STB, disruption to the video caused problems with both the MPEG audio and the Dolby Digital audio.

Another STB took approximately 5 seconds to recover from an error to the Dolby Digital elementary stream. With most of the STBs, the recovery time was found to be below 0.5 s.

A/V synchronization

Test streams contained synchronization (sync.) signals that could be used to measure the exact sync. delay through the STB.

The relative timings of audio and video outputs were found to be very variable, both between different STBs and for each STB under the different conditions in which it was tested, e.g. recovery from changes of channel, recovery from errors and general acquisition of streams.

In what follows, all timing measurements were made on the S/PDIF output. In all cases where precise timing figures were measured for A/V offset, the offset exceeded the recommended tolerances, – 5 ms (audio early) to + 15 ms (audio late).

With most STBs, there was inconsistency in the measured A/V timing, even when the same service was being acquired several times over.

In most cases, if an STB has audio advanced on video for MPEG, it also has Dolby Digital advanced on video. (This is the same for audio delayed on video.)

Within any particular STB, the variation in A/V sync. from its average value is limited to +/– 20 ms.

Where two different bitrates were tested, there was generally no significant difference in the A/V synchronization for a particular STB.

	Range of measured A/V offsets	
	MPEG-1 L2	Dolby Digital [a]
Earliest/latest offset	– 51 to + 70 ms	– 310 to + 40 ms
Typical figures (80% of STBs tested)	– 10 to + 30 ms	– 20 to + 30 ms

a. With Dolby Digital, one would expect an earlier offset to account for an external decoder. The measured value does not include any adjustment for this offset.

S/PDIF output

Most STBs gave consistent signals on the S/PDIF output. However, one STB took several seconds for the output to stabilise (irregular data-burst timing) after acquisition of a service.

Alternative sample rates

At 48 kHz, no problems were encountered except in the circumstances given above.

At 44.1 kHz, some boxes gave drop-outs on MPEG and/or Dolby Digital audio whilst some STBs failed to give a Dolby Digital output.

At 32 kHz, these problem got worse and more STBs were affected. Also one STB changed audio pitch on the MPEG audio.

Summary

Due to the pressure of time and the wide range of STBs on the market, these results are just a snapshot of the performances of a small range (numbering 25) of the representative STBs at the time of the tests. The Focus Team only tested the performance of Dolby Digital multichannel STBs and has not yet evaluated the equivalent parameters for other multichannel audio systems.

For radio broadcasters, the single biggest issue lies in the inability of some STBs to acquire and identify a radio service.

For television broadcasters, the three most significant problems are:

- the variability and range of A/V synchronization;
- the inability of the STBs to revert to the user-selected audio format automatically;
- the absence of audio on the analogue outputs when a multichannel audio signal is selected.

John Couling is the Professional Product Manager at Dolby Laboratories, working in the fields of digital broadcast, digital cinema and DVD. He holds a Bachelors Degree in astrophysics from Bristol University (UK) and started at Dolby over eight years ago, supporting the DVD studios and authoring companies to enable the roll-out of DVD discs with Dolby technologies in Europe. More recently, he has also been involved in the development and launch of Dolby's Digital Cinema presentation system – a system designed to replace 35mm film with digital playback and projection, on which he has two patents pending.

As the longest serving member of the UK broadcast team, Mr Couling helped develop the technical specifications for many of the broadcast products that are manufactured by Dolby. These are used in TV and radio stations, and post-production facilities around the world to enable broadcasters to transmit surround sound programming. He also works closely with European, Asian and Australian broadcasters to enable them to put their surround sound programming on-air. In 2005, he was recognised by the Academy of Television Arts and Sciences for his contribution towards the Emmy Award winning technology Dolby E, used by broadcasters to simplify the adoption of digital surround sound.

John Couling sits on various broadcast technology committees, such as the EBU's B/MCAT Focus Team and the Digital Video Broadcasting (DVB) Project. He has also presented papers at major conferences and shows, such as IBC and AES.

Franc Kozamernik graduated from the Faculty of Electrotechnical Engineering, University of Ljubljana, Slovenia, in 1972.

He started his professional career as an R&D engineer at Radio-Television Slovenia. Since 1985, he has been with the EBU Technical Department and has been involved in a variety of engineering activities covering satellite broadcasting, frequency spectrum planning, digital audio broadcasting, audio source coding and the RF aspects of various audio and video broadcasting system developments, such as Digital Video Broadcasting (DVB) and Digital Audio Broadcasting (DAB).

During his years at the EBU, Mr Kozamernik has coordinated the Internet-related technical studies carried out by B/BMW (Broadcast of Multimedia on the Web) and contributed technical studies to the I/OLS (On-Line Services) Group. Currently, he is the coordinator of several EBU R&D project groups including B/AIM (Audio in Multimedia), B/VIM (Video in Multimedia) and B/SYN (Synergies of Broadcast and Telecom Systems and Services). He also coordinates EBU Focus Teams on Broadband Television (B/BTV) and MultiChannel Audio Transmission (B/MCAT). Franc Kozamernik has represented the EBU in several collaborative projects and international bodies, and has contributed a large number of articles to the technical press and presented several papers at international conferences.

Members of Focus Team B/MCAT take a short break during a winter meeting

Conclusions

This article summarizes the experience of those EBU Members who have already started regular multichannel audio operations, or are in the process of doing so. The EBU has tested a number of commercially-available DVB STBs and has detected several problems, which are reported in EBU Tech Doc. 3311 – *EBU Guidelines for Multichannel Audio in DVB* [1].

EBU Members are strongly committed to complying with the existing DVB standards which specify the tools for multichannel audio. The aforementioned Guidelines should help EBU Members to implement MCA in a compliant way.

The EBU B/MCAT campaign described in this article has already helped many DVB STB manufacturers to remove some deficiencies from their commercial products. The activities of B/MCAT have also helped broadcasters to transmit their radio and TV signals in compliance with the existing DVB transmission standards.

The main beneficiaries of this work however will be the end users. A user who is satisfied with the received services and who gets good value for money is a common objective for both the broadcasters and the manufacturers.

As a result of experience with these tests, Dolby has launched a comprehensive range of bit-stream tests for its licensees and is working with manufacturers to refine the necessary test schedule.

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Appendix A
Descriptive list of the test bit-streams

Identification of television and radio services

- TV service streams with different PIDs.
- TV service streams with MPEG-1 L2 and Dolby Digital audio, and streams with Dolby Digital only.
- Radio service streams with MPEG-1 L2 or Dolby Digital audio, or with both MPEG-1 L2 and Dolby Digital audio.
- Radio service streams with a dummy video PID (i.e. signalled in SI but no video elementary stream).

Switching audio streams on and off within a service

- TV services with either Dolby Digital audio added and removed or MPEG-1 L2 audio added and removed. All SI tables updated.
- TV services with either Dolby Digital audio added and removed or MPEG-1 L2 audio added and removed. All SI tables are left unchanged.

Dynamic changes in audio data rate

- TV and radio services covering the complete range of Dolby Digital data rates.
- TV and radio services switching between two common data rates such as 384 kbit/s and 192 kbit/s, or 448 kbit/s and 256 kbit/s.

Robustness to errors

- Transport packet and elementary stream corruptions and drop-outs.

A/V synchronization

- TV services at two different data rates for A/V sync. measurement.

Alternative sample rates

- TV services with MPEG-1 L2 and Dolby Digital audio at 48 kHz, 44.1 kHz and 32 kHz sample rates.