Testing the new television tape formats for news and sport

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Last year, two new digital tape recording formats were launched, aimed at the news, current affairs and sports sectors of television production: Sony Betacam SX and Panasonic DVCPRO. In co-operation with the manufacturers, EBU Group P/DTR carried out extensive tests on these new formats and their reports on the tests became available in April of this year. These will be made available only to EBU Members.

In this article, the Author presents a synopsis of the EBU reports on these two new tape formats.

1. Introduction

In spite of the loudly-expressed opinion that tape is dead, broadcast equipment manufacturers are introducing new tape recording formats at ever-increasing rates. In early 1996, Sony and Panasonic separately announced new digital formats which were intended to fill the gaps in their existing product ranges – caused by the introduction of digital formats at the higher levels of quality (and expense) while relying on analogue equipment for the day-to-day operations of ENG and EFP. The proposals would separately result in robust easy-to-use and inexpensive equipment which could be used where speed and cost were important and the production scenario was simple. This type of operation makes up a large part of the in-house production of many television broadcasters, and EBU Members showed a lively interest in these two new formats. They seemed to be particularly attractive for news, current affairs and sports operations.

The EBU Production Technology Management Committee (PMC) asked EBU Project Group P/DTR (Magnum: Digital Television Recording) to investigate these two new formats. The P/DTR group had been given advance notice by the manufacturers of their intentions to develop these new formats and had drafted an EBU Statement, D73 [1], which outlines the requirements of the users for new digital production systems. The EBU group – and its predecessor, MAGNUM – had already carried out tests on previous generations of television tape formats, for example:

– Digital Betacam and D5 in 1995;

– D2 and D3 in 1992 [2];

– Betacam SP and MII in 1988 [3].

It was natural therefore that P/DTR should conduct tests on the newly-proposed formats. The group reached agreement with the manufacturers on the principles of what should be tested and how. The more-detailed negotiations for the test arrangements took longer than expected, as both manufacturers had their own development timetables and the respective products would reach fruition at different times. The P/DTR group also

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decided not to conduct competitive tests on the formats. There was room for a number of different approaches to meeting the needs of broadcasters and it seemed very unlikely that any single format would ever achieve the universal status gained by the quad format in the early years of television recording.

However, the tests would be meaningless unless the aims and methods were clearly defined beforehand. So a vital part of the negotiations with the manufacturers was to agree representative scenarios in which the equipment would be used, and to devise realistic models that could be used to test the machines with the resources available.

The tests started in late 1996 and were carried out by a group of EBU Members from the IRT, the BBC, Channel Four, RAI and RBT. Other members of the EBU group were involved in expert evaluations of those aspects that depended on the opinions of the users. The tests were carried out in collaboration with the respective manufacturers who provided the equipment under test, and carried out modifications to allow some detailed measurements to be made. The reports on the tests were ready in April 1997 and, by agreement with the two manufacturers, will only be available to EBU Members.

Figure 1
Most of the tests were carried out at the IRT in Munich.

As with all tests made during the early days of a new format, it is important to separate the format itself from its implementation. Equipment can and does improve as new models are developed. Features are added or removed to make the equipment more attractive. Prices of equipment and supplies are adjusted to meet the market conditions. Tests can thus only provide a snapshot of a moving target. However once the basic parameters of a format are decided, such as the footprint on the tape and the signal processing, these cannot be changed without massive inconvenience and cost to the users. If broadcasters are tempted to complain at the rate of introduction of new recording formats in television, they only have to look at how often there are changes to the software and hardware in their office computers.

2. The testing

Most of the tests were performed at the IRT laboratories in Munich; the subjective evaluations were carried out by the RAI Research Centre in Turin.

The tests were carried out on six separate aspects:

1. **Format robustness**: how reliably the data could be recovered from tape in various adverse conditions likely to be encountered in practical use.
2. **Encoding format**: how the video, audio and data components of the television signal were processed.
3. **Integration into different production scenarios**: the overall performance of both formats during production operations.

Abbreviations

DCT	Discrete cosine transform
DSCQS	Double-stimulus continuous quality scale
EFP	Electronic field production
ENG	Electronic news gathering
FEC	Forward error correction
IEC	International Electrotechnical Commission
IRT	*Institut für Rundfunktechnik GmbH* (German broadcast engineering research centre)
ISO	International Organization for Standardization
JPEG	(ISO) Joint Photographic Experts Group
NLE	Non-linear editing
MPEG	(ISO) Moving Picture Experts Group
PCM	Pulse code modulation
RBT	*Rundfunk-betriebstechnik GmbH* (German company specializing in broadcast operations technology)
SDI	Serial digital interface
VITC	Vertical interval time-code
Y/C	Luminance/chrominance

Format Parameters		Betacam SX	DVCPRO
Tape width (nominal)	(mm)	12.65	6.35
Tape material		Metal particle	Metal particle
Tape thickness	(µm)	14.5	8.8
Maximum recording duration	(min)	S: 60, L: 184	M: 63, L: 123
Video sampling luminance	(MHz)	13.5	13.5
Video sampling chrominance	(MHz)	6.75	3.375
Video quantization	(bits)	8	8
Active lines / frame processed		608	576
Audio sampling	(kHz)	48	48
Audio quantization	(bits)	16	16
Audio channels		4	2
Channel code		S–NRZI PRIV	24–25
Error correction		Reed-Solomon product code	Reed-Solomon
Recorded data rate	(Mbit/s)	43.8552	41.85
Shortest wavelength	(µm)	0.744	0.487
Track pitch	(µm)	32	18
Tracks / frame		6 (average value)	12
Longitudinal tracks		Control, Time-code, Aux.	Control, Cue
Tape speed	(mm/s)	59.575	33.85
Head / tape velocity	(m/s)	19.1	10.2

As implemented		Betacam SX	DVCPRO
Drum diameter	(mm)	81.4	21.7
Drum frequency	(Hz)	75	150
Record heads		2	2

Table 1
Format and implementation parameters of the Betacam SX and DVCPRO machines tested by the EBU group.

4. **Compatibility**: how the equipment performed when used with other formats.
5. **Compliance with specifications**: how the equipment met various interface and signal specifications normally expected of television equipment.
6. **Format implementation**: this tested the equipment and how it operated.

Each of these is dealt with in more detail below. In spite of the reluctance to compare them directly, the two formats will be dealt with together in order to avoid unnecessary repetition.

3. The formats

The two new formats have been described in many other publications, so only a brief description is given here. *Table 1* lists their major parameters.

3.1. Betacam SX

The Betacam SX format has been developed by Sony. It uses $^1/_2$-inch tape and cassettes of the same size as the Betacam SP and Digital Betacam formats. In the case of the SX format, the digital signal recorded on tape has been designed to be more rugged. It uses a higher level of digital compression (DCT-based) than Digital Betacam, which results in a lower bit-rate after coding. More generous forward error correction (FEC) can be used at the same time as relaxed mechanical parameters to ensure that the data on tape is recovered with low error rates, even in adverse conditions. In addition, the SX datastream on tape is organized so that it can be recovered as individual blocks which enables a non-tracking replay technique to be used.

The video compression is based on the techniques used in the recently-agreed 4:2:2 profile of

MPEG. It uses an IB sequence[1] of pictures at a data-rate of about 18 Mbit/s. Four studio-quality (48 kHz, 16-bit) PCM audio channels are provided. The format also provides for a longitudinal control track, time-code facilities and auxiliary tracks.

The studio equipment tested included a so-called *hybrid* version of the recorder – the Betacam SX Hybrid – which contains an integral hard disk. Data from the tape player can be transferred to the disk at about 4 times normal play speed, and the resulting material can be edited on the disk for play-out. The operation of this equipment is quite different from a traditional studio recorder. The manufacturer is still developing this concept and, since the EBU tests, several important modifications have been made to the equipment and the way in which it operates.

3.2. DVCPRO

The DVCPRO format has been developed by Panasonic Broadcast. It is based on the consumer DV format and uses much of its hardware and electronics. Using $^1/_4$-inch tape, the cassettes are the same size as the larger cassettes of the DV format. The recording system uses efficient error correction to reduce the need for mechanical accuracy but, otherwise, it is a conventional helical-scan system with a control track. The video signals are compressed using DCT algorithms and chip-sets developed for the DV format. The signal coding is 4:1:1. Each frame is coded individually (intraframe-only) at a video data-rate of about 20 Mbit/s. Two studio-quality (48 kHz, 16-bit) PCM audio channels are provided. The format has a longitudinal control track and a longitudinal audio cue track.

4. Format robustness

4.1. Error correction, concealment and headroom indication

Forward error correction is a vital element in the design of a digital recorder. The FEC, and the associated arrangement of data on the tape, have to compensate for corruption of the datastream due to the many possible imperfections in the tape path. All FEC strategies break down at some point in which case it is necessary to replace the data rather than attempt to correct it. Replacement, or concealment, depends on there being redundant data available. In the case of uncompressed video or audio data, there is usually sufficient redundancy in the signal to enable errors to be concealed without unduly degrading the output. For compressed video data, however, concealment is less effective because the redundancy has already been largely removed (the higher the compression factor, the less redundancy there is). The data recovery, therefore, has to depend almost totally on the error-correction system. There are particularly severe consequences in compressed systems if an entire DCT macro-block is corrupted. Both formats therefore use robust error-correction strategies and provide considerable redundancy in the video data signals.

The audio channels of both formats also have considerable redundancy (DVCPRO: 100%, Betacam SX: 159%).

In addition, the SX Hybrid recorder uses a “non-tracking” technique where a large number of heads scan the tape and more than one track picks up the data. Error-free samples are selected from the data blocks and then assembled into the correct sequence.

Both machines use a “traffic light” system (green – amber – red) to indicate the error performance.

The EBU group assessed the performance of the error-correction strategy by moving the heads away from the recorded tracks and logging the error-rates against the off-track position. The manufacturers had provided specially-modified machines for these tests. These measurements showed that the error correction on both formats performed well, even under adverse conditions. A number of experts confirmed the effectiveness of concealment by observations made on the picture quality.

The traffic-light indicators worked well; they provided a useful warning of the range of error correction in hand. However, the onset thresholds appeared to be different between the two formats.

4.2. Robustness to environmental influences

News and sports operations can take place in a wide variety of climatic conditions, ranging from alpine winters to tropical summers. These requirements were defined many years ago in EBU Statement D31-1981 [8]. The EBU investigated whether the recording footprints could be maintained within the range of temperature and humidity conditions that can be encountered in television programme acquisition. Recordings were made in a climate chamber under a range of environmental conditions. These sections were replayed and edited under controlled studio con-

1. Intra-coded frame followed by a bidirectionally-predicted frame.

ditions. The error rates were then measured to see if they changed over the sections that had been recorded in different conditions. The tape was also developed (i.e. processed) to make all the data tracks visible, and the straightness and position of the tracks were then measured.

Both formats showed little variation in the track footprint and any changes were well within the range of the error correction.

4.3. Edit stress test

The EBU tested the mechanical robustness of both the tape transport and the tape itself by making repeated edits at the same point. Due to the IB structure used in the SX format, tape edits were only possible at restricted points in the video structure. Therefore, a different procedure had to be used for the two formats. The error rates were measured to see if they changed over the edited sections.

Only very small differences were found in these investigations and the errors were well within the range of the error-correction systems used.

4.4. Channel failure strategy

Head failure or head-clogging are common problems in tape operation, especially during operations in the field. The EBU simulated a head failure to test the effectiveness of the shuffling and concealment in the worse case, and to verify that alarms were given. They disabled one playback head and observed the impact on the quality of the audio and video output, and they checked the occurrence of error flags.

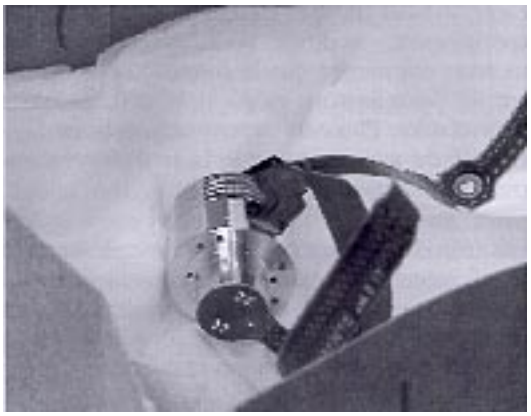


Figure 2
The scanner assembly from the Panasonic DVCPRO machine.

Figure 3
The scanner assembly from the Sony Betacam SX machine.

The DVCPRO studio machine was able to detect a failed replay head and switch automatically to a record head to cover the missing signal. This effectively maintained the output signals at the same time that an alarm was given.

The non-tracking playback system on the SX Hybrid machine could cover the loss of up to two heads by using the output from the other heads. On the SX camcorder, a single head failure was visible on the video output but there were no audio errors.

If a head became clogged during recording, the machines of both formats detected abnormal recording currents and raised an alarm.

5. Format implementation

5.1. Scanner replacement test

The heads of all helical formats move in contact with the tape at high speeds and steadily wear away. This is likely to happen several time in the life of a machine and it is important to get the machine back into service by replacing the heads and/or the scanner assembly as quickly and easily as possible (*Figs. 2* and *3*). The EBU group checked the complexity of the procedure to replace the scanner by logging the time needed for the mechanical dismantling and re-installation, the servo adjustments and optimization of the assembly. In addition, the EBU verified the accuracy achieved by examining an edited section inserted into a recording previously made on the old scanner.

The group concluded that, on both implementations, the replacement of a scanner was relatively quick and straightforward. It was possible to produce accurate recordings with the replacement scanner.

5.2. Playback at shuttle speeds

Users want to sort, locate and identify their programme items. In particular, they often need to find a very short item on a long tape. The EBU group asked experts to assess the off-tape picture and sound quality during high-speed shuttle. In the case of the SX Hybrid machine, these assessments were also made off the hard disk. The per-

formance of a Betacam SP machine was used as a reference.

This comparative assessment was not as easy as it sounds because the visible effects of the DCT compression blocks are quite different to the familiar noise-bar effects of analogue recording. Furthermore, the visibility of the DCT blocks varies randomly with shuttle speed: the quality can be poor at one speed but much better at nearby speeds above and below. Comparisons at fixed speeds can be unfair to one or other implementation. The assessments were made over a range of speeds up to x50 (and above for the SX format). The experts were also asked to assess the shortest length of material that could be located at various shuttle speeds.

Because of the difficulties mentioned above, the ratings should only be taken as a coarse indication. As a very rough summary, both formats were rated worse that Betacam SP, particularly at the slower speeds. However, the pictures were still usable.

Similar listening tests were made on the audio quality in shuttle mode, where extensive processing is necessary in order to produce recognizable sounds from the digital tracks. On both formats, the digital audio was muted at shuttle speeds above the lower range. The DVCPRO format has an analogue audio cue track that can be used to locate audio segments.

5.3. Data integrity after power failure

This test was made to find out if the tape is damaged in the event of a power failure at the worst possible moment, i.e. at maximum shuttle speed. After this somewhat drastic but nevertheless plausible treatment, both tape transports slowed down under control and the tape could be recovered and played with no observable ill effects. The hard disk in the SX Hybrid recorder survived the same abuse.

5.4. Removal of stuck cassette

If a machine stops for any reason during an important replay, it may be necessary to extract the tape and put it into another player. The EBU group evaluated the time needed to carry out this operation and noted any difficulties encountered. They found that with both implementations, the tape could be rewound manually and the cassette extracted without damage, although this took a few minutes and needed some practice and a knowledge of the procedure.

5.5. Acoustic noise

Most users are accustomed to the comparatively high noise levels made by studio recorders, arising from the rapidly-rotating scanners. These noise levels are far less tolerable in camcorders, especially when separate sound equipment is not used. The EBU group measured the operating noise levels of the machines in an anechoic chamber at the IRT in Munich. The machines were not as quiet as desirable but the noise levels heard were no worse than is the case with current equipment. The camcorders were quieter than the studio machines.

5.6. Compliance with EMC specifications

It is becoming more important – for legal as well as technical reasons – that all broadcast equipment complies with the European or IEC Standards for electromagnetic compatibility. The machines were tested for the interference fields they generated, their resilience to electrical discharges and the influence of external electrical fields on the operating functions and the output signal quality.

In some cases the equipment did not pass these tests, mainly because some items, such as mains adapters, had not been designed to meet the European requirements. The manufacturers are confident that production models will comply with these requirements.

6. Encoding format

Early digital television recorders (D1, D2, D3, D5) were intended to be transparent to the input signal. Even the Digital Betacam format used such a low level of compression that it aimed to be "subjectively" transparent. In recent digital television recorders, the designers have made compromises between the theoretical transparency to the complete television signal and practical factors such as cost, size, weight, etc. The EBU group evaluated the consequences of these decisions from a number of aspects.

6.1. Ancillary data capacity available

A serial digital interface (SDI) signal has a large unused area in the vertical and horizontal blanking intervals (VBI and HBI) of the picture. This is used for a variety of signal types such as embedded audio, digitized analogue test signals, "analogue" data signals such as teletext, and true digital data. In recorders, some of these signals are discarded, some are extracted and carried on other parts of the data track (for instance, the

embedded audio) and some are passed through the video-processing chain.

The EBU groups examined how these options were exploited on the equipment under test and noted the proposals made by the manufacturers for future models.

The SX format records most of the usable blanking lines but passes them through the video compression chain. The data on one of the VBI lines in each field can be extracted and recorded transparently as data.

Currently, the DVCPRO format does not record any blanking lines but can extract the VITC, record it as data and reinsert it into the replay output. It can also record data from about two lines of the luminance VBI. Other options are promised for the future.

6.2. Interaction between VBI data and the active picture

In the SX format, teletext and other signals inserted in the VBI from lines 9 to 22 and 322 to 335 are recorded via the video compression system. The group found that, depending on the active picture content, the VBI signals were somewhat distorted on playback.

The DVCPRO format does not record the VBI signals as part of the video data.

6.3. Picture and sound quality in different replay modes

In television operations, recorders are frequently used to replay in slow-motion or still-frame mode. This is an essential requirement of a format intended for use in news and, especially, in sports production. The EBU group asked the expert viewers and listeners to compare the picture and sound from these new formats with those from Betacam SP at slow speeds of up to normal forward speed, and also in reverse. The expert viewers considered that the normal picture quality was available at these speeds. The expert listeners judged that the sound quality was acceptable at slow to normal speeds, being about the same as that produced by the Betacam SP format.

6.4. Editing accuracy

The editing accuracy of a recording format is an important parameter. Modern television production demands complete freedom to insert and assemble sequences. Ideally it should be possible to join any two sequences from either programme segment at any picture. This was possible on the DVCPRO studio recorder.

With the SX format, the situation is more complex because the IB frame sequence of the compression system suggests that editing points will be more restricted. Bidirectionally-predictive (B) frames need to access both the preceding and the following intra-coded (I) frames for correct decoding. Strictly speaking, the only way to preserve the integrity of the datastream during an edit is to decode and recode both the bitstreams. In practice, the B frame occurring immediately before an edit point can be converted into a predictive-coded (P) frame by referring only to the frame before. Unfortunately, the SX equipment available for the tests was not functioning as fully as the manufacturer intended. However, since the EBU tests, the SX Hybrid recorder and its edit controller have been modified to improve the editing operation. The EBU has agreed to re-assess this aspect of the SX equipment.

6.5. Picture quality of different compression algorithms – expert comments

The picture quality obtained from analogue recorders was always the best available, given the limitations of the technology. With the advent of the D1 digital format, the picture quality was theoretically perfect, in other words transparent to Rec. 601 [4] signals. With the more recent digital formats, compromises have sometimes been made between the video quality and various other factors such as robustness, size and price. The EBU evaluated the video quality of both formats under test to see if it was acceptable, taking account of any advantages offered as a result of these compromises.

Two types of picture-quality tests were carried out: expert viewing and subjective evaluations. The subjective evaluations were complex and time-consuming, and thus were limited to the SX and DVCPRO formats. The expert viewing tests, on the other hand, also included the DV, DVcam and Digital-S formats.

The *DV* format is aimed at the general public but is already in use by broadcasters.

DVcam is derived from the DV format. It is intended to be a lightweight technology for acquisition at a “professional level”.

The *Digital-S* format is based on an extension of the DVCPRO chip-set and uses S-VHS tapes. It is intended to be an economic format, and provides sufficient headroom for post-production operations when used “professionally”.

The EBU group took the opportunity to assess the basic quality of each individual format and to receive advanced warning of incompatibilities between any combination of formats when used in concatenation. The experts viewed a wide range of different test sequences, with the Betacam SP formar serving as a familiar reference. Any interconnections between the equipment were made via an SDI to eliminate the effects of poor interfaces.

7. Integration into different production scenarios

7.1. General

Under controlled conditions, the EBU group set up a series of subjective picture-quality evaluations to test the two new formats. The subjective evaluation of compressed formats is difficult because different compression algorithms have widely different effects on different pictures. Theory and experience have led to a range of picture sequences that are known to be difficult for various existing compression systems. It is also known that some pictures are critical if compressed to some bits-rates but not at all critical at higher bit-rates. Most of the existing testing experience comes either from systems with high compression, exploiting as much as possible the temporal redundancy, or from systems working at low compression ratios where little or no information is lost.

The two formats under test use moderate compression and one of them (SX) exploits temporal redundancy, although only over adjacent frames. The EBU group took great care to select pictures that were both realistic and fair to both systems. They chose six sequences representing a range of criticality for compression systems of these sorts. In particular, they included sequences with fast action and much detail to represent typical news and sports material.

Having chosen the pictures, the group then established three scenarios to represent typical production processes. Again, they tried to make these as fair as possible to the formats under test. Merely evaluating the quality after multiple generations is not very informative because once a signal is compressed, the recording and replay processes are transparent provided the error correction is working. The compression systems have to be forced to recode, using different DCT blocks, by altering the picture content.

The three scenarios chosen for the tests were:

– **Acquisition**, where the material is broadcast directly with no significant post production;

– **Hard news**, where the processing of the material is fairly simple (editing, the addition of titles, etc.);

– **Magazine**, where the material is subjected to more-complex post-production processes.

The subjective evaluations were performed in accordance with the DSCQS method normally used for such tests [5][6]. The viewers – all *non-experts* in television – were seated at two different viewing distances: close to the screen for critical viewing (4H, i.e. four times the screen height) and at a normal viewing distance (6H). Two sorts of references were included – absolute references (4:2:2 quality) and relative references (Betacam SP quality).

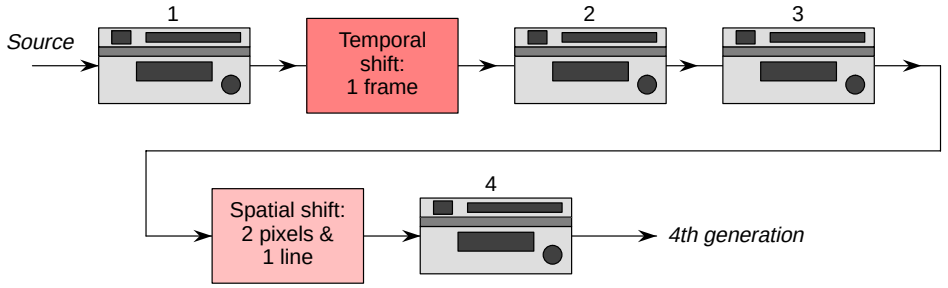
A recording of the test sequences is available to allow others to repeat the tests.

7.2. Quality in isolation

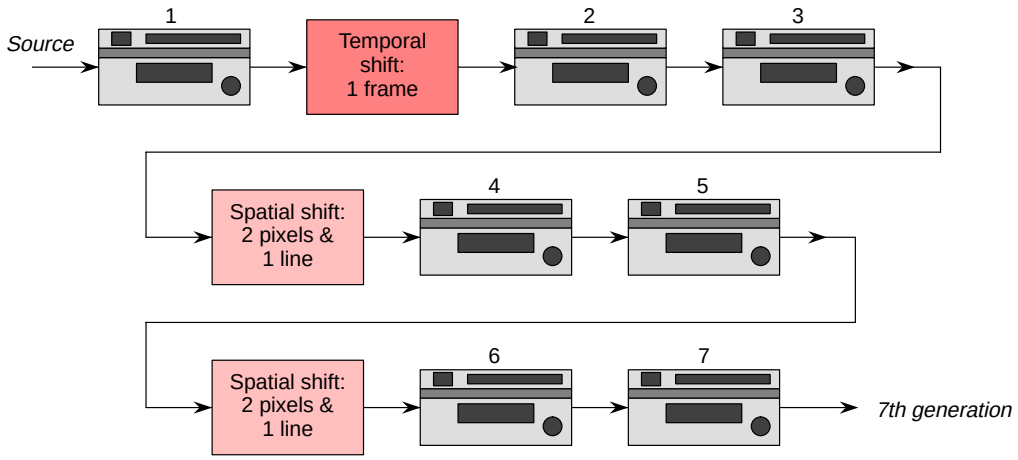
The Acquisition scenario was simply a single generation of compression and decompression. For this, the viewers rated both formats slightly worse quality than the reference but comfortably below the normally accepted threshold of transparency. Interestingly, both were also rated slightly worse than the Betacam SP reference.

In the News scenario, both a temporal and a spatial shift separated four generations of compression and decompression (*Fig. 4a*). This was to make sure that the compression algorithms were not simply repeating what they had already done. The viewers rated the quality to be generally transparent with the exception of one sequence at normal viewing distance (6H) and two sequences at the closer distance. The overall quality was rated much the same as Betacam SP. This was also quite surprising as it showed that the compression artefacts were seen to be as significant as the noise, delays and other defects that are traditionally associated with analogue recording.

In the more-demanding Magazine scenario, a temporal shift and two spatial shifts separated seven generations of compression and decompression (*Fig. 4b*). Much greater differences were noted between both formats and the absolute reference. In fact, at the closer viewing distance (4H), most sequences were rated considerably worse than transparent for the SX format, and all the sequences for the DVCPRO format. At the normal viewing distance, both formats were rated overall at about the threshold of trans-



a **News scenario**



b **Magazine scenario**

Figure 4
The test chains for the News and Magazine scenarios.

parency, with considerable differences between the results from different sequences. In this scenario, both formats were consistently rated considerably better than the Betacam SP reference which suffered conspicuously from accumulations of Y/C delays.

These conclusions were supported by the opinions of *expert viewers* who assessed sequences of different source quality and content. Their conclusions were:

1. **First-generation basic Acquisition scenario**: Betacam SX suffers from artefacts, especially for sequences with high motion content. With DVCPRO, there is a visible reduction of colour resolution in critical scenes but otherwise the format does not seem to be very sensitive to picture content. On average pictures, both the formats are similar to Betacam SP.

2. **Four-generation News scenario**: The two formats are considered to be satisfactory for news broadcasting; the picture quality is similar to Betacam SP.

3. **Seven-generation Magazine scenario**: With both formats, artefacts of different kinds are visible on critical pictures even at large viewing distances. On average, the picture quality from neither format is considered to be completely satisfactory for broadcast applications, even though both are better than Betacam SP.

The experts added the important rider that the acceptability of the two new formats was with reference to the existing Betacam SP quality, and took into account their experience of current operations and practical factors such as cost, etc.

7.3. Quality through transmission channels

A further series of viewing tests was carried out to establish if an existing transmission chain (represented by PAL) or a future transmission chain (MPEG-2: 6 Mbit/s option) would seriously interact with either format. The source material was

the output of the Magazine scenario. The conclusions of the experts were that:

– any impairments produced by both formats are still visible at the end of a transmission chain (MPEG-2 or PAL);

– both formats are considered to be as suitable as Betacam SP for use in production, given a PAL or MPEG-2 transmission chain.

7.4. Quality when used with other production systems

It is quite likely in today's conditions that material on one format will be introduced into a production chain based on the other format, especially in a news situation. The group investigated this possible concatenation of the two formats for the News scenario. There were no dramatic effects but the experts concluded that the output appeared to collect all the impairments of the different algorithms. Therefore, the simultaneous use of incompatible formats continues to be a risk.

In routine production, it is possible that either format could be used as a source for existing or future non-linear editing (NLE) systems. A system using Motion JPEG was selected as typical of the higher-end systems which use compression. It was tested at two levels of compression, both of which used considerably higher bit-rates than the SX and DVCPRO formats. The experts concluded that any post-production operations that are performed with high bit-rate algorithms (MJPEG at 40 and 48 Mbit/s) do not seem to degrade the picture quality further. This was true for chains ending in the studio as well as for chains which included transmission systems.

8. Replay compatibility

It is attractive to the user of a new format if the machines can replay recordings made on a preceding format or an associated format. The proposals from the manufacturers were that:

– the SX format machines could replay Betacam SP tapes which share the same cassette size;

– the DVCPRO format machines could replay DV and DVcam tapes either directly or with a suitable mechanical adapter;

The EBU group recorded a wide range of test sequences in the SP, DV and DVcam formats. A series of evaluations was then carried out to compare the tape playback performance of (i) the SP tapes played back on an SP machine and on the SX machine under test and (ii) the DV/DVcam tapes played back on DV/DVcam machines, as appropriate, and on the DVCPRO studio machine under test.

The EBU group found that, generally, there was good replay compatibility between the SP/SX formats and between the DV/DVcam/DVCPRO formats. However, they found some misalignments in the machines under test, particularly regarding the audio tracks. There seems no reason why these problems should not be corrected in the production-line equipment when it is delivered.

9. Compliance with general broadcast specifications

The last series of test made by the EBU group, in collaboration with the German National broadcasters, were measurements on the output and input interface signals. These measurements are perhaps not strictly concerned with the formats themselves but rather with the hardware implementations of the equipment under test. Nevertheless, even a perfect format will be unacceptable if the equipment delivers or requires a non-standard analogue or digital signal which is incompatible with the other equipment owned by the broadcaster. If nothing else, these factors reveal if the manufacturer has seriously considered how the equipment will be used.

The equipment supplied had digital video outputs (SDI with optional embedded audio) and both composite (PAL) and component analogue video interfaces.

The SDI outputs of both implementations were found to be within specification with the exception that the rise and/or fall times were too fast. The consequences of this would depend on the infrastructure in use.

Measurements made at the analogue video outputs, derived from SDI inputs, were within specification, thus confirming the quality of both the analogue interfaces and the digital-to-analogue converters of the formats under test. Further measurements made on (i) the analogue *component* video outputs derived from the *composite* inputs and (ii) the analogue *composite* video outputs derived from the *composite* inputs, confirmed the quality of the internal decoders and coders (as the internal processing of both formats is in component form). These measurements were made in electronic-to-electronic and play modes, with and without genlock references. Very little differences to the specification were measured in any mode.

The EBU Group also checked the blanking of the output signals, particularly the vertical blanking

where the VBI lines were separated from the video and recorded as data. They found that the blanking was accurately applied with the exception of some small inconsistencies. The VITC could be inserted in a range of lines on the output.

The audio interfaces were also tested over combinations of embedded audio: AES/EBU digital and analogue. Both implementations had embedded audio in the SDI interfaces. Although the interfaces were transparent to the full 24-bit capability of the interface, only 16 bits were recorded and replayed from tape. The DVCPRO only measured 15-bit performance through the tape path but this may have been caused by a fault on the equipment supplied.

The SX equipment did not have a separate AES/EBU audio interface. The DVCPRO implementation was found to be satisfactory in this respect.

The analogue interfaces and the A/D and D/A converters were tested on both implementations and found to be satisfactory. Given the frequent problems due to differences in analogue audio levels, users are well advised to check the setting of analogue interfaces.

10. Follow-up tests

Since these test were carried out, a number of developments and proposals have been made by the manufacturers. The most significant are:

– Sony has further developed the editing procedure on the SX Hybrid recorder;

– Panasonic has announced a DVCPRO-50 format with less compression.

The EBU group has agreed to test these new developments as well as carry out further tests on the Digital-S, DVcam and DV formats mentioned above. Watch this space!

11. Conclusions

Although aimed at similar markets, the Betacam SX and DVCPRO formats – and the way they have been implemented in hardware – show that there is no universal solution to the needs of broadcasters. Both formats have been developed to complement the existing product ranges of their respective manufacturers. Both manufacturers seem to be looking over their shoulders at the fast-approaching DV format, aimed at the general public, and at the same time looking upwards to the high-end formats used for multi-generation post production.

At the moment, the high ground is occupied by the pure Rec. 601 formats, D1 and D5. The “almost Rec. 601” Digital Betacam format is situated slightly lower but nevertheless is used for all but the most stringent work. Equipment in these formats is recognized as being too valuable to risk in the rough and tumble of everyday production in the field. Hence the SX and DVCPRO formats are aimed at the market for portable, rugged equipment, but somewhat above the level where equipment can be regarded as expendable.

Both manufacturers also recognize that simple, quick editing in the field is needed for many programmes, as well as the possibility to transfer material to a studio-based editing system without undue loss of time. The signals in both formats are designed to be used in the studio as well as in the field, even though the broadcaster’s studio equipment will be quite different – probably based on servers and workstations. Hence the emphasis given by the EBU to testing the performance of the compression systems used by the two formats.

The results of the EBU tests suggest that there may still be a gap in the product range – above these formats but below the level of almost-lossless compression. Today, a lot of interest is focused on a quality level of around 50 Mbit/s,

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preferably using an open standard such as the 4:2:2 profile of MPEG. This view is reflected in the recent EBU Statement, D80 [8].

It is perhaps too early to predict how the SX and DVCPRO formats will perform in the studio, where the future seems to belong to disk-based systems. However, in the field environment of news, current affairs and many sports operations, both these formats perform well. They have their differences but it would be a brave person who could make an absolute choice between them. In the words on the fairground operator: *what you lose on the swings, you make up for on the round-abouts*.

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EBU Seminar on Production Techniques: *Networks in the Studio*

This seminar – to be held at EBU Headquarters from 28 to 30 January 1998 – is intended for technical and programme executives in television organizations. It will provide a bridge between the studies of future technical standards for the studio signal path, and the concerns in providing production facilities.

Networks in the Studio will focus on the work of the **EBU/SMPTE Task Force** (see *page 13*) which aims to harmonize the standards for processing and distributing packetized television signals in the production area.

A presentation of their work will be given first. The seminar will then address four applications of such standards in the television production world:

- news;
- post production;
- archives;
- multimedia.

Each application will be dealt with during half a day, with a balance of technical and operational considerations.

The seminar will be open to all EBU members and non-members alike. It will be held in English.

The *Advance Programme* for the seminar will be released in October. It will also contain information about registration and accommodation in the Geneva area.

If you would like a copy of the *Advance Programme* when available, please contact Mr Jean-Jacques Peters on:

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