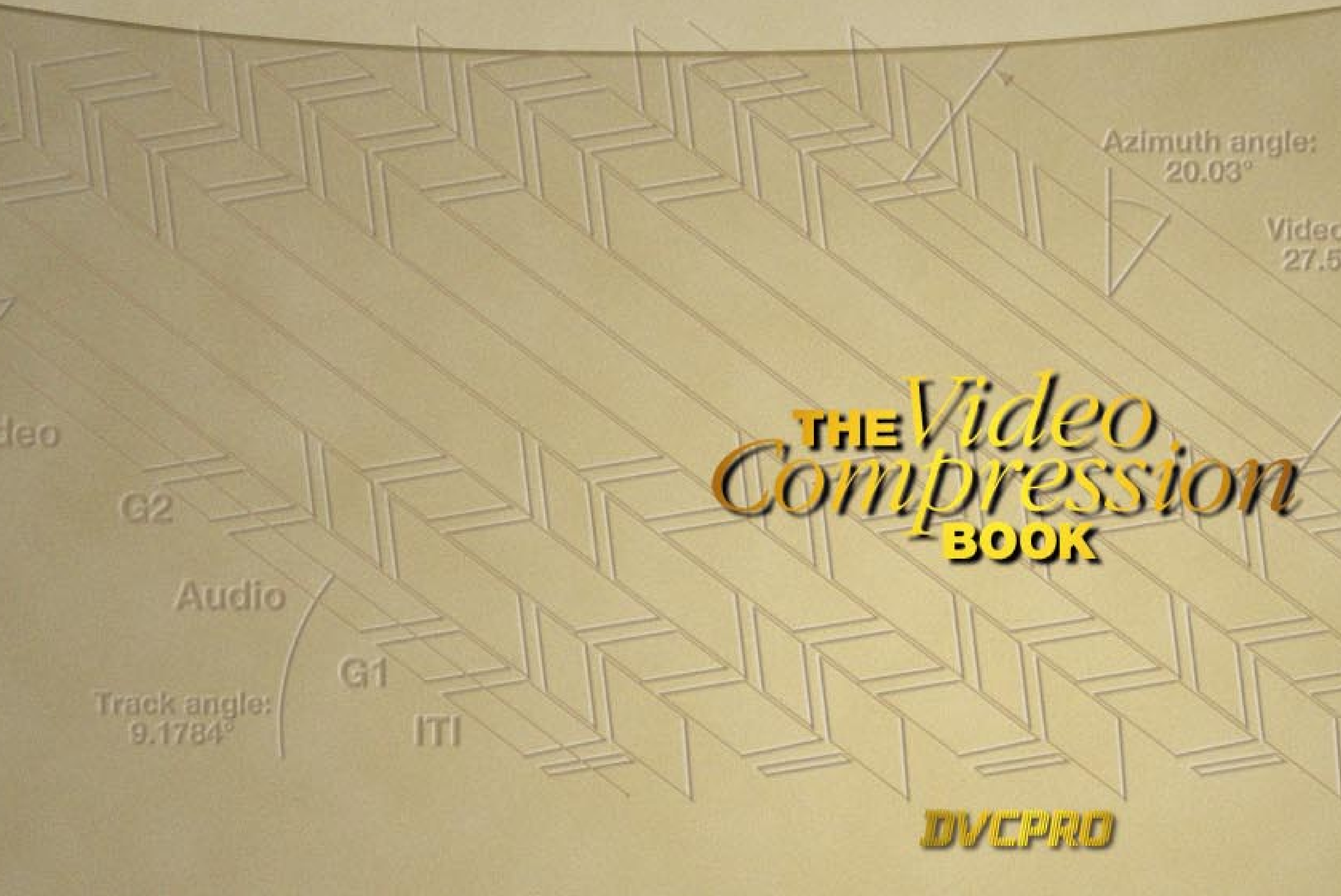
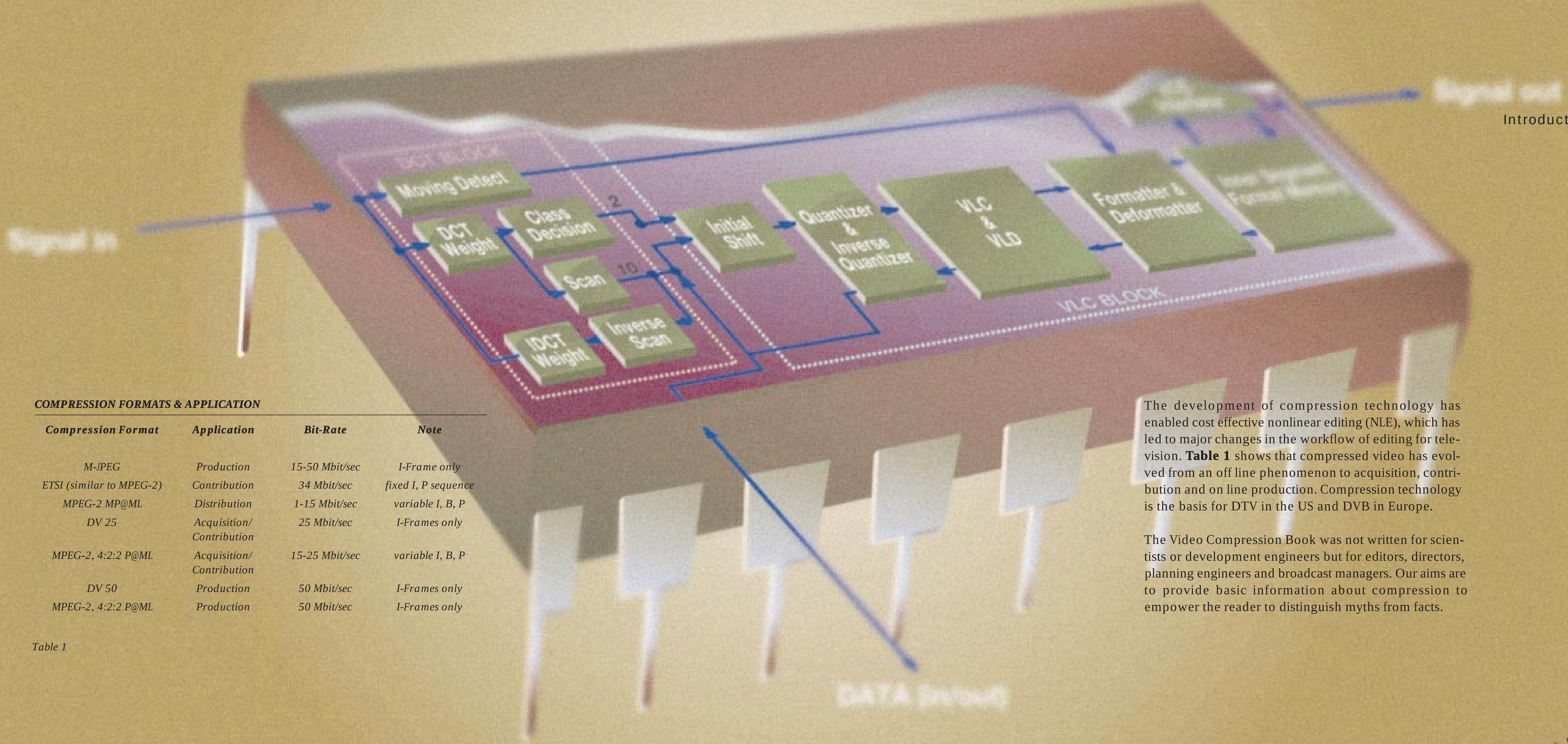
TECHNOLOGY

THE Video Compression BOOK



DVCPRO



Introduction.

The development of compression technology has enabled cost effective nonlinear editing (NLE), which has led to major changes in the workflow of editing for television. **Table 1** shows that compressed video has evolved from an off line phenomenon to acquisition, contribution and on line production. Compression technology is the basis for DTV in the US and DVB in Europe.

The Video Compression Book was not written for scientists or development engineers but for editors, directors, planning engineers and broadcast managers. Our aims are to provide basic information about compression to empower the reader to distinguish myths from facts.

COMPRESSION FORMATS & APPLICATION

Compression Format	*Application*	*Bit-Rate*	*Note*
M-JPEG	*Production*	*15-50 Mbit/sec*	*I-Frame only*
ETSI (similar to MPEG-2)	*Contribution*	*34 Mbit/sec*	*fixed I, P sequence*
MPEG-2 MP@ML	*Distribution*	*1-15 Mbit/sec*	*variable I, B, P*
DV 25	*Acquisition/ Contribution*	*25 Mbit/sec*	*I-Frames only*
MPEG-2, 4:2:2 P@ML	*Acquisition/ Contribution*	*15-25 Mbit/sec*	*variable I, B, P*
DV 50	*Production*	*50 Mbit/sec*	*I-Frames only*
MPEG-2, 4:2:2 P@ML	*Production*	*50 Mbit/sec*	*I-Frames only*

Table 1

What does digital video signal compression mean?
Why can we compress digital video signals?
Why do we compress digital video signals?
Will compression stay with us or is it a temporary technique?

Throughout this booklet compression is defined as taking a digital video signal (an SDI signal coded according to ITU 601 with a data rate of 270 Mbit/sec) and applying a compression process which reduces that data rate.

Before dealing with compression, it will be helpful to review certain fundamental concepts of communications theory. Video information – like any information – can be divided into three parts:

- The Redundant Element: This is information that has already been sent once and is repeated. A normal video signal contains an abundance of natural redundancy. Spatially adjacent pixels within the same television frame, as well as large parts of adjacent television frames are very often similar or even identical.
- The Irrelevant Element: The human eye can discern certain deficiencies in some displayed image but not others. Those it cannot discern are called irrelevancies.
- The Core Element: This is the remaining essential part of the video information that is neither redundant nor irrelevant.

Compression seeks to reduce both the redundant element and the irrelevant element of a digital video signal. Unfortunately – as indicated in Figure 1 – the boundaries between all three elements are fuzzy. The ability to exploit redundancies depends on the intelligence of the signal analysis performed during compression and on the size of the memory used for that analysis. The irrelevancy of an element can only be defined by human eyes and therefore depends on subjective decisions. One person's irrelevancy is another's relevant information. Note that high compression factors very often result in eliminating parts of the essential core information, producing impairments visible to average observers.

Elements of Video Information

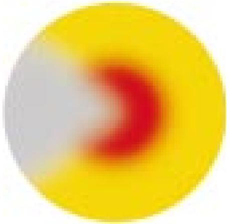


Fig. 1

🟨 *video information which is redundant*

🟥 *core of essential video information which is non-redundant*

▨ *video information which is irrelevant*

Most compression schemes operate on video frames, i.e. the image is processed as one picture. Since the preponderance of video is produced by interlaced scanning, the frames are composed of two fields with a small but finite temporal difference. When the two fields are combined into one frame for compression the temporal shift can significantly reduce the redundant element. This has also brought attention to the 3:2 pull down technique used in the transfer of 24 frame film to 60 field (30 frame) video wherein some frames have significantly different images in the two fields.

Economic forces drive compression. It reduces the bandwidth needed to transport video signals from one location to another and minimizes the amount of storage space needed on disk or tape. Reduced bandwidth and storage space mean lower costs.

This will still be true in the future – even taking into account the expected continuing cost reductions for bandwidth and storage space. Independent of those costs, compression will always offer the ability to transport more information over a given bandwidth, or to transport compressed signals in a shorter time span than uncompressed signals.

SUMMARY

The very nature of the video signal allows the removal of irrelevant and/or redundant elements which are either not essential for the displayed image or allow the original to be re-created without loss.

What does "lossless" compression mean?

What does "lossy" compression mean?

Why can’t one have both compression down to a constant data rate, and a constant quality of the compressed signal at the same time?

Scene Complexity Defines the Elements of Video Information

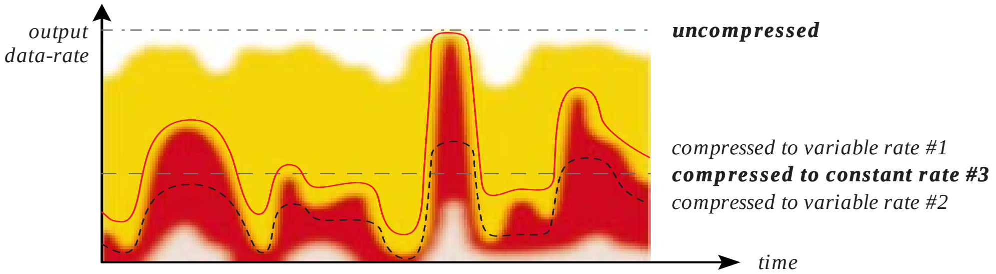


Fig. 2

🟨 *video information which is redundant*

🟥 *core of essential video information which is non-redundant*

▨ *video information which is irrelevant*

The amount of redundancy and irrelevancy within a digital video signal depends on the complexity of the captured scene. Complexity refers to the amount of fine detail (spatial information) contained in the scene as well as the type and speed of movement (temporal information). The percentage of both redundancy, and irrelevancy, is therefore a function over time. The size of both components is unrelated to each other.

Consider a data rate **(#1 in Figure 2)** that follows, but does not fall below the amount of the essential core information present in the video signal – it is able to transport a compressed signal that can be decoded without any visible deviation from the original. This complete reconstruction is possible because this degree of compression does not effect the essential core part of the signal. The computing power required, the size of video memory needed, and the mandatory real time performance limit the economic effectiveness of such compression schemes.

Compare that to a data rate **(#2 in Figure 2)** that always follows a certain fraction of the essential core information. This can only carry a lossy compressed video signal because the compression process has eliminated essential information. Because the percentage of that missing part stays constant, one can expect a constant quality although the data rate varies with the complexity of the scenes.

Variable data rates are not efficient for real time transmissions over fixed bandwidth systems. In the case of non-real time applications, all variable rate signals can be transported at a constant rate. Variable data rates impose no problems on disk type storage devices, but the mechanism of a tape recorder requires a constant rate.

Constant quality at a constant data rate can only be provided by an uncompressed signal. A constant data rate **(#3 in Figure 2)** that falls below the maximum level of the essential core information cannot always be achieved without adversely effecting that essential information. As explained above, the distinction between relevance and irrelevance is a subjective one. As higher compression factors are employed, the partial removal of relevant information cannot be avoided. All compression schemes attempt to do this in a way that leads to a graceful degradation of the video signal. Although a constant data rate is ideal for fixed bandwidth systems, it also has a potential for picture quality degradation, which in turn depends on the complexity of the actual scene content.

SUMMARY

The amount of the essential, non-redundant portion of the video signal varies over time depending on scene complexity. Squeezing the compressed signal through the bottle-neck of a constant data rate scheme leads to loss of essential information. The result is picture quality that is dependent on scene content. Compression schemes are usually designed to handle this conflict gracefully.

Do analog artifacts influence compression results?

What can be done to optimize results for a given compression system?

There are in fact some analog artifacts that influence compression results. The worst of these is signal noise. This is caused by the fact that noise is random and therefore contains no redundant component. Compression schemes judge noise as essential core information and they try to code the noise as accurately as possible. In doing this they limit the number of bytes available to code other, more relevant parts of the video signal. Special test signals like "Diva with Noise" were designed to check the performance of compression schemes in the presence of noise. For example, noise reduction is often applied prior to MPEG-2 MP@ML coding to achieve a better compression quality.

All modern compression systems operate in the component video domain, so applying compression to original composite (NTSC or PAL) material requires decoders. Decoders must eliminate most of the color subcarrier artifacts in the video picture or else the compression scheme will waste a lot of bytes in coding those unwanted residual signals.

Excessive horizontal and vertical aperture correction also reduce the effectiveness of any compression scheme, by burdening the compression scheme with irrelevant detail.

SUMMARY

Noise, residual NTSC or PAL artifacts, and excessive aperture correction limit the effectiveness of compression.

Influence of Analog Artifacts on Compression

Normal video picture

Noise reduces the amount of redundancy within the picture and drastically limits the performance of any compression scheme.

Excessive horizontal & vertical aperture correction reduces the effectiveness of any compression scheme (resulting in lower quality or higher compressed data rate).

Fig. 3

What does DCT mean and what does it do for compression?

Today all relevant compression schemes are based on the DCT coding method. DCT stands for "Discrete Cosine Transform". Transform means moving or transforming the video signal from the spatial domain to the frequency domain. The spatial domain is defined by the sampling raster, where each pixel has an assigned numerical value for its intensity. The transform translates the pixels (typically grouped in an 8 by 8 array or block of 64 pixels) into one DCT block with the same number of coefficients. Each DCT block is an array of 8 by 8 spectral coefficients that define the energy by frequency. It is of great importance to notice that the transform itself neither adds nor removes any information. DCT is not compression. What determines any losses rests upon what is done with the information while it is in its transformed state.

DCT-Transformation

Fig. 4

pixel / line	m	m+1	m+2	m+3
n	110	106	98	92
n+1	112	105	97	90
n+2	109	107	97	94
n+3	111	107	95	91

DCT block

202.6	14.8	-0.4	-1.1
0.1	-0.2	-0.3	1.1
-0.1	0.3	-0.1	-0.3
0.6	-1.6	-0.3	-0.8

For each transform there is an inverse formula that can be used to recover the original picture block from the transform coefficients.

Figure 4 shows an array of 16 pixels. While DCT blocks usually have 64 coefficients, for simplicity the block size in this example was reduced to 16. Assume that the decimal digits correspond to the amplitude values of a luminance signal. Using the Discrete Cosine Transform, this array of pixels is translated into an array of spectral coefficients. The coefficient in the top left corner of the array represents the DC value or average value of the entire array; the coefficient in the bottom right corner represents the highest spectral frequency within the array. Distributed between them are the other AC coefficients.

The DCT transformation itself does not perform any compression. It is just the first of several steps that prepare the signal for the final step of compression that will be explained in the next chapter. In a second step, quantization is applied to the individual DCT coefficients as shown in **Figure 5**. Each of the DCT coefficients are multiplied by the factors provided by the quantization table. The task of this "weighting" is to match the

Quantization of DCT-Coefficients

DCT block

202.6	14.8	-0.4	-1.1
0.1	-0.2	-0.3	1.1
-0.1	0.3	-0.1	-0.3
0.6	-1.6	-0.3	-0.8

X

Quantization Table

1.0	1.0	0.9	0.8
1.0	0.9	0.8	0.7
0.9	0.8	0.7	0.6
0.8	0.7	0.6	0.5

ROUNDING

Quantizer

Quantized DCT

203	15	0	-1
0	0	0	1
0	0	0	0
0	-1	0	0

Fig. 5

significance of the individual coefficients to the human visual system. Since the human visual system is less sensitive to high resolution detail, high frequency coefficients are assigned weighting factors smaller than 1. The weighted coefficients are then rounded, which results in the array shown on the right hand side of **Figure 5**. The combination of weighting and rounding can be referred to as "quantization" of the DCT coefficients. It can be seen that a great number of the coefficients in this array are now equal to zero, and that several zero coefficients are grouped together. These groups of "zeros" do not need to be transmitted or recorded in their entirety, but can be shortened using various mathematical techniques.

It should be reiterated that the special expertise involved in perfecting a compression method does not lie within the DCT. The latter is a purely mathematical process that can be reversed without losses. The art or skill lies within the quantization of the resulting coefficients. The quantization process is the lossy step in the compression scheme because it is there that some information is lost forever.

SUMMARY

The Discrete Cosine Transform is a reversible mathematical process. Compression is achieved by quantization of the DCT coefficients. The quantization tables take the properties of the human eye into account.

Motion-JPEG compression
Is Motion-JPEG standardized?

DCT Based Compression – M-JPEG Type

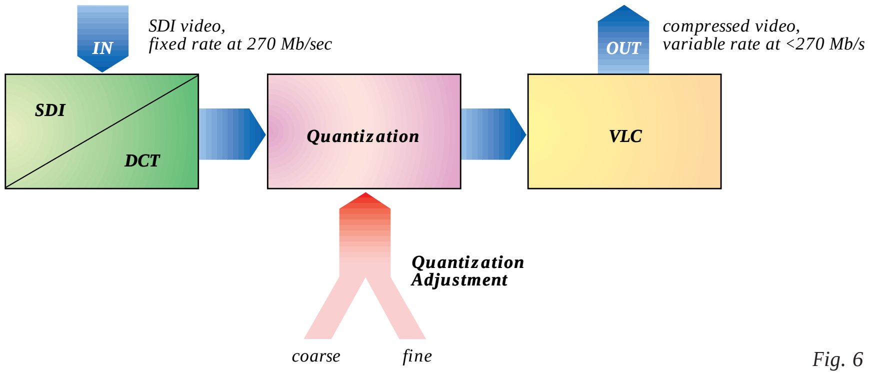


Fig. 6

The Joint Photographic Experts Group (JPEG) set the first standard for data compression of still pictures for photojournalism. This standard evolved into the Motion-JPEG method now widely used for nonlinear editing (NLE) systems by a variety of manufacturers. M-JPEG can be either field or frame bound.

Motion-JPEG uses an 8 by 8 block DCT transform and limits the compression to the two-dimensional spatial domain. It does not use temporal compression outside the frame boundary. The M-JPEG compression scheme as shown in **Figure 6** consists of three major parts:

- the digital video (SDI) to DCT transformation.
- the quantizer for the DCT coefficients.
- the variable length coder (VLC).

Note that these basic three functions that form the compression scheme will appear again as part of other, more advanced compression systems like DV and MPEG-2.

The SDI to DCT transform can be considered lossless, although there are in fact some mathematical rounding errors due to the limited number of digits (bits) used for the computations.

The main cause for quality loss, and conversely, the main tool to achieve compression is the quantization of the DCT coefficients. Strictly speaking, quantization is the preparation necessary to perform the actual compressed output.

Compression is actually realized by the variable length coder (VLC), a process that is completely lossless and fully reversible. It can be said that in the spatial domain all pixel intensity levels are of equal probability. In comparison, the DCT or spectral domain is quite different. After quantization, the probability of being equal to zero is much greater for coefficients representing higher spectral frequencies. The variable length coding (VLC) process provides fewer bits (or less data rate) for the coefficients with higher probability of being zero, and more bits for the coefficients with a lower probability of being zero. This is accomplished using a table that assigns a short "word" for the more common quantization data and larger "words" for less common data results. Of course, in the digital domain, the words are ones and zeros as is the data. VCL is simply a sophisticated mathematical method to gain efficiency. By careful ordering of the sequence or hierarchy of coefficients, the VLC tries to avoid wasting bits on the transmission of zero coefficients. The output data rate is not constant, but depends on the scene content and the selected coarseness of the quantizer.

Performance of M-JPEG Compression

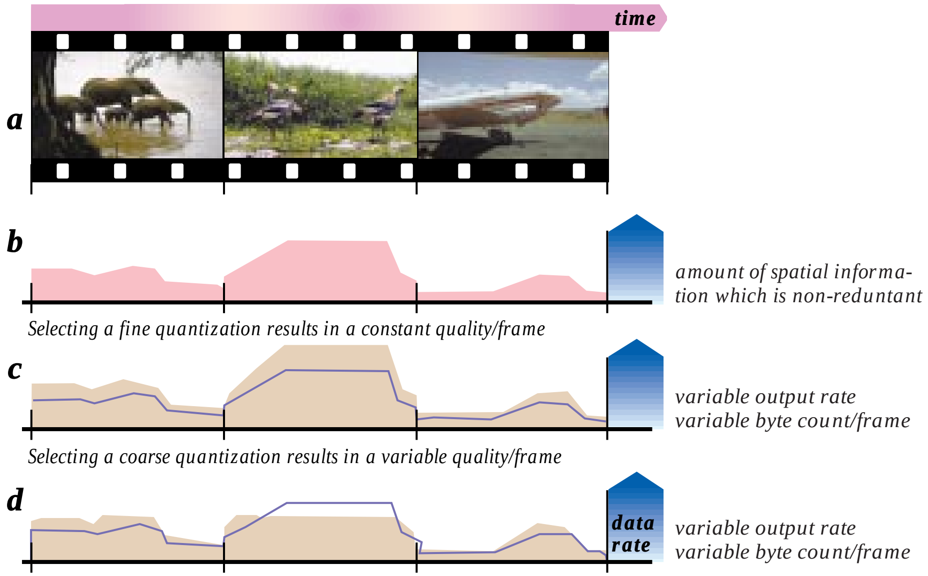


Fig. 7

The Motion-JPEG compression scheme allows a wide variety of design parameters. The "quantization adjustment" is done by selecting and applying a specific quantization table. This selection provides the possibility of adapting the data rate and picture quality of the compressed signal for a specific application. This design flexibility means M-JPEG exists today in diverse implementations and at various bit rates. Since many of these implementations are not compatible with each other, Motion-JPEG cannot be considered a firmly defined standard.

Figure 7a shows a sequence of frames to be coded by the two-dimensional M-JPEG compression. Each frame has a different amount of core information that is non-redundant **(Figure 7b)**. The output rate is always variable, and depends on picture content.

Selecting a fine quantization for the DCT coefficients provides a large number of coded bytes that are sufficient to carry the essential core of video information. This core contains information that is not repeated (non-redundant) within the video signal. The fine quantization results in a constant quality per picture as long as the output rate exceeds the amount of core information by some amount **(Figure 7c)**. The thin line indicates the trajectory of the amount of core information.

Selecting a coarse quantization for the DCT coefficients provides fewer coded bytes, and they may not be sufficient to carry the complete core of video information. The result is variable quality that is dependent on the picture content. Pictures with a low degree of spatial redundancy suffer the most **(Figure 7d)**.

The quantization adjustment may be controlled by the picture content. The variable output rate of M-JPEG compression schemes make them most suited to disk type storage. However, since video tape recorders require a constant number of bytes per frame for editing purposes, M-JPEG is not used for video tape.

SUMMARY

Motion-JPEG contains the same basic three block compression structure used in the more sophisticated systems like DV and MPEG-2. The output data rate is not constant, but depends on the scene content and the selected coarseness of the quantizer. Disk recorders are the ideal tools for recording a signal with variable amounts of bytes per frame. M-JPEG cannot be considered as a firmly defined standard.

How to develop a constant data rate for a compressed signal. The smoothing buffer.

DCT Based Compression – Feedback Type

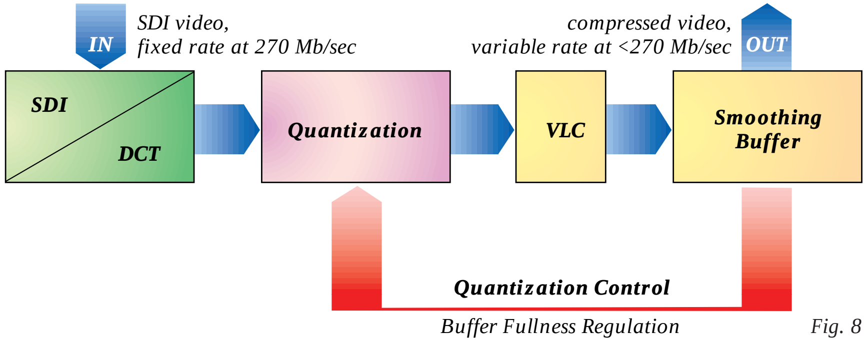


Fig. 8

The variable length coding of quantized DCT coefficients based on a fixed quantization table leads to an output data rate which is not constant but depends on scene content and the selected quantization table. Although ideal for disk recording, this behavior of M-JPEG hinders real time transmission over fixed bandwidth channels and storage on video tape recorders.

The coefficients within the quantization table are the only available parameters to influence the output data rate. To control the output rate a so-called "smoothing buffer" is added to the M-JPEG compression scheme. The buffer is filled with the VLC coded signal and sends a control signal back to the quantizer. This control signal provides information with respect to the fullness of the buffer.

Imagine the smoothing buffer as a bucket of water with a small hole in the bottom. The bucket is being filled constantly, but the quantity of water being added is somewhat random. At the same time, a constant quantity of water is leaving the bucket each second (through the hole in the bottom). The task is to control the water going into the bucket in such a way that the bucket never overflows or runs dry.

To avoid underflows and overflows of the data buffer, quantizer selection is used to control the amount of data entering the buffer. Selecting quantization tables with a coarser quantization reduces the input bit rate to the buffer; selecting a finer quantization increases the amount of bits entering the buffer. It must be noted that selecting the quantization tables to control the data rate impacts the picture quality. Limiting the input rate to the buffer reduces the quality of the coded picture. Larger buffer sizes allow a smoother control of the quantizer and promise better picture quality. In addition, it should be noted that the decoder needs a similar buffer to reconstruct the signal.

As will be explained later, a constant output rate does not necessarily equate to a constant byte count per frame that is required for applications like storage on video tape. The use of a smoothing buffer is not the best way to achieve a constant byte count per frame. This control can only guarantee that the process will not exceed a certain maximum byte count per frame, but it will not always reach the same number of bytes per frame. To achieve this, data without any information is inserted into the output stream ("bit stuffing").

The feedback type of DCT based compression shown in **Figure 8** is still based on a two-dimensional spatial compression. As explained in the next chapter, MPEG-2 adds the means to apply a three-dimensional compression, exploiting the redundancy between successive frames as well. This simple feedback type of DCT compression, shown in **Figure 8**, is identical to the MPEG-2 4:2:2 profile based only on I-Frames, a relatively recent addition to the MPEG structure.

SUMMARY

A smoothing buffer can be used to regulate the data rate of the compressed signal to a constant level. Control is achieved by adjusting the coarseness of the quantizer, which in turn effects the picture quality. The addition of the smoothing buffer converts a variable rate with constant quality to a constant rate with variable quality. A constant output rate does not necessarily mean a constant byte count per frame. A fixed amount of data per frame is required for storage on video tape.

Three-dimensional compression with MPEG.
The MPEG-2 design criteria.

MPEG-2 Compression Scheme *(simplified)*

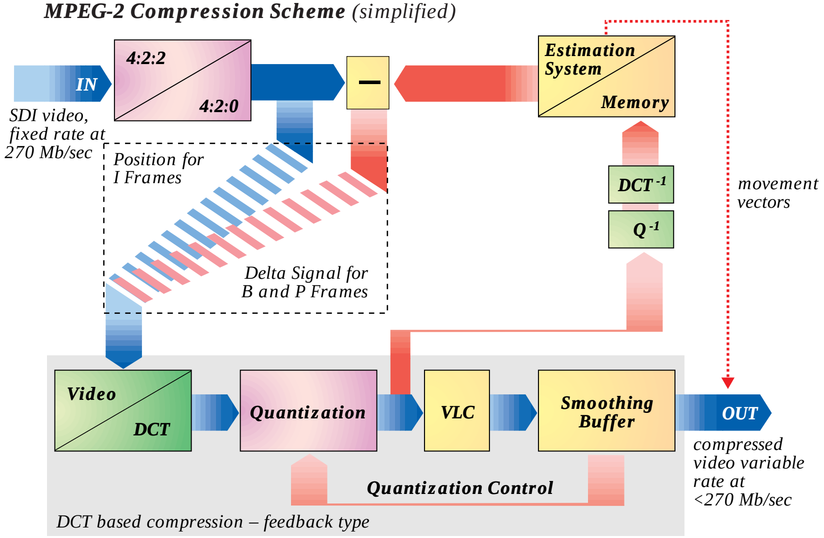


Fig. 9

MPEG-2 adds three-dimensional compression to the simple feedback DCT based compression explained earlier. This exploits the redundancy between successive frames as well as within individual frames. The signal leaving the quantizer is not only VLC coded, but decoded to a video signal as well. By means of frame memories, the system tries to estimate how the next input picture to be compressed may look. Only the difference between the estimation and the input signal is fed to the DCT transformation. In the case of a good estimation of the incoming signal, this difference will become very small and can be compressed to a much lower rate than the complete picture. The estimation system includes movement analysis. The resulting movement vectors must be added to the compressed video signal to enable the decoder to perform an identical picture estimation.

MPEG-2 Frame Sequence *(typical)*

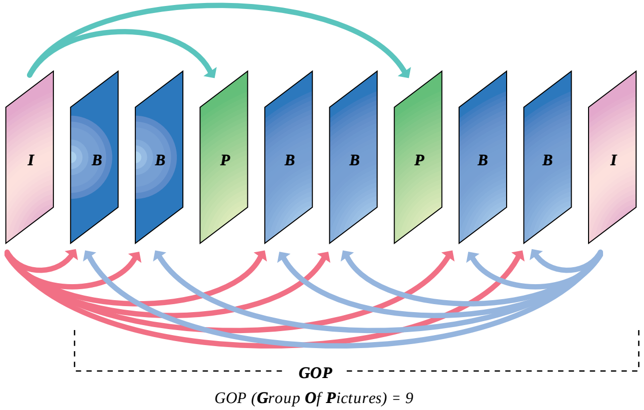


Fig. 10

Depending on the reference picture used for the estimation, the MPEG-2 signal is composed of 3 types of frames **(Figure 10)**, which are contained in a so-called **G**roup **o**f **P**ictures (GOP):

- I Frames: pictures coded without reference to any others in a sequence,
- P Frames: pictures coded differentially with reference to a previous or subsequent I or P Frame,
- B Frames: pictures coded differentially with reference to both previous and subsequent I or P Frames.

The Group of Pictures is the group of frames between successive I frames. While GOP length can vary, a length of 12 frames is typical. B and P Frames contain much less data than I frames. To reconstruct a frame that has been coded as a B or P Frame the entire Group of Pictures must be decoded.

MPEG-2 is a family of compression schemes; it is grouped in Profiles and Layers covering both standard television and HDTV. The examples given in this booklet are based on standard definition television (SDTV) but can generally be applied to HDTV as well by extrapolation. Within the layers for standard TV the so-called Main Profile and the 4:2:2 Profile are of the most interest. **Figure 9** shows the block diagram for the Main Profile (MPEG-2 MP@ML) which first uses a raster transformation for the incoming signal. This raster transformation changes the pixel raster of the 4:2:2 SDI signal to a 4:2:0 raster format. It must be noted that this transformation is a non-reversible, lossy compression. The 4:2:2 Profile (MPEG-2 4:2:2 P@ML), often called the Professional Profile, avoids this raster transformation for that reason.

MPEG-2 can offer better picture quality at higher compression ratios than the M-JPEG type of compression explained above. This gain in performance is based on the additional temporal compression. However, due to its GOP structure, it is not ideal for editing purposes. A cut or edit within a GOP sequence requires complex splicing techniques such as those described in SMPTE 312 M, or the decoding and re-encoding of the signal. Both of these can have negative effects on the picture quality and are addressed later in this booklet.

MPEG-2 does not give unambiguous rules for compressing television signals, but rather offers a rich toolbox that allows the creation of different versions of MPEG-2. The flexibility of MPEG-2 Main Profile can be a great advantage in distribution applications where bandwidth is often a constraint, e.g. DVD or DTV to the home. Statistical Multiplexing of signals to facilitate the carriage of multiple MPEG signal streams over such restricted bandwidth paths is one of the benefits of this flexibility. For professional applications, especially within television facilities, this flexibility can cause interoperability problems. This is due primarily to the fact that only the decoder is firmly specified within the MPEG standards.

Because of the potential for incompatibility, the flexibility of the MPEG-2 format must be restricted for production applications. Various parameters such as color sampling raster, splicing flags, GOP length restricted to one (I frames only), and bit rate variation are limited or constrained. The necessity for this type of "supplemental standardization" will continue in order to allow the use of MPEG-2 within TV centers.

One may wonder why all of this was not done several years ago during the definition of the MPEG-2 compression scheme. Simply put, the inventors of MPEG-2 never had television production applications in mind. Their goal was to replace the analog NTSC and PAL distribution formats with a modern digital system. They only intended to use this advanced compression technology for the final process of distribution to home viewers.

The asymmetrical nature of mass distribution means that the number of decoders in home TV receivers will be many orders of magnitude greater than the number of encoders placed at the transmitter or station. Therefore, the logical and economical approach was to make the decoder as simple as possible, and to shift complexities to the encoder. In addition, it was thought that the volume of the consumer market and the competitive nature of the manufacturers would advance the performance and therefore lead to rapid adoption. Therefore, within the MPEG standards, only the decoder is firmly specified so that every decoder will work. Each manufacturer is free to design encoders as they wish as long as the standardized decoder is able to decode their signals, and as the technology improves, the encoded signal can improve.

Note that for both professional applications within TV facilities and those contained in a single piece of equipment, this approach is unsuitable. In such applications the process is much more symmetrical, with approximately equal numbers of encoders and decoders. However, the lack of a standardized MPEG-2 encoder means there is no guarantee of MPEG-2 quality, a potentially fatal flaw in MPEG for professional applications.

The raster transformation used in MPEG-2 MP@ML is based on chrominance subsampling (4:2:0). Similar to the analog SECAM transmission system, only one chrominance signal per line is coded and transmitted. While it may be acceptable for distribution, this can have a significant impact on the picture quality after some types of signal processing – chroma-key, for example. Therefore, the MPEG-2 4:2:2 Profile was developed. In combination with a pure I Frame coding structure, and under this condition only, some of the weaknesses of the transmission format for studio applications can be eliminated. However, these same constraints defeat most of the specific advantages of MPEG-2. Indeed, what is left is no longer a format suitable for transmission.

Performance of MPEG-2 for a Frame Sequence with Minimum Movements & No Scene Change.

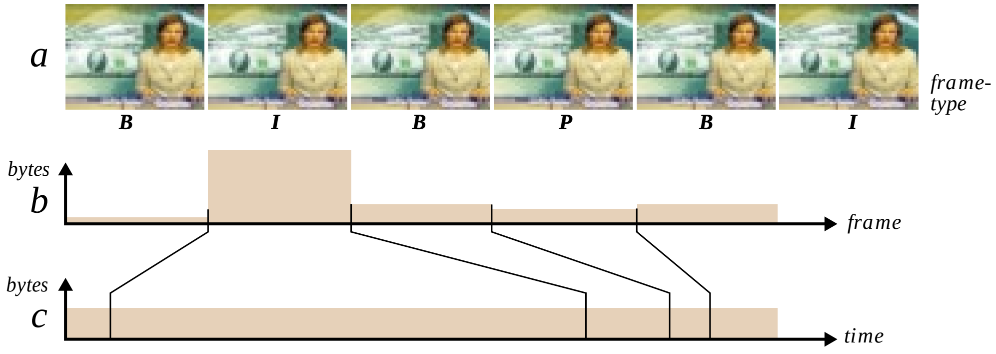


Fig. 11

The block-diagram for the I Frame only MPEG-2 4:2:2 Profile is identical to the simple feedback DCT based compression which was explained in detail in the previous section. Please refer to Chapter 5 and 6 for further details about the performance of such 4:2:2 schemes.

Figure 11a shows a sequence of frames coded by three-dimensional MPEG-2 compression. This frame sequence contains neither a scene change nor fast movements. The high temporal redundancy between successive frames results in very few bytes per B and P Frames. Due to its pure spatial coding, the I Frame shows a much higher number of coded bytes **(Figure 11b)**.

Figure 12a shows a sequence of frames coded by three-dimensional MPEG-2 compression. This frame sequence contains both a scene change and fast movements. Both reduce the temporal redundancy and therefore the effectiveness of the three-dimensional compression. Note that the

Performance of MPEG-2 for a Frame Sequence with Scene Change & Fast Movements

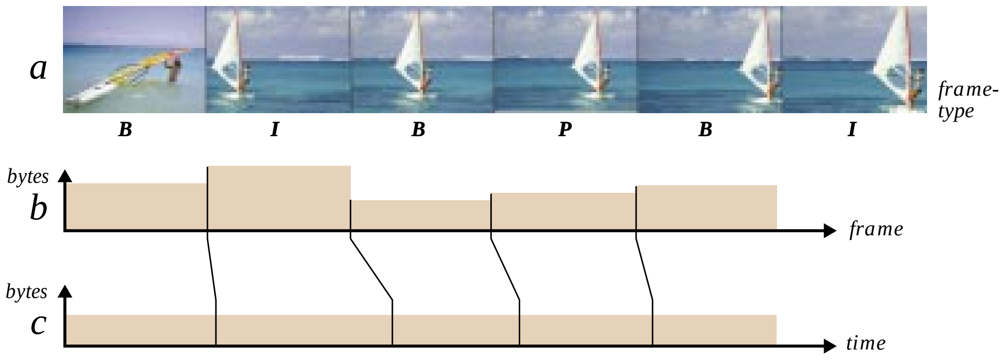


Fig. 12

result is very close to pure spatial compression based on I Frames only. In this case, all pictures show a similar amount of bytes per frame independent of their I, B or P nature. The byte count varies from frame to frame depending upon the individual spatial redundancy and the degree of remaining temporal redundancy **(Figure 12b)**.

Figure 13a shows a sequence of identical still frames coded by three-dimensional MPEG-2 compression. This produces the maximum possible temporal redundancy between successive identical frames, resulting in no data in the B and P Frames. The I Frame alone carries all the bytes that are necessary for the transmission of still picture information **(Figure 13b)**.

In all three examples, the smoothing buffer converts the variable byte count per frame **(Figure 11b, Figure 12b, Figure 13b)** to a variable time per frame to achieve a constant output rate of MPEG-2 compression **(Figure 11c, Figure 12c, Figure 13c)** for transmission.

Performance of MPEG-2 for a Frame Sequence with Still Picture and No Scene Change.

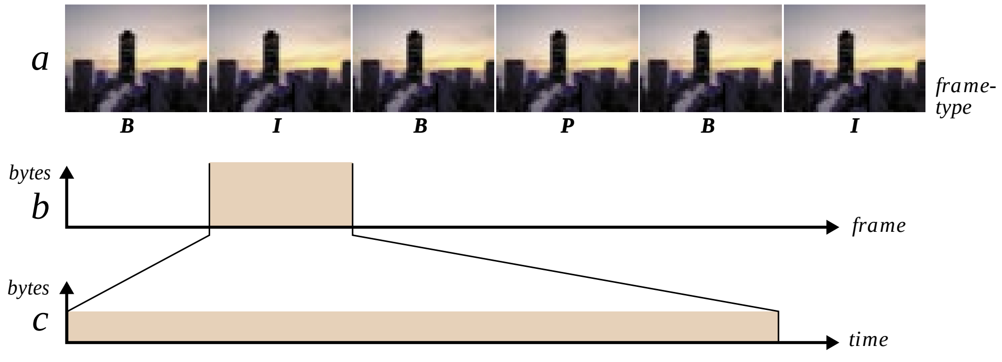


Fig. 13

This variable byte count per frame means that MPEG-2 compression is also not the ideal tool for storing signals on video tape, since a constant number of bytes per frame are required for editing purposes. For this reason, a consortium of leading companies developed a compression scheme that is tailored to the operational needs of video tape recording.

SUMMARY

MPEG-2 exploits the redundancy between successive frames to provide a highly efficient distribution and transmission system, but it was not designed for editing purposes. The use of MPEG-2 within TV facilities requires additional supplemental standards. The introduction of the 4:2:2 Profile to avoid the 4:2:0 chrominance sub-sampling is only the first step. MPEG-2 is a flexible but not unambiguous set of rules for compressing television signals. Only the decoder is firmly specified, and each manufacturer is free to design a unique encoder as long as the standardized decoder is able to decode its signal. This means there is no guarantee of MPEG-2 quality through multi-vendor systems.

DCT based compression with a "Look Ahead" or Feed-Forward technique.

A DCT based compression system optimized for video tape recording.

DCT Based Compression – Feed-Forward Type

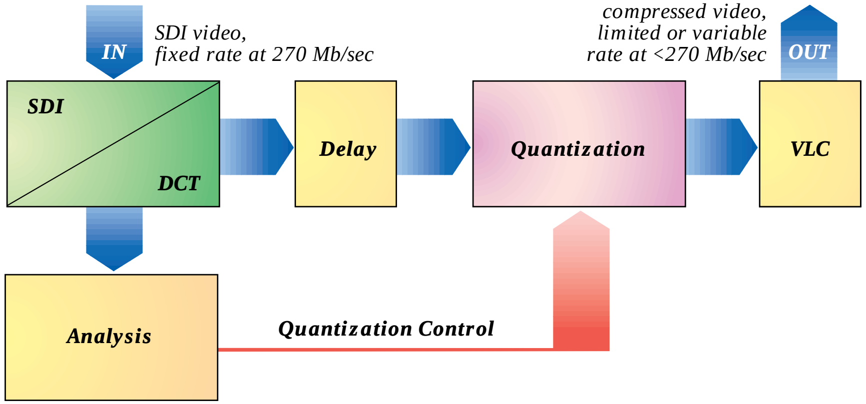


Fig. 14

The constant output rate achieved in MPEG-2 by utilizing a smoothing buffer does not necessarily yield the constant byte count per frame that is required for storage on conventional digital video tape. Buffer control can guarantee not to exceed a certain maximum byte count per frame, but it cannot guarantee to always reach the same number of bytes per frame. To achieve that, "bit stuffing" techniques are employed wherein data that does not represent picture information is inserted into the output stream. This procedure wastes precious data space, especially on tape.

As previously described for MPEG-2, a feedback loop can be used to control the output rate. This section explains a feed-forward technique based on an analysis of the DCT coded video signal. The possible byte count per frame is continuously pre-calculated by analyzing all the DCT coefficients for a wide variety of quantization tables. Assume the system uses 10 different quantization tables. This will produce 10 different quantizer "results", and the number of coded bytes per frame computed for each of the 10 possible choices. For the actual final processing of the signal, the specific quantizer that provides the byte count closest to but not higher than the chosen fixed limit per frame is selected.

Obviously, this feed-forward technique demands a high degree of computing power. In addition the pre-calculations take a finite amount of time, so a small signal buffer is inserted between DCT transform and VLC coding.

Combining this feed-forward technique with a three-dimensional compression (like MPEG-2) and long GOP sequences would require far too much storage space for the pre-calculation. The DCT coefficients of the complete GOP would have to be stored for all possible quantizers. The most appropriate application of the feed-forward technique lies in the two-dimensional spatial compression, making it the ideal tool for the storage of compressed signals on video tape. DV based compression relies on this technique for this reason. DV compression is explained in detail in the following chapters.

SUMMARY

Feed-forward DCT based compression is the ideal technique for compressed video recording because it provides a fixed byte count per frame for the compressed signal. This system is best when three-dimensional compression is not needed or desired, as is the case with video tape recording or video signal manipulation.

DV compression

The DV compression system is based on the feed-forward DCT compression described above. Since users require frame accurate editing, three-dimensional compression is not appropriate. The feed-forward fixed byte count per frame properties of DV compression make it the ideal technique for compressed video recording. The feed-forward technique also gives DV an extremely powerful analysis tool that will be explained in detail later. In addition, an Intra-Frame Block Shuffling process was added to DV to further enhance the performance.

The DV compression system has found application in non-linear systems and servers designed for broadcast and professional applications that require the same editing flexibility as traditional video tape. The 6.35 mm DV format is embodied in products from many manufacturers designed for the consumer and quasi-professional market place.

DV Based Compression as Used in DVCPRO50 at 50 Mbit/sec

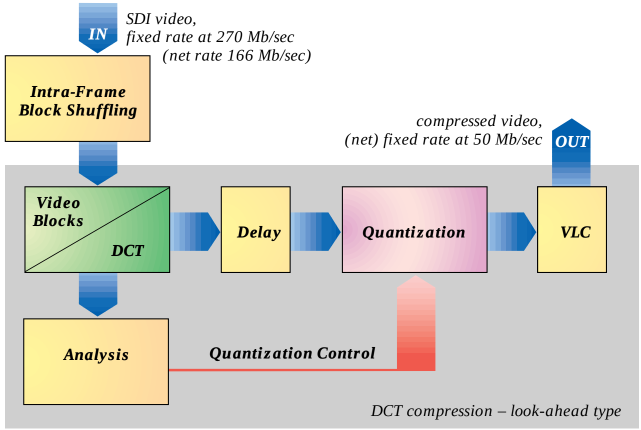


Fig. 15

The DVCPRO family applies DV compression for professional applications in two closely related versions; 25 Mbit/sec and 50 Mbit/sec. **Figure 15** shows the Feed-Forward quantization control, and Intra Frame Block Shuffling in the 50 Mbit/sec. version.

The 25 Mbit/sec version is shown in **Figure 16**. A raster transformation from 4:2:2 to 4:1:1 at the input is done first

DV Based Compression as Used in DVCPRO at 25 Mbit/sec

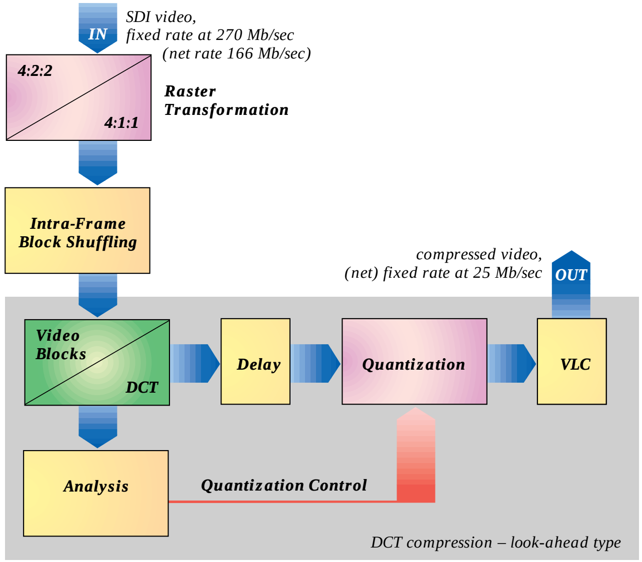


Fig. 16

Compression Formats with Raster Transformation

TV standard / compression	525 lines	625 lines
DVCPRO	4:1:1	4:1:1
DV consumer products	4:1:1	4:2:0
MPEG-2, ML@MP	4:2:0	4:2:0

Table 2

to ease the task for the quantizer. This makes a very cost effective format when the primary purpose is acquisition and recording/playback.

In the consumer domain, the DV compression system uses two formats for raster transformation **(Table 2)**. In the 525 line domain a 4:1:1 raster structure was selected to reduce the overall data or bandwidth requirements while facilitating image manipulation. In Europe, consumer 625 line DV follows the raster transformation (4.2:0) used by MPEG-2 to provide a better commonality between digital distribution via DVB and future DV digital home recorders. While the drawbacks of line sequential color (4:2:0) for professional applications have been well known since the advent of SECAM, it is outside the scope of this booklet to explore the selection of 4:2:0 for MPEG-2. Note that a 4:2:0 raster scheme has merits for progressively scanned images.

Figure 17a shows a sequence of frames coded by DV compression. Since DV compression is not sensitive to the type of sequence due to its purely spatial coding, the frame sequence may contain scene changes, fast movements, or even individual pictures as shown.

Performance of DV Based Compression

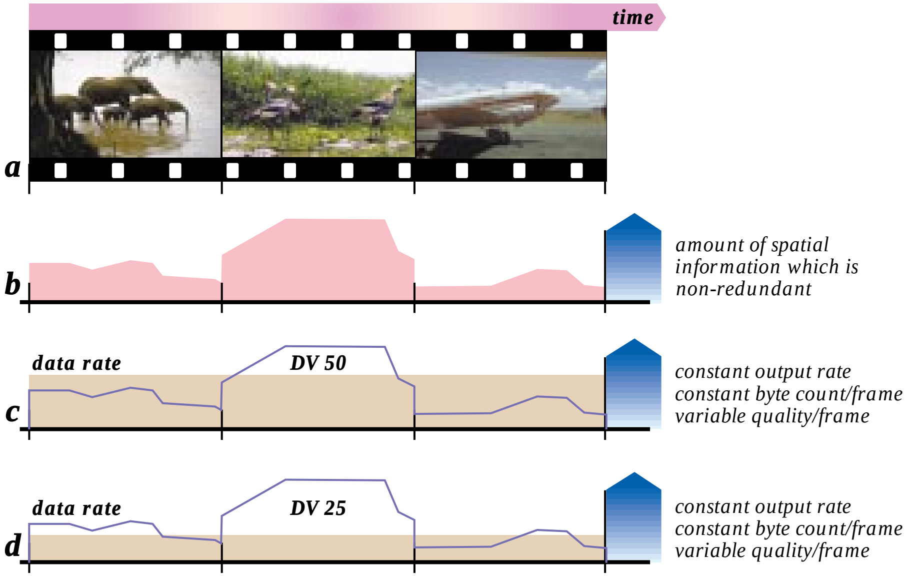


Fig. 17

Each frame has a different amount of core information that is non-redundant **(Figure 17b)**. The output rate will always be constant due to the constant byte count per frame performance of DV compression **(Figure 17c,17d)** as described earlier.

The output rate of DVCPRO50 with 50 Mbit/sec **(Figure 17c)** provides a finer quantization (3:1 compression) for the DCT coefficients compared to DVCPRO (5:1 compression) at 25 Mbit/sec. **(Figure 17d)**. Both DV compression types yield variable image quality depending on the picture content. Pictures with a high degree of spatial redundancy are less effected by the compression **(Figure 17c, 17d)**.

SUMMARY

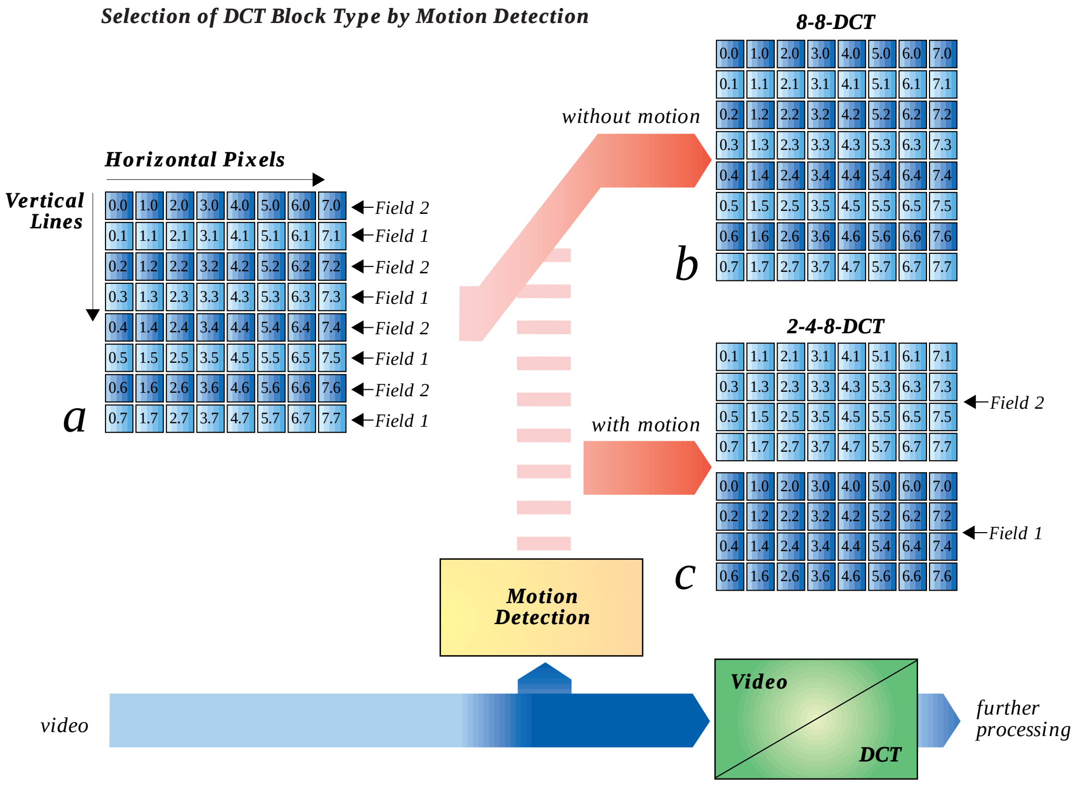
Video tape recorders require a constant number of bytes per frame to facilitate editing. DV compression provides this based on a feed-forward technique combined with block shuffling and a powerful analysis tool for optimizing the DCT quantization.

DV compression details (1).
Processing of interlaced images.

As was mentioned at the beginning of this booklet, compression methods are generally based on frame based processing. Many compression schemes deinterlace the video prior to processing. DV compression employs a somewhat unique method of processing interlaced pictures, but similar methods could also be used by the other compression schemes.

The video picture is divided into blocks of 8 by 8 pixels **(Figure 18a)**, the size of a normal DCT block. Each block consists of 8 pixels horizontally and 8 pixels vertically. When taken as a frame, the vertical pixels belong alternately to the first or second field of an interlaced scanned image. There are two options when processing interlaced pictures, frame processing or field processing. Frame processing converts the 8 by 8 pixel block **(Figure 18a)** with its interleaved fields into the DCT domain **(Figure 18b)**. Field processing separates each 8 by 8 pixel block into two 4 by 8 blocks, one with pixels from the first field, the other with pixels from the second. Both blocks are then DCT transformed independently **(Figure 18c)**.

Field processing performs better than frame processing in moving areas with fine details. In this case, the movement destroys most of the correlation between the pixels on alternate lines due to the temporal changes between fields. That in turn reduces the redundancy and limits the effectiveness of any compression.



Selection of DCT Block Type by Motion Detection

a

0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	Field 2
0.1	1.1	2.1	3.1	4.1	5.1	6.1	7.1	Field 1
0.2	1.2	2.2	3.2	4.2	5.2	6.2	7.2	Field 2
0.3	1.3	2.3	3.3	4.3	5.3	6.3	7.3	Field 1
0.4	1.4	2.4	3.4	4.4	5.4	6.4	7.4	Field 2
0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	Field 1
0.6	1.6	2.6	3.6	4.6	5.6	6.6	7.6	Field 2
0.7	1.7	2.7	3.7	4.7	5.7	6.7	7.7	Field 1

b: 8-8-DCT

0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0
0.1	1.1	2.1	3.1	4.1	5.1	6.1	7.1
0.2	1.2	2.2	3.2	4.2	5.2	6.2	7.2
0.3	1.3	2.3	3.3	4.3	5.3	6.3	7.3
0.4	1.4	2.4	3.4	4.4	5.4	6.4	7.4
0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5
0.6	1.6	2.6	3.6	4.6	5.6	6.6	7.6
0.7	1.7	2.7	3.7	4.7	5.7	6.7	7.7

c: 2-4-8-DCT

0.1	1.1	2.1	3.1	4.1	5.1	6.1	7.1	Field 2
0.3	1.3	2.3	3.3	4.3	5.3	6.3	7.3	
0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	
0.7	1.7	2.7	3.7	4.7	5.7	6.7	7.7	
0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	Field 1
0.2	1.2	2.2	3.2	4.2	5.2	6.2	7.2	
0.4	1.4	2.4	3.4	4.4	5.4	6.4	7.4	
0.6	1.6	2.6	3.6	4.6	5.6	6.6	7.6	

Fig. 18

Frame processing performs better than field processing when little or no motion exists between the two fields of one frame. In this case, the redundancy within an 8 by 8 block is larger, providing twice as many samples per local detail within the picture as compared with a 4 by 8 block.

Frame processing may also perform better with some types of moving pictures when the moving parts show little or no detail. In this case, only the boundary between the stationary and moving parts of the picture will effect some 8 by 8 pixel blocks.

DV compression combines the advantages of both frame processing and field processing. Two modes, 8-8 DCT **(Figure 18b)** and 2-4-8 DCT **(Figure 18c)**, are selectively used to optimize the data reduction process, depending upon the degree of content variation between the two fields of a video frame.

The selection is done on a block by block basis, because in this mode, decisions can be made based upon content analysis of small areas of the picture, and the DV system adapts itself to scenes containing both moving and non-moving features.

SUMMARY

Frame based DCT conversion performs better than field based processing when little or no motion exists between the two fields of the frame. Field processing is better in detailed moving areas. DV compression has the advantages of both frame processing and field processing by adapting the mode based on motion content.

DV compression details (2).
Macro Blocks and video segments.
Shuffling of DCT blocks: a means to further enhance compression quality.

Intra-Frame Macro Block Shuffling of DV Compression

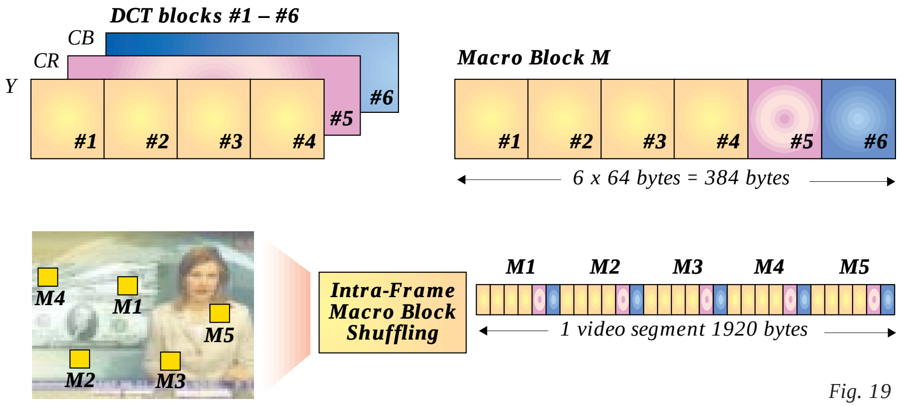


Fig. 19

The 8-8 or 2-4-8 DCT blocks described above are grouped into so called Macro Blocks. One Macro Block ("M") formed by combining four adjacent DCT blocks of the luminance signal **(#1 to #4 in Figure 19)** and two DCT blocks **(#5, #6)** that represent the accompanying color information. The resulting Macro Block contains 6 DCT blocks of 64 bytes, or 384 bytes of DCT coded video. Figure 19 shows the 4:1:1 sampling raster of the DVCPRO at 25 Mbit/sec recording format; the process is essentially doubled for DVCPRO50.

Five Macro Blocks are selected from five diverse locations within the image and are combined into one so-called video segment. Each video segment contains 5 Macro Blocks of 384 bytes, or 1,920 bytes of DCT coded video. Note that no compression has yet been applied.

The other video segments are formed by repeatedly combining five other Macro Blocks, again taken from five different locations within the picture. This process is called "shuffling" of the DCT (macro) blocks since the blocks are not adjacent in the image.

Since each of the five Macro Blocks within one video segment represents picture content from a different part of the image, each part may differ in nature. One may contain a high amount of picture detail with little spatial redundancy while another may contain no detail with a high degree of spatial redundancy. The advantage of this shuffling process is that, as a result, video segments always contain an average amount of redundancy.

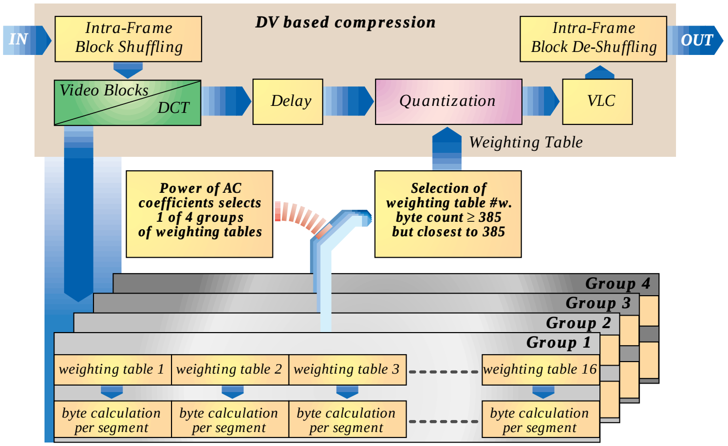
DV compression, like the other compression systems described above, is based on quantizing of DCT coefficients. The same quantization table is used for all DCT blocks within a Macro Block. Different quantization tables may be used for different video Macro Blocks depending on the analysis of the picture signal. This analysis, which was referred to earlier, is explained in the next section.

SUMMARY

Block shuffling ensures that the effects of compression are equally distributed within an image. Shuffling averages picture parts of high detail with parts of low detail without needing to analyze the picture content.

DV compression details (3).
Pre-analysis of DCT blocks optimizes compression results.

Pre-Analysis of DCT Blocks for Optimized Quantization



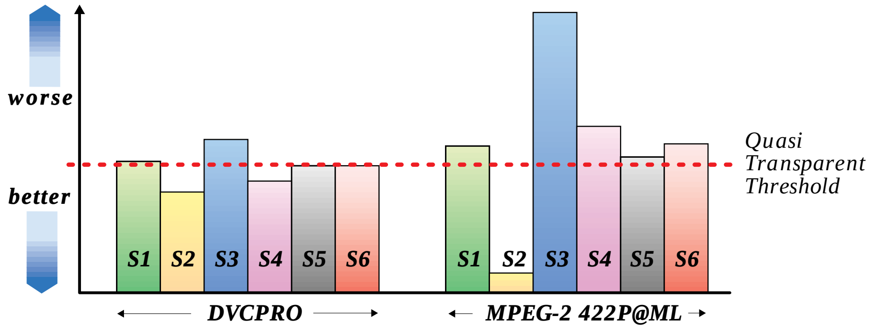
1 video segment = 1920 bytes uncompressed = 385 bytes compressed

Fig. 20

The strength of DV compression is that it enables analysis of DCT coded blocks of video prior to the actual compression process. The goal is to fully optimize the actual compression process that follows. Note that MPEG-2 is based on a completely different scheme. The MPEG compression process is controlled via a feedback loop after the actual compression has taken place. It could be said that DV looks ahead while MPEG-2 looks backwards.

The following section explains the basic principles but not the actual implementation of the pre-analysis procedure. This pre-analysis process is performed separately for each uncompressed 1,920 bytes video segment (5 Macro Blocks).

Picture Impairment through Compression to 50 Mbit/sec



** measured at 4H viewing distance for 6 different scenes S1 to S6 after 7 generations of compression*

Fig. 21

All the DCT based compression schemes rely on the quantization of blocks of DCT coded video signals. The quantization is performed by applying weighted factors to each DCT coefficient, i.e. each block of DCT coefficients is multiplied with the factors provided by the quantization table.

DV compression can select among 64 different quantization tables. The task of the table selection process is to match the significance of the individual DCT coefficients to the human visual system and to achieve a constant byte count per frame at the same time. The 64 quantization tables are organized into 4 groups of 16 tables each. Group 1 contains quantization tables optimized for very high spatial detail within the picture. Group 4 is optimized for very low spatial detail, and the other two groups are for medium levels of picture detail.

The compression process first selects one of four groups of quantization tables based on the measured power of the AC coefficients within the DCT blocks. The power of the AC coefficients (See Chapter 4) is an indication of the amount of spatial detail in the picture.

The DV compression process then selects the final quantization table to be used from the 16 remaining choices. Each of the remaining 16 quantization tables is applied to a virtual compression of the DCT coded video signal, and for each of these tables the resulting compressed bytes per segment are counted. A selection is then made using these results so that the final byte count at the output of the compression is closest to, but not exceeding, 385 bytes. The selected table is then actually used to perform the compression. This analysis of the picture, by pre-calculating the number of compressed bytes, guarantees a constant byte count per frame, which is needed for video tape recording and other television production applications.

The additional steps of block shuffling minimize the effect of variable picture quality depending on scene content. Figures published by the EBU on the work of the EBU/SMPTE taskforce confirm this. **Figure 21** shows a comparison between DVCPRO and MPEG-2 422P@ML. The compressed data rate was 50 Mbit/sec and the viewing distance was four times picture height. The impairment caused by the compression methods was judged subjectively for 6 different scenes after the signal had passed through the process of compression & decompression seven times with pixel shift (pixel shift is a technique that will be explained later). From **Figure 21** it can be seen that the amount of variation in picture quality for DVCPRO is drastically minimized compared to MPEG-2. This performance is of special importance when the video signal must pass through the compression process more than once, as will be discussed later.

SUMMARY

The powerful key to DV compression is the analysis of DCT coded blocks of video prior to the actual compression process. Based on multiple parallel trial compressions with 64 possible alternatives, the optimal quantization table is selected for the actual compression. This method guarantees the constant byte count per frame which is needed for video tape recording. Additionally, block shuffling minimizes the influence of scene content on picture quality.

Switching and editing of compressed video signals (1).

Switching of MPEG-2 Encoded Signals

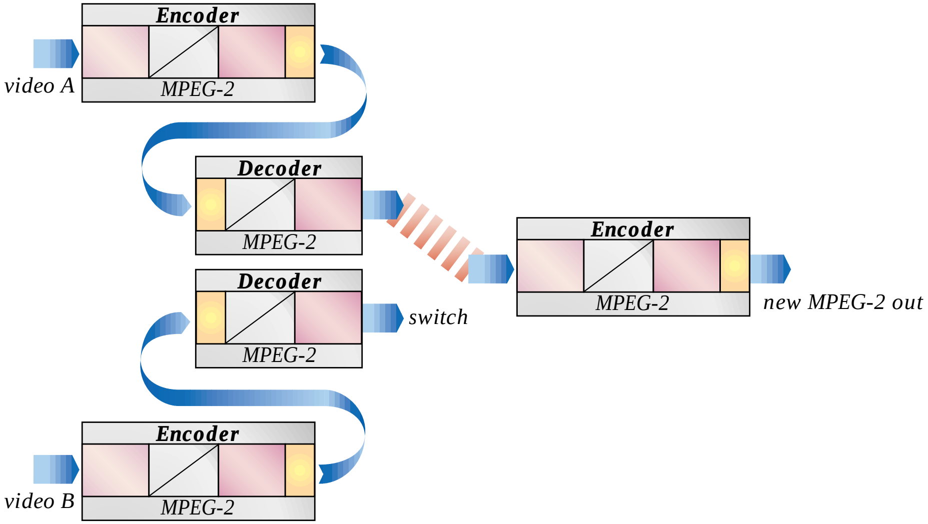


Fig. 22

Switching and editing are the main tools of television production. Operational restrictions related to the switching and editing of composite NTSC and PAL video signals are well known. Assembling individual scenes requires keeping the sequence or phase of the color subcarrier undisturbed. NTSC and PAL were never optimized for production or post production purposes, but were developed for effective distribution of color signals to millions of home receivers. Their main task was to deliver color, and still produce a subjectively undisturbed picture on the then-current black and white TV receivers!

Digital component video (SDI) overcame the operational restrictions caused by composite NTSC and PAL. Unfortunately, history is repeating itself. The inventors of MPEG-2 never had the applications found within TV centers in mind. Since their goal was to replace the analog PAL and NTSC video distribution and transmission formats with a digital method using advanced compression technology, MPEG-2 is based on a scheme of GOP sequences. These GOP sequences create the same problems for editing as the color subcarrier relationship does for NTSC and PAL.

SMPTE Standard 312M defines a "work around" process which requires the marking of potential downstream switch points during the first MPEG-2 encoding. To fulfill such a requirement, it must be possible to foresee these switch points. Assume an anchorman in the television center is talking to a person located in an external studio. If the remote contribution signal is coded in MPEG-2 MP@ML, then the director of the News show, located back in the television center, has no possibility whatsoever of placing the in-and-out flags in the external signal at the points where he would like to switch between the local signal and the external one.

These limitations may be avoided to a large extent when the switching between two MPEG-2 signal sources is done as video in the decoded SDI domain **(Figure 22)**. However, the price to be paid is threefold: additional hardware, significant cumulative signal delays, and loss of picture quality due to the decoding from MPEG-2 to SDI before the switch and the re-encoding into MPEG-2 after the switch. The use of helper signals can limit this unavoidable quality loss to the series of frames just before and after the switch, but helper signals also add complexity.

This is another big operational burden that should not be overlooked. The decoding as well as the coding process of MPEG-2 MP@ML signals lead to extreme signal delays for picture and sound. These delays can easily reach an order of magnitude that will make any "live" conversation between an anchorman in the television facility and another person located in an external studio extremely difficult (to use the earlier example).

DV compressed video sources can be switched or edited without any of the above mentioned problems, and incur minimal latency. This allows the seamless interleaving of signals with different compressed data rates as explained on the following page.

SUMMARY

MPEG-2, which is based on temporal compression, imposes significant restrictions on switching and editing compressed signals. When operational conditions prohibit the adding of splice flags at the MPEG-2 encoder site, switching requires the decoding and subsequent re-encoding of the compressed signals, but the impact is threefold: additional hardware, signal delays and loss of picture quality. With special decoding and re-encoding circuitry and the use of additional "helper" signals, the quality loss can be limited to the series of frames just before and after the switch.

Switching and editing of compressed video signals (2).
DV compression details (4).

Seamless Interleaving of DV Coded Signals with Different Compression Factors

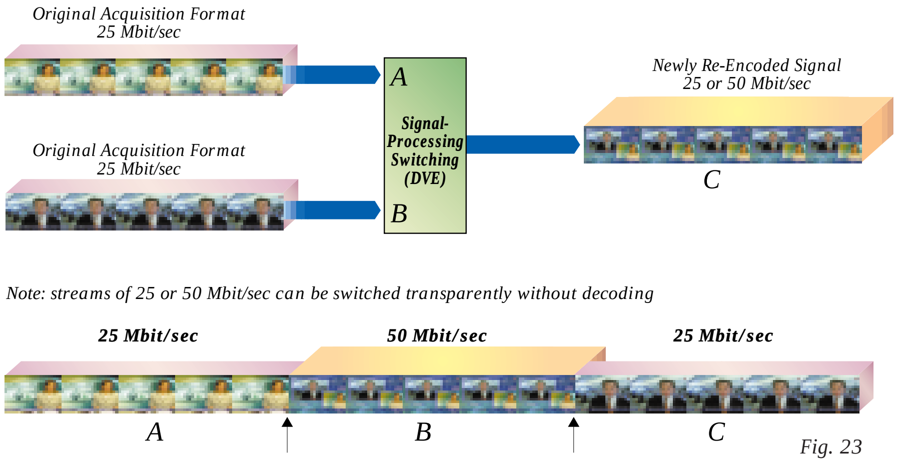


Fig. 23

Video Stream Composed of Seamlessly Interleaved 25 & 50 Mbit/sec DV Signals

Figure 23 shows two source signals (A, B) coded in the original acquisition format of DVCPRO at 25 Mbit/sec. As we described earlier, compressed DV streams can easily be switched or spliced at any frame without decoding. However, during the production process some signal processing may require the decoding of these DV signals, e.g. performing a digital video effect to create a new signal (C). This new DVE signal (C) could be re-encoded into DV at 25 Mbit/sec, but it is often advisable to re-encode such signals into DV at 50 Mbit/sec. This ensures that no re-encoding losses become visible.

With DV it is not necessary to transform all scenes (especially untouched scenes) from 25 Mbit/sec to 50 Mbit/sec. 25 Mbit/sec and 50 Mbit/sec compressed signals may be seamlessly interleaved within the same video stream.

In the DV domain, this assembling process is frame accurate, without any restrictions or need to mark with splicing flags, and it therefore fulfills all editing requirements. This is a result of the fact that compression for both the 25 Mbit/sec and 50 Mbit/sec versions of DVCPRO are based on a complete codec definition.

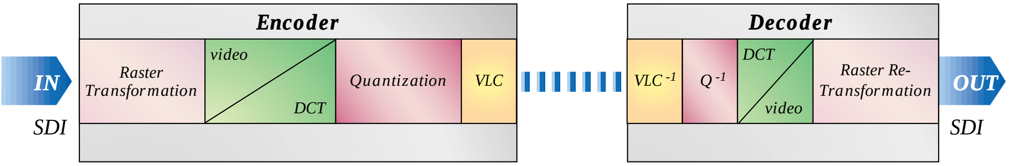
Note that retaining the acquisition and contribution material in their original 25 Mbit/sec coding as long as possible has its economic benefits. In addition to savings on tapes and equipment, it also reduces the need for costly storage space on disk-servers.

SUMMARY

DV compressed video can be switched and edited without any restrictions. In addition, it allows the seamless interleaving of DV signals with 25 and 50 Mbit/sec.

Cascading of DCT based compression codecs.

Sources of Quality Losses in DCT Based Compression Codecs



Codec = Encoder + Decoder

Fig. 24

There are several sources of quality losses in DCT based compression codecs even without cascading, as shown in **Figure 24:**

- Raster transformations cause visible resolution losses due to filtering processes.
- The transformation from video (SDI baseband signal) to DCT coefficients and vice versa may incur rounding errors that may be invisible.
- The quantization of the DCT coefficients causes the dominant loss of quality for all DCT based compression schemes.
- The variable length coding (VLC) causes no quality loss at all.

VLC *= no losses*	🟨
Quantization *= highest losses, main source of losses*	🟥
SDI / DCT-Transformation *= rounding errors*	🟩
Raster Transformation *= resolution losses due to filtering processes*	🟪

Cascading Compression Codecs Caused by a Sequence of Different Applications

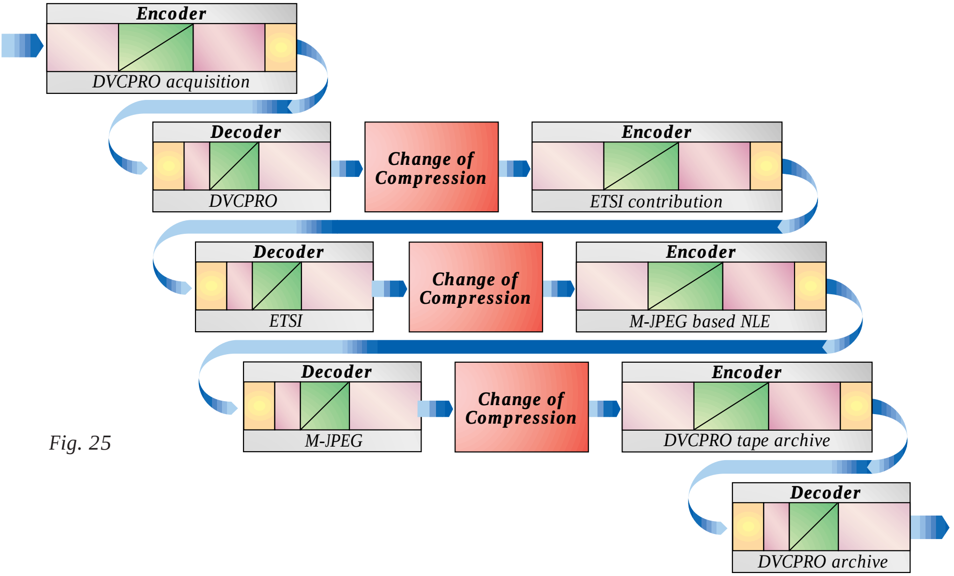


Fig. 25

Cascading of DCT based compression codecs impacts picture quality because the quantization of the DCT coefficients is repeated several times. Note that repetition of raster transformations can be performed by filtering which can adversely impact every generation, or can be done by digital resampling techniques that have no impact on signals which had already passed through at least one filtering process.

The simultaneous use of different varieties of compression within one TV facility cannot often be avoided. Such variety exists even within the same compression family (M-JPEG, MPEG-2, DV). This may lead not only to the necessity of transcoding but to a cascading of compression codecs as well.

A practical example for the cascading of DCT based compression codecs is shown in **Figure 25**. The clips are captured originally with DVCPRO equipment at 25 Mbit/sec. Transmission to TV facilities may use an MPEG-2 ETSI contribution format. The clips are stored in the Motion-JPEG format and edited on a non-linear editing system. The result is stored on video tape in the DVCPRO50 format and placed in a tape archive for later re-use.

In the above example four compression codecs are cascaded, including three changes of the compression format. This is a simple example; the daily operational needs of the real world may ask for a much higher number of cascaded codecs. It is therefore preferable to minimize the cascading from the beginning.

Imagine that in our simple example the ETSI contribution format is replaced by DV contribution via ATM. The NLE system based on M-JPEG can be replaced by a non-linear editing system based on DV. In this scenario, all compression transcoders can be eliminated. There are no additional costs for this hardware, and no pain through the quality losses caused by each of the transcoding processes. As previously mentioned, DV based compression does not require transformation from 25 Mbit/sec to 50 Mbit/sec because both compressed signals can be seamlessly interleaved within the same video stream.

One may ask why this scenario should not be portrayed as all MPEG-2. As described earlier, the virtue of MPEG is temporal compression, but temporal compression is inappropriate for editing and acquisition.

Cascading Compression Codecs Caused by a Sequence of Different Processing Steps

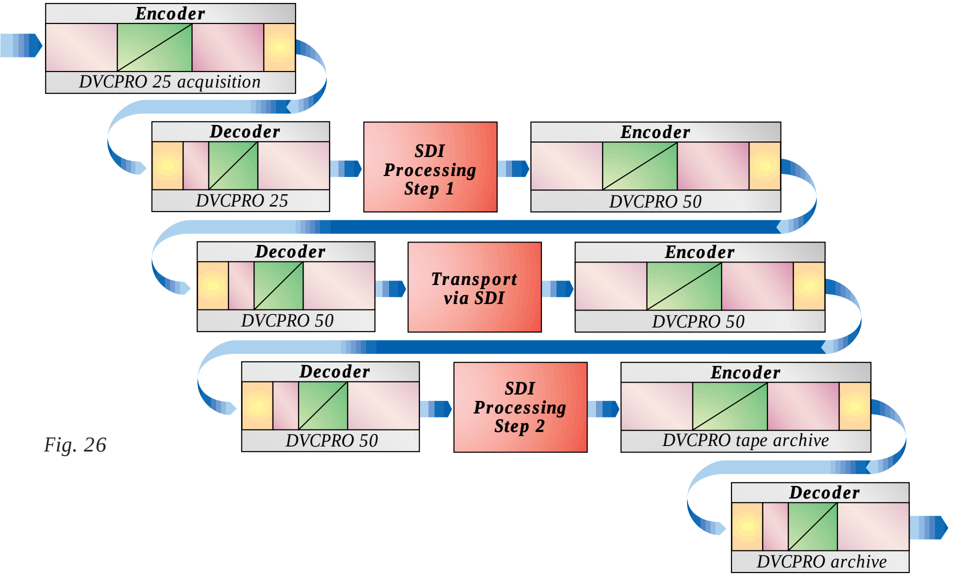


Fig. 26

The cascading of compression codecs is not caused purely by the use of different compression formats. Complex signal manipulations cannot be done in the compressed domain. Processes like mixing, digital video effects (DVE), chroma-key, gamma correction, and complex processes of titling and logo insertion are performed in the baseband domain of the SDI video signal. In **Figure 26** these signal manipulations are identified as SDI processing step 1 to step 2. Operational practices may ask for a much higher number of processing steps.

Since the cascading of compression codecs may become inevitable, the EBU/SMPTE taskforce decided to judge different compression formats not solely on their so-called first generation performance. Adding another compression cycle leads to the next generation indicated by increasing the number by one. The generation number is therefore equal to the number of cascaded codecs.

Schematic Trajectory of the Signal to Noise Ratio over the Number of Cascaded Compression Codecs

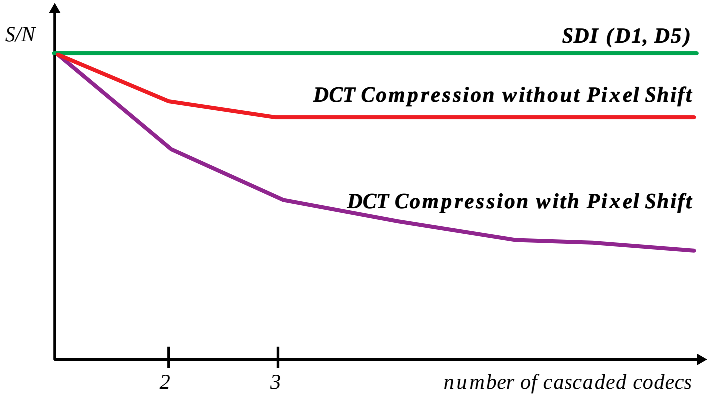


Fig. 27

Testing done by the EBU included a pixel shift of 2 luminance pixels horizontally and/or a shift of 1 or 2 line(s) vertically. This pixel shift simulates the post-processing steps between the compression codecs **(Figure 26)** and ensures that the compression process "sees" and operates upon different pictures, although this small shift allows the images to appear identical to the viewer.

When comparing cascading tests or data, one must not forget to check if the test included the pixel shift procedure or not. Comparing tests not done under the same procedures will lead to very misleading results, as illustrated in **Figure 27**. For the same compression format the calculated signal to noise ratio without applying pixel shift is significantly better than the signal to noise ratio with pixel shift.

SUMMARY

Cascading of compression codecs will become inevitable because complex signal manipulations cannot be done in the compressed domain. To minimize the need for cascading, the original compression format should be retained from acquisition through contribution and post-processing down to archiving. The multi-generation performance of compression formats should usually be judged by the pixel shift method.

Conclusion.

The different compression schemes discussed in this booklet are all based on the Discrete Cosine Transform (DCT) of digital video and the subsequent quantization of the DCT coefficients. While they may be optimized for different applications, it would be an error to conclude one should use the optimum type of compression for each different application. Transcoding processes from one compression format to another, or in some cases from one compression ratio to a different one, are not without impacts. Additional hardware is needed, reductions in picture quality occur, and unwanted signal delays aggregate.

Table 3 associates four compression formats (M-JPEG, MPEG-2 MP@ML, MPEG-2 422P@ML, DV based) with three performance characteristics (constant data rate, constant byte count per frame, variable data rate). The note "t.b.d." means that future supplemental standards may be able to provide this performance.

Table 4 links four applications (non-linear editing, distribution, switching, and video tape recording) with three performance characteristics of compression formats (constant data rate, constant byte count per frame, variable data rate). The note "t.b.d." means that the performance is not adequate.

Compression Formats and their Performance Characteristics

Characteristic Compression	Constant Data Rate	Constant Byte Count / Frame	Variable Data Rate
M-JPEG			●
MPEG-2 MP@ML	●	t.b.d.	
MPEG-2 422P@ML	●	t.b.d.	
DV based	●	●	

Table 3

Applications and their Performance Requirements

Characteristic Compression	Constant Data Rate	Constant Byte Count / Frame	Variable Data Rate
Non Linear Editing	●	●	●
Distribution	●	●	
Switching	t.b.d.	●	
TV Tape Recording		●	

Table 4

Compression Formats and Matching Applications

Application / Compression	Non Linear Editing	Distribution	Switching	TV Tape Recording
M-JPEG	●			
MPEG-2 MP@ML		●	t.b.d.	
MPEG-2 422P@ML	●		t.b.d.	t.b.d.
DV based	●		●	●

Table 5

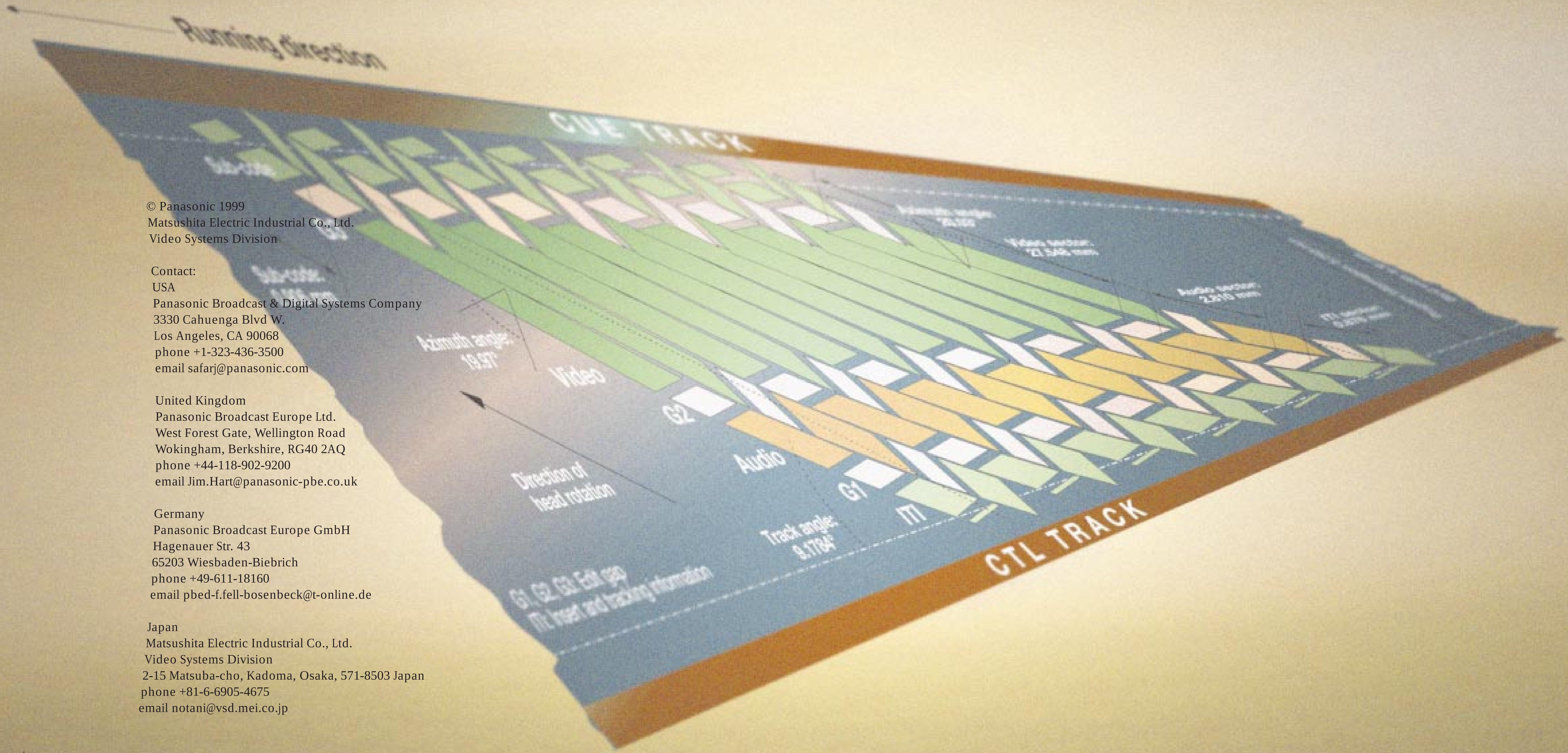
Table 5 relates applications to compression formats. The note "t.b.d." means that some supplemental standards do provide this application but this is not universally true.

Motion-JPEG cannot fulfill the requirements of tape recording and switching, but is an ideal tool for non-linear editing.

MPEG-2 MP@ML, due to the temporal nature of the compression, cannot fulfill the requirements of non-linear editing or video tape, but is the ideal tool for distribution.

MPEG-2 422P@ML can be used for non-linear editing, but needs additional supplemental standards to be used for switching and tape recording purposes.

DV-Based compression can handle all applications within production and postproduction without the need for supplemental standards, but is less efficient then MPEG-2 for transmission (remote contribution).



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