Super Reality – Refining HD

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ABSTRACT: The demand for high bit-rates in HD acquisition and post-production in certain applications such as feature filmmaking, etc place great demands on the storage media. This applies particularly in the case of full bandwidth (4:4:4) signals being recorded to the "portable" media of cassette tape.

Maintaining backwards compatibility to existing and future HDCAM recorded material was also considered to be of prime importance in furthering the move to high definition video production.

Sony, through the development of the Super Reality tape format, has addressed the issue of minimising compression effects to give greater freedom in the post-production process thus enabling higher quality final display of the producer's craft. The original HDCAM concept and product has now been refined to give greater "quality" on tape while still supporting HDCAM.

This paper looks at the technologies used in the "Super Reality" products and how they achieve the high bit rates necessary for high end High Definition production.

INTRODUCTION

When the HDCAM format was released in the market a new era in high-end television production, commercial production and even movie-making applications arrived. Sony through the development of the multi-frame rate camcorder, the HDW-F900, together with the production VTR, the HDW-F500, soon enhanced these early products. These new products helped blur the divide between television and movie-making productions.

Globally there has been a steady rise in HD programming, to the extent that it is now becoming mainstream, and the HDCAM format has become the most popular format in general usage. In order to ensure international interchange of HD program material Sony has participated in the development of the ITU 709 global standard and committed the HDCAM product range to that standard.

The popularity of the HDCAM format has driven demands for even higher quality and higher recorded bit rates, with the ability to store at least two hours of program on suitable media. Not only was there demand for greater capacity in video but also a demand for greater capacity to cope with multi-channel audio was voiced.

In responding to these requests from the broader HD community for more headroom in digital recordings Sony has introduced an additional HDCAM format to be known as HDCAM-SR. This format enables higher data transfer rates, greater storage capacity and more audio channels than existing HDCAM models.

OVERVIEW OF HDCAM-SR

The HDCAM-SR product range has been developed around Sony's commitment to the ½ inch videocassette tape product as a storage medium for program material. This enables ready support for playback of other products, HDCAM and Digital BETACAM (optional), used in high-end production for SD and HD television programs.

The SRW-5000 studio recorder is similar to the HDW-F500 in that it is a multi-frame rate recorder and it acquires each picture frame according to the industry standard which specifies a sampling structure of 1920 x 1080 active pixels (H x V). As a studio recorder the SRW-5000 has all of the editing capabilities and features that have come through the Digital BETACAM and HDW-F500 platforms (including pre-read editing, variable speed and jog playback).

To provide a flexible platform for the various disciplines in the HD production environment the input and output configurations of the SRW-5000 has been refined to give the capability of 4:4:4 RGB input as an option to the normal 10bit 4:2:2 HDSDI input. Together with this input option there is built in the ability to up-convert and down-convert plus an optional 3:2 pull down is available for those working in a 60i environment.

Because of the interest from the moviemaking industry the SRW-5000 support the various progressive formats. However, the SRW-1, the portable HDCAM-SR recorder, offers additional facilities to give maximum flexibility in image capture. Through refining existing design ideas by adding innovative concepts the video data rate recorded to tape is increased to 880Mbps. This allows for recording of 4:4:4 images in the field with very high picture quality, thus ensuring very good multi-generation performance. The high bit rate of the SRW-1 allows for the simultaneous recording of two 4:2:2 High Definition signals with high picture quality. There is also the facility to cascade a number of the tape units to one processing unit thus giving continuous recording or backup features.

With the introduction of this format there is more to recording high bit-rates than just the recorder. Another refinement of the HDCAM format has seen the refining of the tape itself. With data obtained from years of tape manufacture Sony has come up with a tape that is a suitable companion for the new HDCAM-SR recorders. The tape media has been refined so that overall it is thinner and stronger than was previously possible.

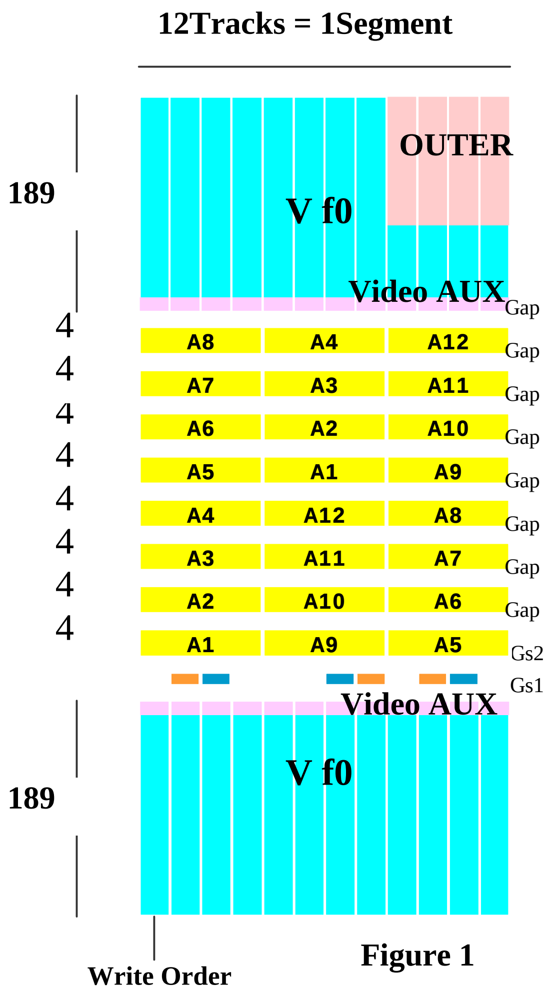

Figure 1

A further challenge in the use of a “standard” cassette shell is the desire of program makers to have the ability to record at least two hours of program on one cassette. This is easily achieved with the SR format with durations of 155 minutes for 24P recordings, 148 minutes for 25P (and 50i) recordings and 124 minutes for 30P (and 60i) recordings. With a small cassette these times fall to 50, 48 and 40 minutes respectively.

Built into the cassette shell is a facility known as Tele-File; this assists in storing and tracking the Metadata that enhances the raw video and audio footage stored on tape. Tele-File also makes the task of archiving easier as it acts as an intelligent label that stores the information electronically allowing for easy readout.

SUPER REALITY TECHNOLOGIES

The HDCAM-SR format is not a recycling exercise of past technologies. It is the implementation of the latest in technologies for all parts of the product; tape media, mechanical components, drum design and electronics. Without the coming together of these disparate areas the SR format would not be as solid as it is.

The format as recorded on tape follows the same basic structure as HDCAM in that along the length of the helical track there are two video segments either side of a group of audio segments. Each Field (or frame) consists of 12 tracks with a pitch of 13.2µm. The minimum recorded wavelength is 0.294µm giving a total video data rate of 440Mbps for the studio VTR. In looking at the track structure it can be seen that the audio information is repeated, but shuffled, in order to reduce errors due to tape damage. (Fig. 1)

a) MPEG-4 SP

The first major new technology is the use of MPEG-4 Studio Profile (SP) as the preferred compression strategy. To make efficient use of this technology Sony has developed an integrated encoding/decoding chipset, which together with other supporting chips realises the compact implementation of the (ISO/IEC 14496-2:2001-1) MPEG-4 SP. The Studio Profile was created to meet the demands of high-resolution image-production applications. It is not constrained by GOP structures and is scalable in its pixel count (SDTV, HDTV, Film-resolution data), its bit depth (10 or 12 bit) and its colour resolution (component or RGB).

To gain maximum benefit from this compression strategy, the HDCAM-SR format uses intra-frame compression for progressive image capture and intra-field compression for interlaced images. The high performance characteristics of MPEG4 SP offer reproduction of visibly lossless images. This enables good multi-generation performance of the HDCAM-SR products.

The compression process uses two parallel processes, Differential Pulse Code Modulation (DPCM) and DCT, to achieve the final result. (Fig 2) The DCT process used in the HDCAM-SR gives an improvement of about 13% over that used in MPEG-2.

The DPCM process is not to be confused with the use of PCM in audio. DPCM is not in itself a compression system, rather it is a technique that decorrelates data. It is a means of separating information from structure. In video and photographic images the intensity value of a pixel is likely to be very similar to surrounding pixels. This is the ideal situation for predictive coding.

Instead of coding an intensity value, we predict the value from our knowledge of the intensity values of one or more nearby pixels. In the HDCAM-SR data is grouped into macroblocks for the DPCM process. The first pixel value of the block is the reference level and the next pixel’s value becomes the differential of the reference. The following pixel values are then the

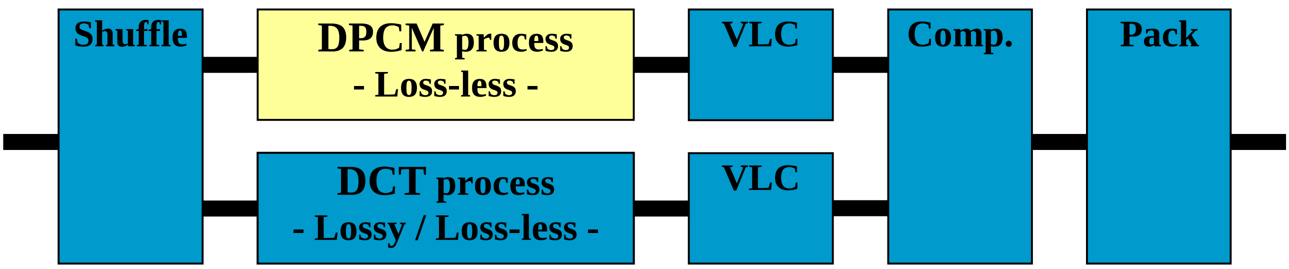

Figure 2

differential of the preceding pixel. There is no loss of original picture information only a reduction in the data required to carry that information. Thus DPCM could be seen as a loss-less compression system.

When the DPCM process is used in parallel with the DCT process in the HDCAM-SR both paths receive the same data from the shuffling process. The DCT process operates at the 8 x 8 block level while the DPCM operates at the 16 x 16 macroblock level. DPCM is very efficient at encoding large flat areas of the picture and when the outputs of the DPCM and DCT processes are compared, the bit rate from the DPCM process could be smaller. Therefore on those occasions the comparator will choose the DPCM data stream to be the output data. This will leave the DCT with a high bit-rate capacity thus allowing the quantiser in the DCT process to operate at a lower "compression" thus improving overall picture quality.

b) TAPE

The second advance in technology is with tape manufacture. The metal particles used for HDCAM-SR are half the length and only ¾ the diameter of the particles used for HDCAM tape. The metal particles have been chosen to retain high energy and small size. The tape surface has been further calendared so that it maximises tape/head contact – a very important property considering the smallest recorded wavelength is only 0.294µm.

The B-H curve of the HDCAM-SR tape is substantially "fatter" than HDCAM with a better than 50% increase in coercivity. Additionally the Output Signal verses Record Current for the HDCAM-SR tape has been improved such that there is a 6dB improvement over HDCAM tape.

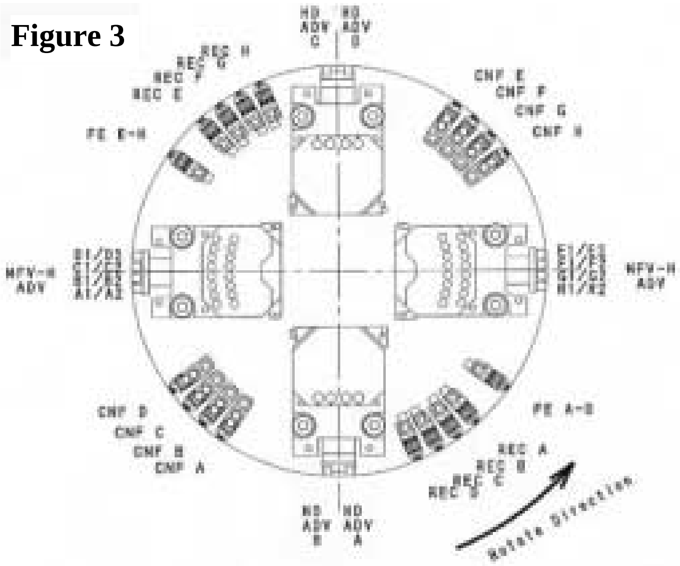

Figure 3

c) DRUM

Drum design is another key technology in the development of HDCAM-SR. The HDCAM-SR drum uses DT heads for normal playback as well as variable speed and jog playback. In order to track 13.2µm tracks a fresh approach to head design was called for. The result is a "four tip - eight gap Embedded Thin Film DT head. The use of twin gap head tips, where the two gaps are slightly offset, increases the tracking tolerance giving an improvement in Bit Error Rate. During playback, both gaps simultaneously trace the same video track. The off-tape data from the gap that produces a higher output signal is used for the actual image playback. In comparison to conventional systems, this unique mechanism allows a wider tolerance in head-to-track tracing.

Even though the HDCAM-SR has a reduced track pitch of 13.2µm the tracking performance is the same as HDCAM because the twin gap head tips have an overall width the equivalent of HDCAM track pitch.

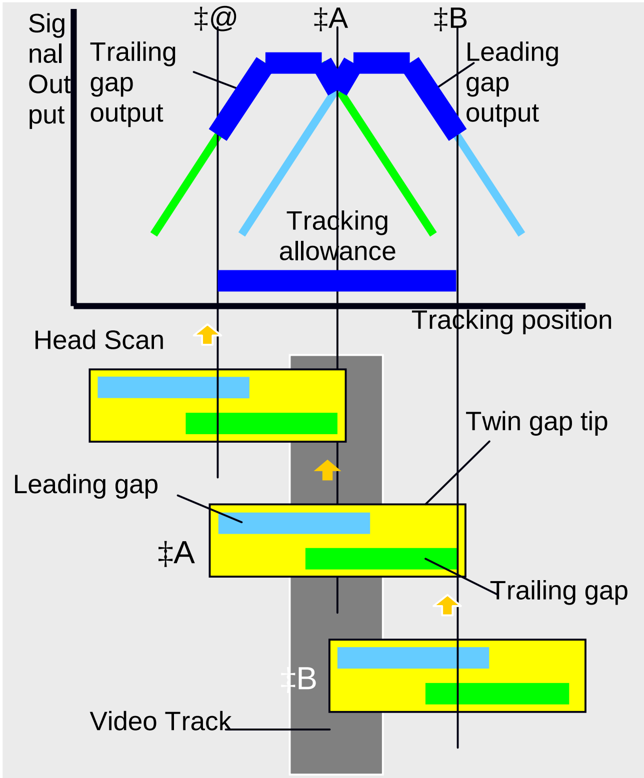

Figure 4

d) ECC

One of the most important facilities offered by a production VTR is the ability to do insert edits. A characteristic of all tape media, stretching, can cause corruption of data at the point of inserting new material. This happens because the original recorded material is now "out of format" because the tape has been stretched slightly. This problem is compounded as the track pitch gets narrower.

Hence with HDCAM-SR using 13.2µm track pitch it was decided to improve the ECC to give very strong correction. The ECC uses Reed-Solomon with 16 symbols for the inner and 12 symbols for the outer (for video) while audio uses the same number of bits as the data. The outer ECC for video is interleaved with the main program data in the tracks. Therefore if you lose one track at the edit point while doing an insert edit, the ECC is sufficient to correct the whole missing track.

e) Advanced Equaliser

There are three strategies used in the advanced equaliser to maintain optimum output. First the well-known technique of OVERSAMPLING, used in the audio world, is applied to the playback RF signal. This has been made possible through advances in chip design and supporting circuitry. This technique reduces aliasing distortion by ensuring the highest frequency signal recovered from tape does not come near the sampling frequency used in the ADC.

Second, the AUTO-EQ circuit uses an innovative method to achieve equalisation of the signal. This method is a great improvement over old analogue methods. This new method uses a Transversal Filter with 15 gain taps, giving the EQ process sufficient range of operation.

As part of the new method, a process called Least Mean Square (LMS), is used to safely choose the correct gain tap of the Transversal Filter by always going forward to a better EQ result therefore there is no possibility of overshoot.

The final strategy in the advanced equaliser is the improvement to the Partial Response IV ML circuit. It uses a combination of PR4ML and NRZ to change characteristics of PR4ML to give better response at both low and high frequencies. This response is similar to the characteristic of the combined tape and head responses, therefore optimising data recovery leading to an improvement in error rate. (Fig 5)

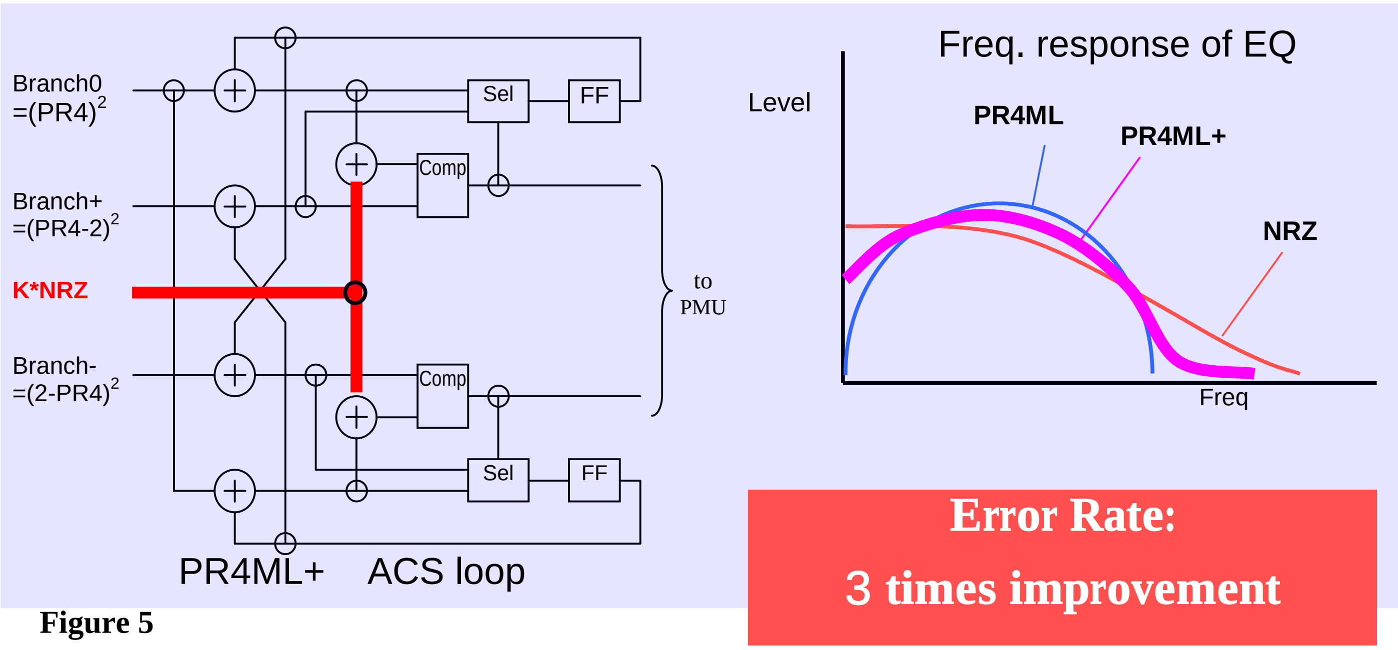

Figure 5

CONCLUSION

Together with all of the strategies above there is the development of encoder/ decoder IC's for MPEG-4 SP along with the development of many other specialist IC's that have enabled the HDCAM-SR format to come to fruition.

These IC's have been developed with the two-fold purpose of maximising data throughput while at the same time minimising power consumption. This is especially the case with the portable SRW-1, which is capable of being powered by a DC source. The other advantage of minimising power consumption is the reduction in heat thus leading to greater reliability of components.

By refining all aspects, tape media, mechanical transport and electronic circuitry, of the recording process SONY has achieved its goal of reliably recording high bit-rate, High Definition signals onto a portable media; ½ inch cassette tape.

Together with other products developed for HD acquisition and postproduction, the new Super Reality (SR) format assists in refining the director's craft in producing film quality footage suitable for a range of markets from Large Screen projection through to viewing at home in a home cinema experience, or even on future G3 products.

The refining of HD is more than product - it is the whole environment from concept through acquisition into the area of production and on into the display of that final refined concept that came to birth in the mind of the producer.

HDCAM-SR seeks to make transparent the "mechanicals" of the birthing process by being a portable and flexible high bit-rate acquisition media that allows for maximum creativity in usage.

Digital broadcasting opens up new vistas of possibility where the details of the ideascape and the horizons are anything but clear. The changeover will require not only training in the technical detail required to produce and transmit sound and pictures (e.g. compression issues), but training in thinking differently about the product and its capabilities in terms of both the content and the look and sound of the product (e.g. links between the Internet and programs and how to use them) and the different production values coming into play with wide screen.