Sound Measurement

An important element in the assessment of video for broadcast is the assessment of its audio content. This audio can be delivered in a range of different forms –mono/stereo/ surround sound; embedded/AES/Dolby encoded; 20bit/24bit. The viewer will be looking not just for clarity in speech but also a realistic spatial effect, especially where surround sound is used.

The viewer can also be expected to be looking for the loudness of the audio signal to be kept within their comfort zone and for consistency in programme loudness both between programmes and between programmes and adverts. This issue of loudness has been growing in importance to such an extent that it has started to take over from peak audio level as the principal factor by which audio is judged.

This white paper looks at the different aspects of the audio signal that producers and distributers need to monitor and shows how these are catered for by the Audio options offered by OmniTek's OTM and OTR waveform analysis systems.

Measuring Audio Levels

There are essentially two approaches to measuring the level of any audio channel – using a VU meter or using PPMs. A VU meter is good for giving a measure of the overall volume level of a programme, but has very slow ballistics. As a result, any peaks in the volume are flattened out and significantly underestimated. To see these peaks, you need to use a Peak Programme Meter or PPM. As its name suggests, this is principally designed to show peaks in the volume level though, with suitable processing, the data can also be used to give information about average levels.

The OmniTek OTM/OTR systems offer a range of user-configurable PPMs, covering both simple channel pairs and channels selected to be applied in a 5.1 Surround Sound configuration. PPMs can also be displayed for audio channels extracted from Dolby-encoded audio.

One set of these PPMs mimic audio meters: an example of these displays is shown in Figure 1. Since V2.3, a version of the displays showing True Peak values of the audio has been offered, determined by 4x oversampling in line with recommendations in the EBU-TECH 3342 supplement to the EBU R 128 recommendation on loudness monitoring.

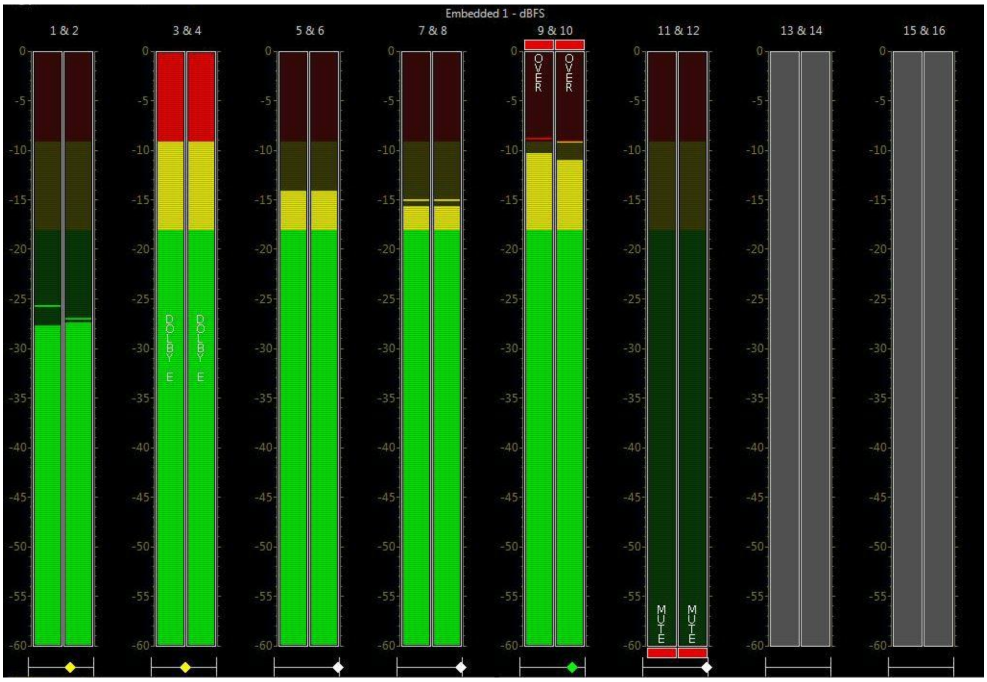

Figure 1: Typical PPM display

The individual PPMs are typically marked out in dBs but to make them easy to interpret, the True Peak versions of the display show anything over a preset Maximum True Peak level in red while the audio meter versions of the display use red, yellow and green colouration in traditional fashion to show how the output compares with preset Permitted Maximum and Alignment reference levels: Green is used to colour the associated bar graph up to the Alignment reference level; yellow to colour parts of the bar graph that between the Alignment level and the Permitted Maximum; while red is used to colour parts of the bar graph that go above the Permitted Maximum should these occur. Optionally, the Peak level that has been achieved either over the last second or over the entire period since the display of last reset (typically at the start of a programme) can be shown via a “Hold Line” drawn above the current bar graph.

In addition, there are OVER and SILENCE markers that indicate where a channel either exceeds the prescribed 'Over' level (over which the audio is deemed to be 'too loud') or falls below the prescribed 'Silence' level at which the audio level is deemed to be so low that it might as well be considered not present. The display also uses CLIP and MUTE markers to indicate where a channels is consistently sampled all-high (CLIP) or consistently sampled zero (MUTE).

Across the industry, a wide range of different physical meters are used to display Peak Program information. In particular, broadcasters such as the BBC and the EBU have established standard metering systems associated with defined Permitted Maximum, Alignment, Over and Silence levels. Over time, these metering systems have become widely used, so as part of its configuration, the OTM/OTR system provides the option to select your chosen metering system, whereupon all the key levels are set to the ones associated with a selected standard. Selecting any of these options also sets the factors controlling the speed at which the meter responds to changes in volume level (referred to as its 'Ballistics') to match the ballistics of the standard metering systems.

Indeed the expectation is that all users will want the PPMs to emulate one or other of the standard metering systems. As a result, the first thing to select on the Audio Config page of the OTM/OTR configuration is the desired Audio Meter type (out of a choice of various versions of dBFS; Nordic; DIN, BBC, EBU and VU meters). The detailed settings then all change to the appropriate values for the selected meter type but you can, if you wish, then modify any of the settings to suit your particular needs.

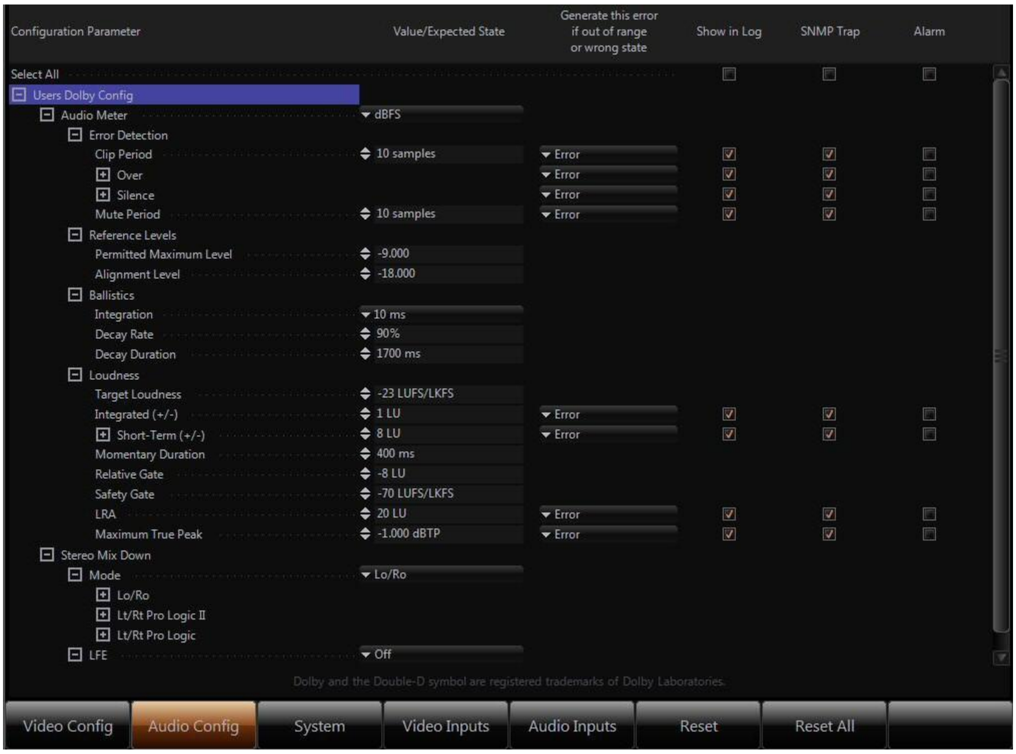

Figure 2: Audio Config page.

Measuring Loudness

Loudness is the current hot topic in video test and measurement, following moves to ensure consistency of average loudness level both between programmes and between programmes and adverts. Loudness itself is highly subjective but the dynamic range of modern digital sound equipment is so wide that limits need to be defined. The interest in loudness level has led both to the introduction of rules regarding how loud a programme can be at any point in that programme and the average programme loudness, and to a change of paradigm in audio measurement from audio level to loudness.

The Loudness monitoring on the OmniTek OTM and OTR systems conforms to the recommendations of EBU Recommendation128 and ITU-R BS.1770-2. The EBU document discusses loudness normalisation and maximum permitted levels for audio signals. The ITU document defines a frequency weighting algorithm (designated the K weighting) for combining the different elements of a surround sound system to give a multichannel loudness measurement. OmniTek have also followed EBU TECH 3341 and EBU TECH 3342, which are supplements to EBU R 128, detailing an EBU Mode of loudness monitoring and defining Loudness Range.

The OTM and OTR systems offer a range of ways of reporting the loudness, initially supported by the AUDIO software option but, since V2.3, supported by the AUDIO_LOUD option (automatically licensed on any system where the earlier AUDIO option was installed). Three basic loudness measures are determined:

- ‘Momentary’ Loudness (determined from 400ms samples of the audio content)
- ‘Short-term’ Loudness (the average of the Momentary loudness values measured over the last three minutes)
- ‘Integrated’ Loudness, giving the average loudness level since this calculation was last reset.

The values obtained are shown in bargraph-style displays, reported in the Status display and logged in Status reports. There are also displays that show how the loudness has varied over time and the statistics of the variation in loudness over time as a histogram.

The primary loudness display is similar to the standard PPMs display in that it comprises bargraphs showing the Short-term Loudness values determined for specified pairs of audio channels. These bargraphs are marked out in the selected Loudness units and coloured in a rainbow from blue to red with the green section centred on the pre-selected ‘Target’ values and of a depth corresponding to twice the ‘Integrated (+/-)’ value set as part of the Audio Configuration.

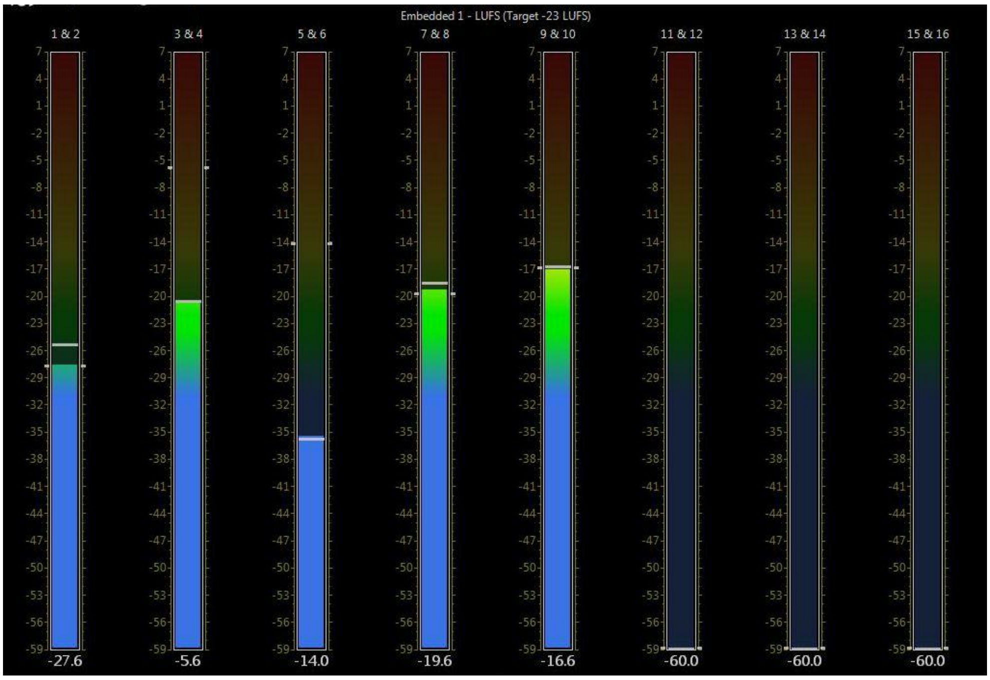

Figure 3: Typical Loudness display.

Other features of this display include:

- Rapidly moving white bars over the bargraphs, marking the current Momentary Loudness value
- White markers on either side of the bargraph showing the calculated Integrated Loudness value, which is also reported at the bottom of the graph.

The various calculated values are also displayed for each channel in the Audio section of the Status View and optionally recorded in Event logs.

For broadcasters, Integrated Loudness values calculated over the duration of each programme are particularly important to record as these ultimately need to be compared with the Target Loudness value. With the OmniTek OTM and OTR systems, these values are readily determined: all the user needs to do is reset the Integrated Loudness calculation before the programme starts and then read the recorded value at the end of the transmission. It is not even necessary to be precise about when the programme starts and when it ends because the OTM/OTR only takes into account those occasions when the loudness is above a ‘gating’ level known as the Relative Gate. As a result, the calculation the OTM/OTR makes is not affected by any periods in the programme during which there is no sound including before the start of the programme and after its end. (Both the Relative Gate and the Target Loudness are available for the user to set as part of the system configuration).

For Surround Sound set-ups, the OmniTek systems includes a loudness bargraph in the special Surround Sound version of the PPM display in which the individual PPMs are displayed in their appropriate positions (see below). This bargraph shows the combined ‘Program’ values of these parameters for the five main channels (L, R, C, Rs and Ls). OmniTek also add an outline to the set of Surround Sound PPMs that gives a visual representation both of how the loudness is distributed between these five channels and of how this is changing in time by joining the Momentary Loudness values for the individual channels. (The ball in the middle of this outline marks the Centre of Sound.)

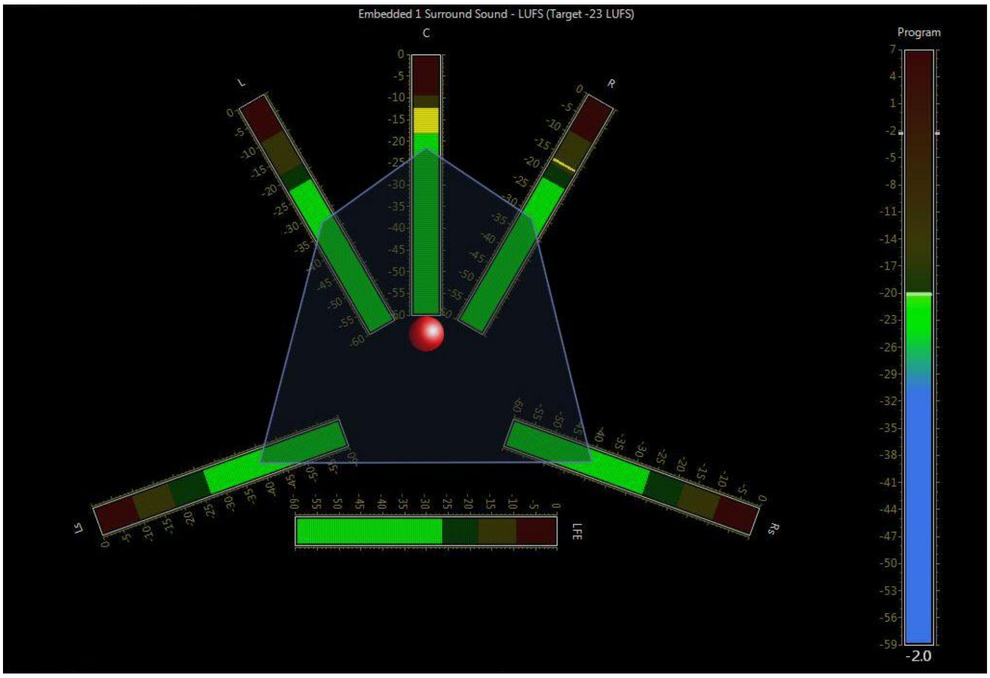

Figure 4: Surround Sound display with Program Loudness meter on the right.

From V2.0, the OmniTek systems also offer both an historical trace of the Momentary Loudness and Short-term Loudness values (as illustrated in Figure 5) and histograms of these loudness values (as shown in Figure 6). These displays also show at the top of the display the current Integrated Loudness value, maximum Short-term Loudness and maximum Loudness Range (see below), together with the current Short-term Loudness and Loudness Range values where space allows. The history shown can cover different time periods from 1 minute to 24 hours.

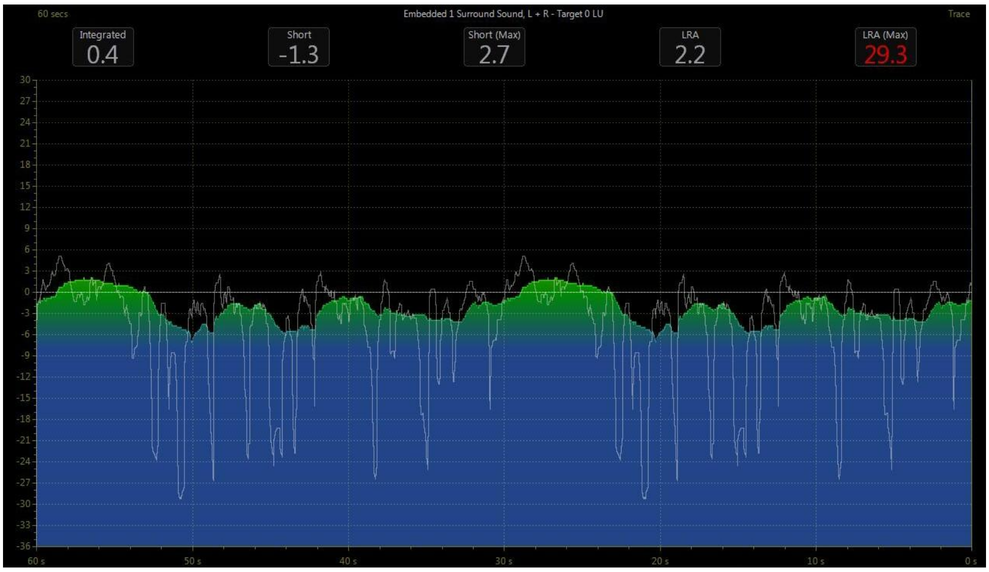

Figure 5: Loudness History trace.

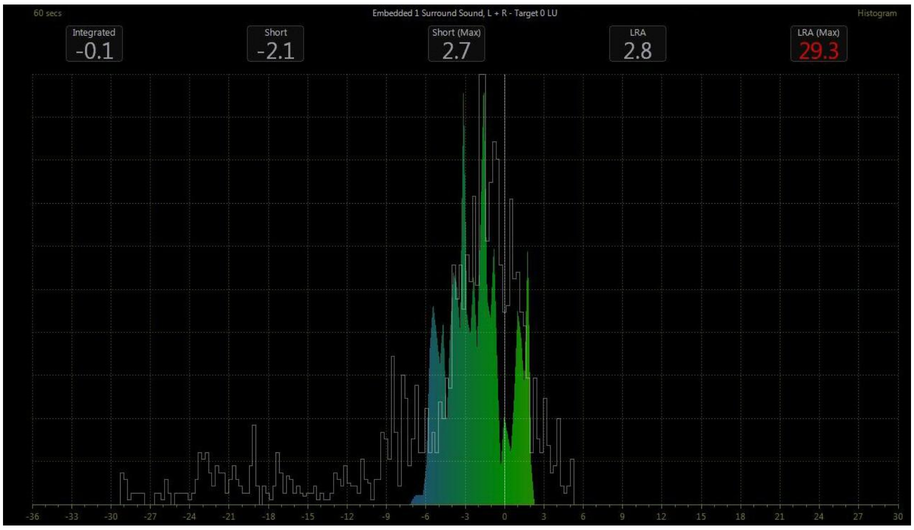

Figure 6: Loudness History Histogram.

Parameters such as the Target value, the periods over which the Momentary and Short-term values are calculated and the levels of the Relative and Safety gates are all user-configurable. The required values are set on the Audio Config page of the Config window.

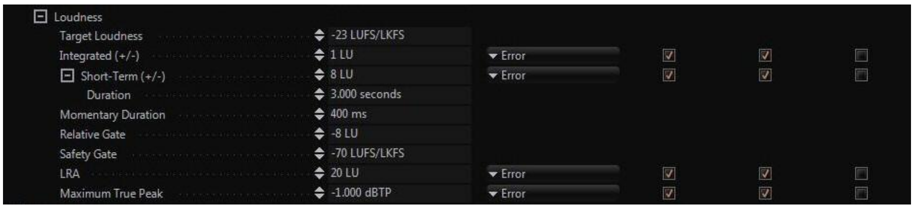

Figure 7: Loudness Calculation Parameters within the Audio Config.

Loudness Range

The EBU Recommendation on Loudness (R 128) specifies Loudness Range (LRA) as one of the aspects of the audio signal that should comply both with the technical limits of the complete signal chain and wih the aesthetic needs of the programme/station.The OmniTek systems use the algorithm defined in the EBU_TECH 3342 supplement to R 128 to calculate Loudness Range. The results are displayed in the form of a graph against time.

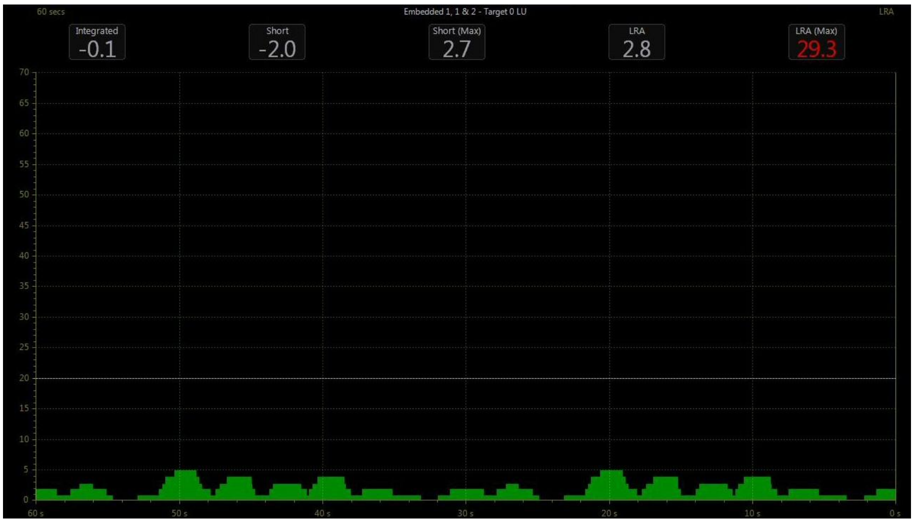

Figure 8: Loudness Example Loudness Range display.

Phase Analysis

Simple one-dimensional analysis of phase relations between audio channels given by set of very simple phase meters shown at the bottom of each bargraph within the standard PPM display. These phase meters each give a quick visual report of the correlation between the audio in the two channels that are displayed.

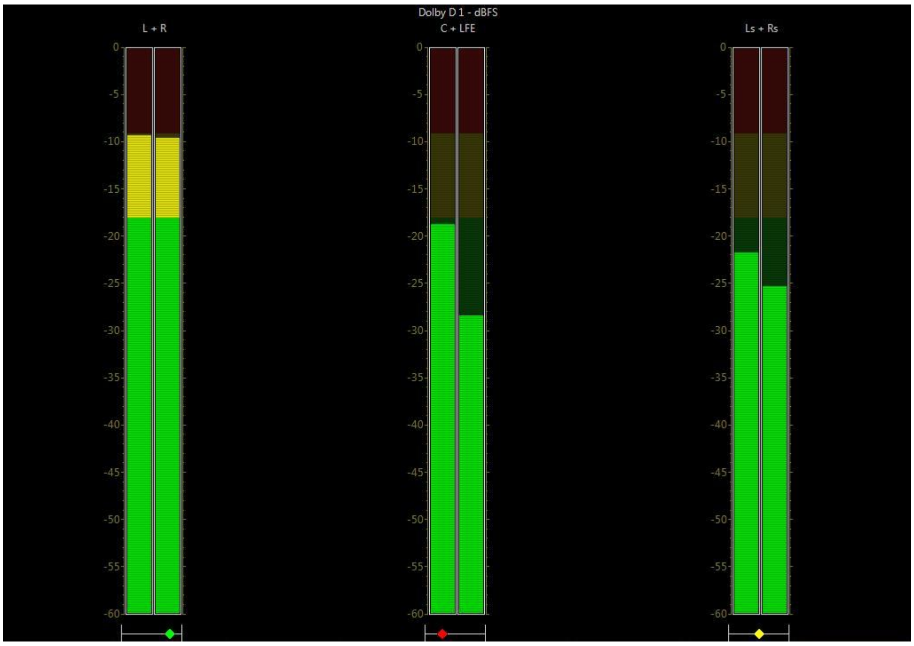

Figure 8: PPMs showing different phase relations. L+R channels show positive correlation (marker to the right); C + LFE show negative correlation (marker to the left); Ls + Rs show no correlation (marker in the middle).

A more detailed view of the phase relationship between a selection audio pair is given through displaying the Lissajous figures that result when the signal from one audio channel is plotted against the signal from the other member of the same stereo pair,

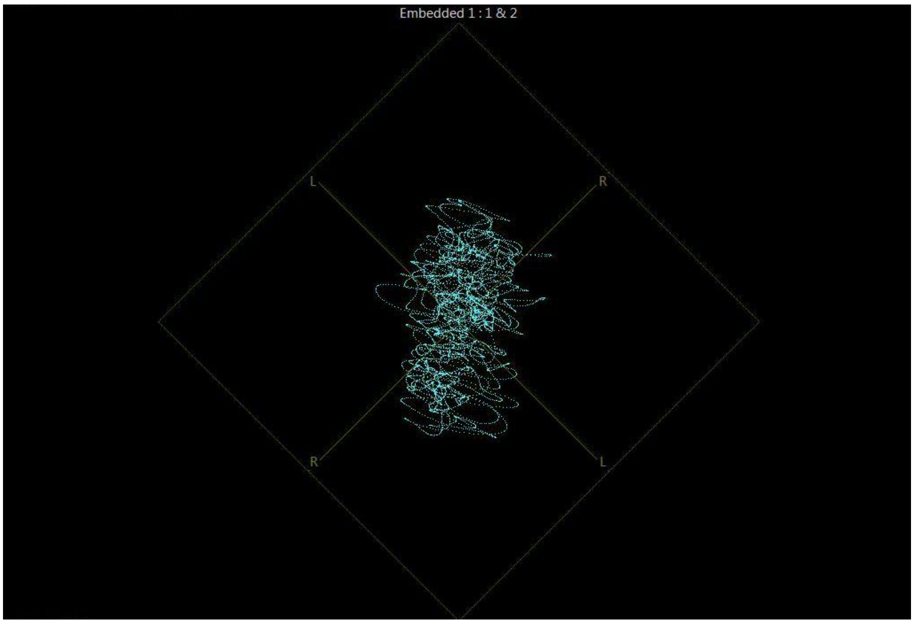

Figure 9: Example Lissajous Figure.

The OTM/OTR's basic Lissajous display shows the figure that results from comparing one half of a stereo pair against the audio in the other channel. (Both the audio input and the stereo pair from that input that is analysed may be selected through buttons offered on the display's 'Button Bar'.)

Other features of the display include an optional Graticule and an Automatic Gain Control (AGC) option that, when enabled, automatically scales the displayed trace to fit the selected graticule. The OmniTek systems also offer a special Surround Sound version of the Lissajous display – see the section on Surround Sound below.

Clipping etc.

Where an audio signal has been clipped, any peaks in the signal that exceed a predefined level will have been cut back to that level, giving each of these peaks a flat top. Arranging that signals that go above a desired level are clipped obviously prevents the audio output system from going to volume levels that are deemed too high but it comes at the cost of some not entirely desirable side-effects. For instance, the effect of clipping on music can be to make all notes sound equally loud. It can also introduce unwanted harmonics into the frequency spectrum.

In the digital world, there can be two key levels. One level is an absolute maximum imposed by the encoding. Audio is expressed using two's complement numbers, so e.g. 20bit audio has an absolute maximum of Ox7FFFF; 24bit audio has an absolute maximum of Ox7FFFFF. The other key level is 'all zeroes'.

The existence of a clipped signal can be seen in two ways on the OTM/OTR. Firstly, any audio channel where the value is consistently all ones is automatically as CLIP(ped) on the PPM display, while any channel where the signal level is over a pre-defined 'Over' level is automatically marked 'OVER'. (Similar markings of 'MUTE' and 'SILENCE', respectively, are applied where an audio channel is either consistently all zeroes or under a pre-defined 'Silence' level.)

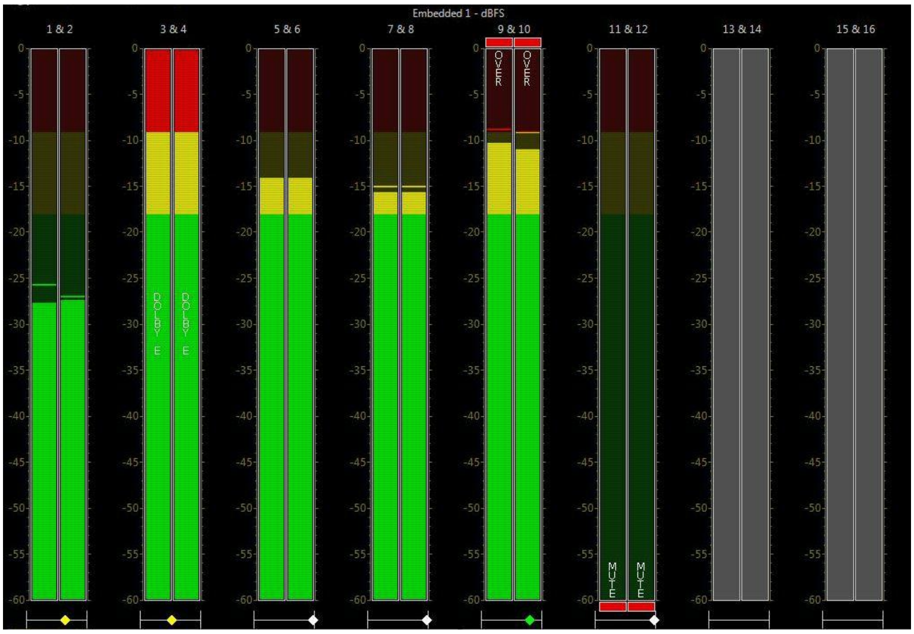

Figure 10: Example PPM display where some channels are OVER and others are MUTE.

The other place where clipping can be detected is on Lissajous figures, where a clipped signal has a distinctive sharp edge to the figure.

Status

Delivered alongside the audio are various bits of 'administrative' information such as: the type of use (professional or Consumer); whether the source is locked or unlocked (where specified); the sample frequency (where known); the channel mode that is being used (e.g. Single or Stereo or "Primary/Secondary"); and the word length.

The OmniTek systems displays this information in Status displays, along with details of current and peak volume levels, Momentary and Sliding Loudness levels and a Present/Absent marker. There are two forms of this display: one takes the form of a set of summaries covering both different aspects of the audio and different combinations of audio channels; the other is a hierarchical listing of all the available status information. These displays also include running counts of the numbers of fields/frames in which pre-defined maximum or minimum levels were exceeded.

Figure 11: Sample Audio Status Summary (showing audio and loudness levels)

Figure 12: Sample Audio (Ctrl) Status Summary (showing the Channel Usage data delivered alongside the audio)

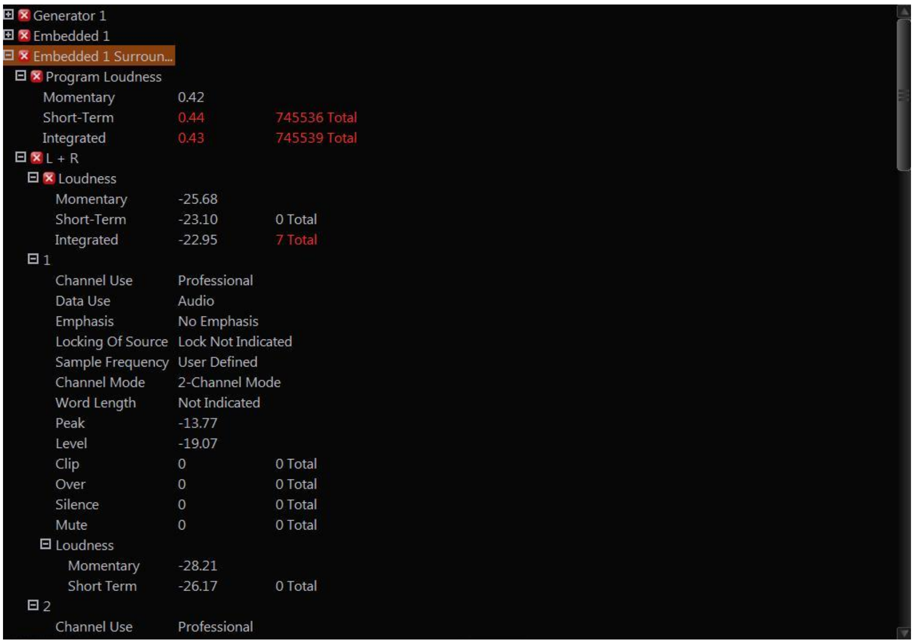

Figure 13: Status View listing of audio data

Logging

The OTM/OTR also offers the option of recording some of this status information in an ‘Event Log’, which can be saved to disk as an XML file along with timing information and, optionally, some descriptive text.

The key to this Event Log is the Audio Config page of the OTM/OTR’s Config window, much of which is concerned with desired maximum or minimum values for the various audio parameters. Alongside the selected values are ‘Show in Log’, ‘SNMP Trap’ and ‘Alarm’ tick boxes that may be used to select the responses that you want to happen when the selected level is exceeded. A tick in the ‘Show in Log’ box specifies that an entry is added to the Event Log at the point that the level in that parameter is exceeded and again when the parameter falls back within the specified limits. A tick in the ‘SNMP Trap’ box specifies that an SNMP Alert is sent at these points, while a tick in the ‘Alarm’ box specifies that an audible alarm is sounded.

The Event Log is simply one of the ‘Status’ Views that can be called up on the screen. It automatically offers a ‘Live’ log, listing events as they happen on the currently selected input video stream. It can also display the results of one or more ‘logging sessions’, which may be started and stopped either manually or at specific points in the video being analysed. These logging sessions are started and stopped independently and may run concurrently. It is the resulting ‘Session logs’ that can be saved to disc as XML files for subsequent analysis.

Alongside these logs, the OTM/OTR also offer a ‘snapshot’ of the Status View information at the start of the logging session, along with a similar snapshot of the status at the end of the logging session and a summary giving the counts of the different type of event that occurred.

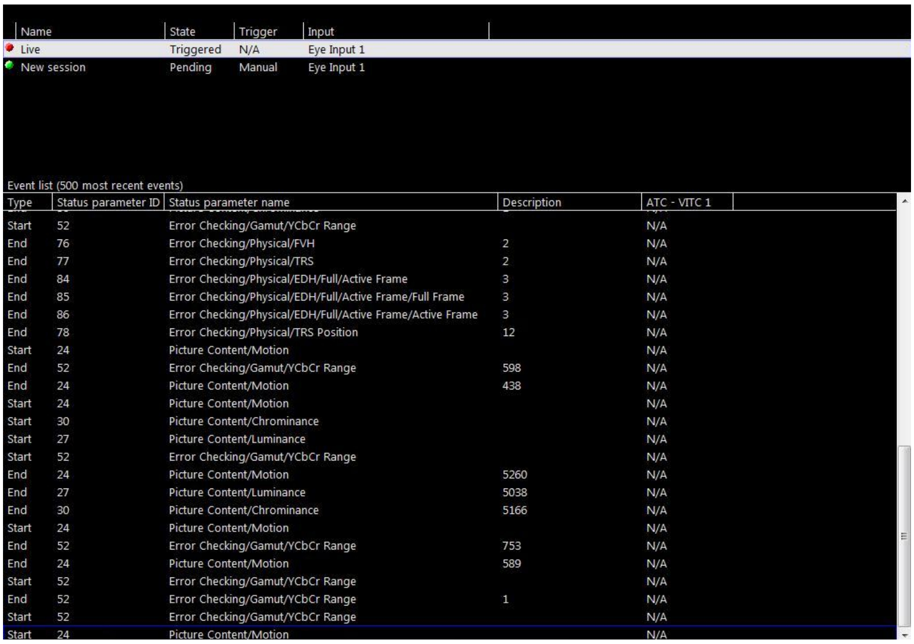

Figure 14: Event Log screen.

Events can also be tracked and responded to by SNMP. SNMP stands for Simple Network Management Protocol and it is commonly used in production line testing both to run the required test sequence and to monitor the instrument under test for conditions that warrant attention from the controlling PC.

The OTM/OTR supports remote control using the SNMP protocol. The protocol is based around SNMP commands sent by the controlling PC to the instrument under test, and SNMP trap signals generated by the instrument when selected conditions occur.

Where the SNMP Trap option is ticked, an SNMP trap will be sent each time the parameter in question exceeds the stated value, and again when the parameter returns to a value within the desired limits. These traps can be used both to advise the controlling software of behaviour outside the desired limits and to trigger an appropriate response from the controlling software.

Surround Sound

The production of a Surround Sound effect involves the use of either 6 or 8 separate audio channels to output separate components of the sound that together give the required sound image. The most common arrangement in which the channels are used is known as 5.1 Surround Sound. The '1' represents an overall 'Low Frequency Effects' (LFE) channel to be output at roughly the centre of the sound image, while the other 5 channels provide the sound to be output in the Front Left (L), Front Right (R), Front Center (C), Back Left (Ls), and Back Right (Rs) positions.

The OTM/OTR supports audio that has been set-up for delivery as 5.1 Surround Sound and it does so in several ways. Firstly the various PPM, Loudness and Lissajous displays described above can all be set up to display their information in terms of L, R, C etc. channels rather than audio channels 1 – 16. The OTM/OTR recognises the channels handled as simple stereo pairs and the same channels handled as components of a Surround Sound system as different audio inputs. All that the user needs to do is first ensure that the correct allocation of channels 1 – 16 to L, R, C etc., then set the display to analyse the required

Surround Sound audio input. The first action uses the Audio Inputs page of the OTM/OTR Config window; the second just requires selection of the required input via the Audio Inputs button offered on the display's Button Bar.

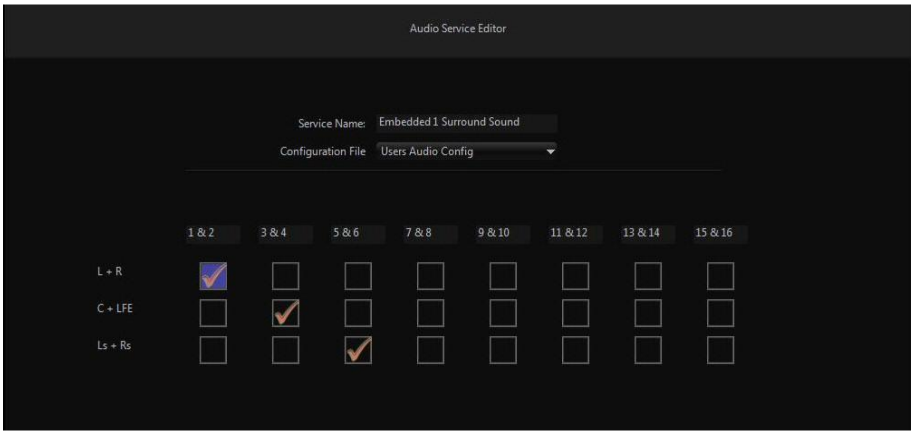

Figure 15: Mapping audio channels to Surround Sound components.

In addition, the OTM/OTR has a couple of special displays for Surround Sound inputs, one for PPMs and the other for Lissajous figures.

The special Surround Sound PPMs display was mentioned above when discussing Loudness. The individual PPMs of this display are created in the same way as the PPMs of the standard PPM View, and are coloured and marked (and configured) in the same way as the standard Audio PPMs described above The Surround Sound element to this display comprises the orientation of the PPMs showing the levels of the individual surround-sound channels according to their ultimate location in space. (The LFE channel, which would ideally be shown perpendicular to the centre of the display, is shown as a separate horizontal meter bar at the bottom of the display.)

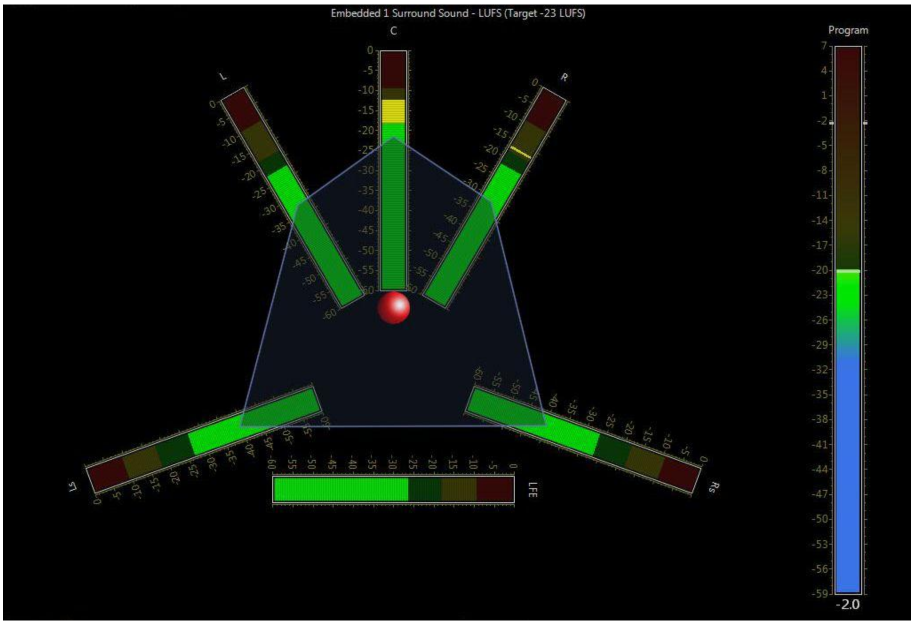

Figure 16: Surround Sound PPMs display.

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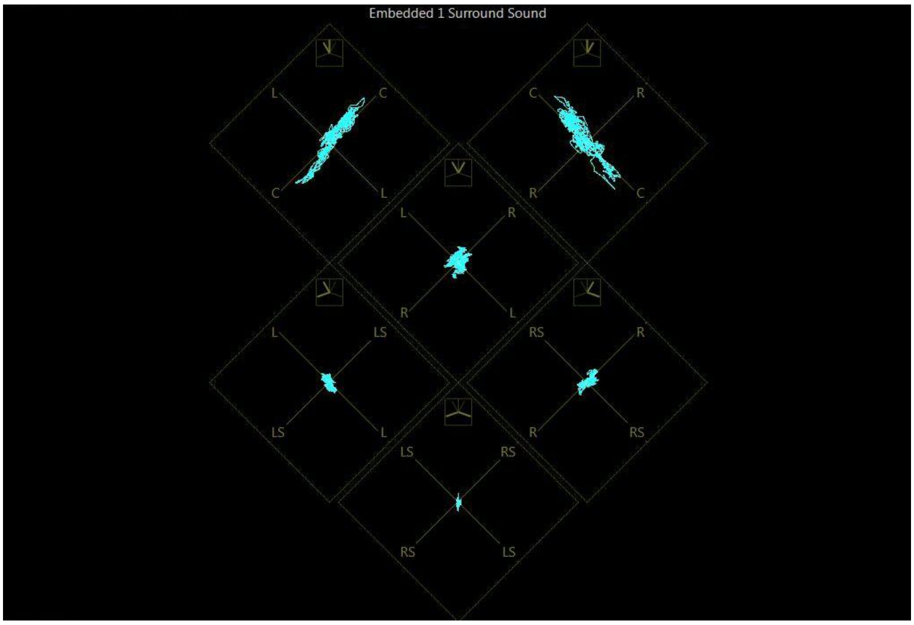

Figure 17: Surround Sound Lissajous display.

The Surround Sound Lissajous display allows the user to see all the different phase relationships that are in play in a single display. It shows the phase relationships between the different components as a set of six Lissajous figures that compare adjacent channels. The channels that are compared are indicated both by labels and by symbols showing their expected positions.

AES/EBU Audio

The audio associated with video can be delivered in a number of ways. One is as audio channels embedded within SDI video. Another is as digital audio data transmitted via separate cables.

The standards for serial transmission of digital audio data transmitted over twisted-pair conductors come from the Audio Engineering Society. Their AES3 standard, co-developed with the European Broadcasting Union, specifies the transmission format over a single twisted pair.

Analysis of AES/EBU standard audio on the OmniTek OTM/OTR is in many respects identical to the analysis of embedded audio. Where it differs is in the requirement for an AES card to be fitted to the OTM/OTR (to handle the audio input) and the configuration settings that are needed to work with this board.

The AES card needed to analyse AES/EBU audio is provided as part of the AUDIO_AES option that is available for the OTM/OTR. This card offers two ports referred to as I/O Ports A and B, and is provided together with two break-out cables, suitable for connecting to equipment with XLR connectors.

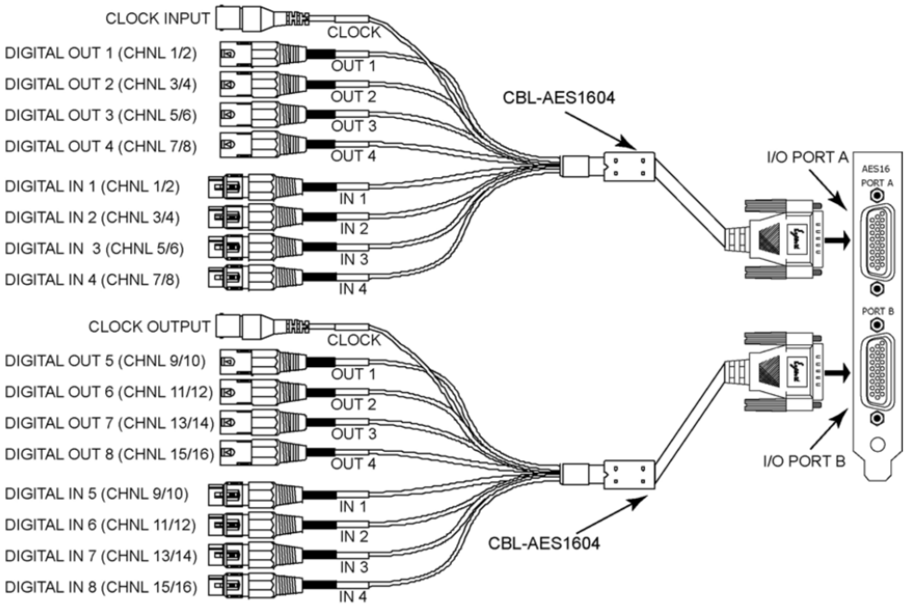

Figure 18: AES Card cabling.

With the AES card installed and configured, AES input may analysed on the selected analyser as AES PPMs, AES Surround Sound or as AES Dolby (where supported). The user simply has to set the Audio Input on the required display to the required AES source.

Dolby

The audio associated with a video can also be Dolby-encoded. Dolby encoding provides a way in which multiple audio channels can be delivered over a single channel pair.

Dolby-encoded audio takes the form of a sequence of frames. The frame format used is defined by the SMPTE 337M standard, which caters for a range of different non-PCM data types to be added to the audio channels.

With the appropriate software options installed, the OmniTek OTM and OTR systems are able to extract Dolby-encoded metadata and Dolby-encoded audio directly from SDI embedded audio, though in future versions, they will also be extract Dolby audio from audio delivered through the AES card (where fitted). The OTMs and OTRs are also able to play out the extracted audio through the AES card.

The OTM/OTR first needs to be configured to direct the built-in Dolby decoder to work with both the appropriate input and the appropriate stereo pair. This is achieved by first selecting the required Dolby input option on the Audio Inputs page of the Config window, then setting stereo pair from which the Dolby is to be taken in the follow-on Audio Services Editor page.

Name	Physical Input	Source	Type
Embedded 1	1	SDI	Pairs
Embedded 1 Surround Sound	1	SDI	Surround Sound
Dolby 1	1	Dolby D /E Decoder	Surround Sound/Pairs
Embedded 2	2	SDI	Pairs
Embedded 2 Surround Sound	2	SDI	Surround Sound
Dolby 2	2	Dolby D /E Decoder	Surround Sound/Pairs

Figure 19: Dolby inputs included among the other audio inputs on the Audio Inputs page of the Config window. Taking the Edit option from the Button Bar displays the Audio Services Editor, ready for the user to select the Dolby data channel

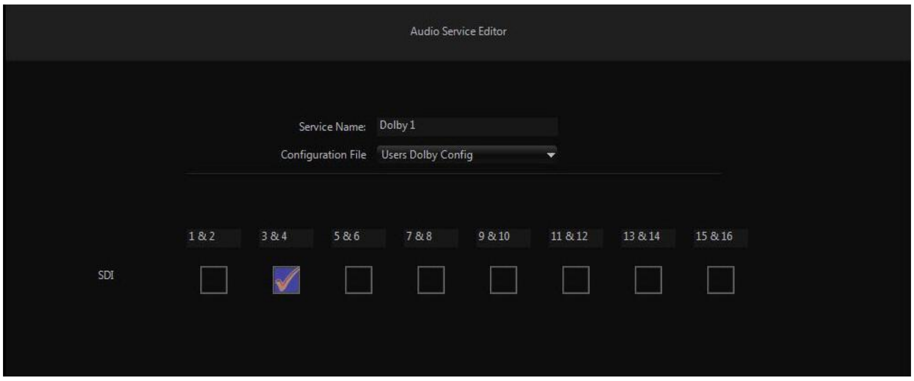

Figure 20: Dolby data channel selection.

The Dolby Decoder remains working with selected Dolby input until an alternative selection is made.

With the OTM/OTR configured for the appropriate input and the required stereo pair (as described above), PPMs can be displayed of the audio encoded within the Dolby data, the loudness of the Dolby audio can be displayed in exactly the same way as the loudness of other audio inputs, and Lissajous figures can be displayed showing the phase relationships that exist between the different channels.

The only special feature of the Dolby versions of these views is that the levels shown, the arrangement of the channels and the way they are labelled are all determined from the decoded Dolby data. Features such as the metering graticule and ballistics that are used and whether Peak Hold lines are displayed are under exactly the same controls as in the embedded audio versions of these displays.

Dolby Metadata

Dolby data is delivered in bursts of 'Dolby frames'. A significant proportion of each Dolby frame comprises metadata detailing how the coded audio is to be handled and metering information.

With the OTM/OTR configured for the appropriate input and the required stereo pair (as described above), the Status display for this input includes a complete decode of the embedded metadata.

The range of information transmitted as Dolby E Metadata is very extensive, so the information displayed is divided into sections. The main sections are as follows:

- **Program Loudness** – determined from the Dolby audio data.
- **Guard Band Position** – the video line at which the Dolby frame was found to start.
- **Bit Depth** – 16-, 20- or 24-bit
- **The Metadata Segment** – giving details such as Program configuration; Frame Rate; Frame Count; and Program Descriptions
- **Subsegment Data** – such settings as the data rate, the intended mix levels, the room type, the A/D Converter Technology used in creating the Dolby data, timecode information, filter and compression data

- **The Audio segment**
- **Various Metadata and Audio Extension segments**
- **The Meter Segment** – the metering information for the audio encoded in the frame
- **'Channels' section** – details for each channels such as whether the channel is present or absent and the level of the current frame.

Playback

The OTM/OTR is able to play back stereo pairs of audio channels either over a pair of headphones or over the OTM/OTR's internal speaker. Where the OTM/OTR includes the AUDIO_AES option, it is also able to play back up to 16 channels of audio over the outputs on the AES card.

Playback of stereo pairs is very straightforward. The required stereo pair is simply selected on the appropriate Audio PPMs display as the video is played out, while the volume is set either by turning knobs on the control panel or through the OTM/OTR's Properties control.

Playback over the AES card is slightly more complex in that the card first needs to be configured but play-out is otherwise very similar, except for being multiple-channel rather than just focussing a single channel pair.

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