Compression

H. Schachlbauer
IRT

The Compression subgroup of the Task Force was set up to provide guidance for the longterm integration of compression into programme production. Its work led to the conclusion that there is no single member of a compression family that satisfies the requirements of a fully-networked digital production facility.

The two compression families ultimately selected by the subgroup were MPEG and DV, each of which offers individual trade-offs in terms of coding flexibility, product implementation and system complexity. This article gives an overview of the factors which led to this choice.

1. Introduction

Compression is a key enabling technology in the context of a fully-networked digital environment – particularly from an economic viewpoint. Through the use of compression, broadcasters hope to achieve significant cost savings in the areas of data transfers, storage, etc. No broadcaster, after all, wants to compress just because of the beauty of compression!

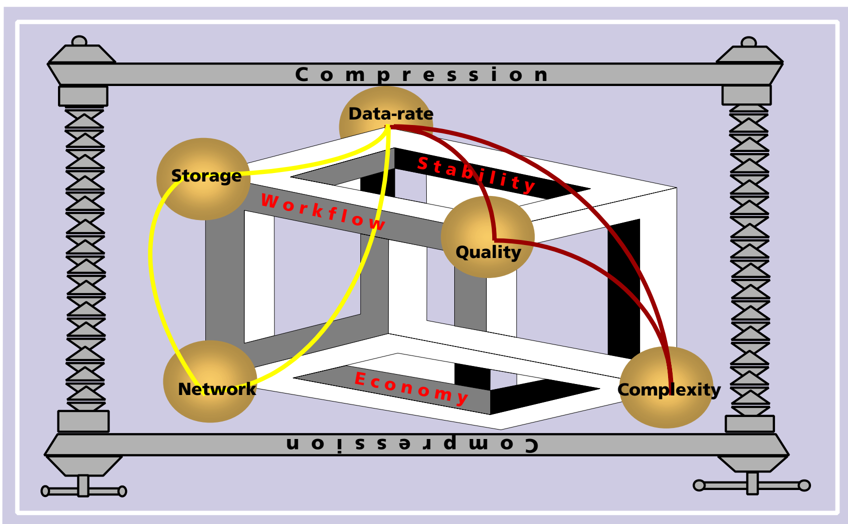


Figure 1
Some of the important issues associated with compression.

There is a very complex relationship between the quality we want to maintain in our broadcasting assets and making that quality truly predictable after a lengthy post-production process. The ultimate quality obtained from a digital production system is dependent on:

Original language: English
Manuscript received: 27/10/98.

- the data-rate;
- the complexity built into the compression system;
- the type of network and the bandwidth available to transport the datastream between the various storage devices and network devices.

The major objective now, in terms of a compression system, is to find an optimum balance between an achievable signal quality which will hold for the next ten to fifteen years, and an economic model which will make networking and storage a viable proposition.

2. Compression considerations

The Compression subgroup was confronted with a range of different and, of course, incompatible compression systems which it had to evaluate and appraise on a piece-by-piece basis.

The following criteria were used:

- the ultimate technical quality that could be achieved, versus the datarate required for that;
- interoperability between compression schemes using, for example, different coding parameters;
- the editing granularity versus the complexity of the network editing control.

We had to verify how all the avaialable compression schemes complied with the requirements we set out in the first Task Force report (April 1997) – namely, and most importantly, the format stability. We did not want to consider formats which would not survive the day, or the next ten years. This meant that the chip-sets had to be provided at an economical price and on an equitable basis. They would have to be standardized, and all the elements required to reproduce the compression system and all the modules pertaining to it (e.g. the mapping into various networks) would have to be laid open, so that any manufacturer could build his equipment from these chip-sets.

We had to look at the picture-quality ceiling available with the different compression systems proposed for today and tomorrow. We also had to look at the availability of integrated decoders and intra- and inter-family agile decoders (which are explained later), and of course we had to look at the pros and cons of choosing a single compression system rather than a whole compression family.

We also looked at the format development potential because, obviously, we did not want to promote a compression scheme having a lifetime not exceeding five, six or seven years – we wanted one which would form a solid basis upon which systems could be built in a very compatible way.

We had to identify possible problems in the area of interoperability and complexity, and we did focus on near-term solutions (a very essential element) because we were very well aware of the fact that broadcasters would implement these systems on a piecemeal basis.

It was quite clear from the beginning that we would have to provide a migration path for broadcasters to proceed from where they are now (i.e. using analogue systems and partially-digitized plant) towards the fully-networked digital environment. At the same time, broadcasters would wish to be able to add elements as and when they wanted to, safe in the knowledge that they could build one element on top of another without making the previous element obsolete.

And of course the subgroup looked at proposed solutions which required a whole network to be in place to make them really work. While we are all hoping that the network approach will actually happen, we are not promoting solutions which are based purely on that approach.

3. The decision process

The subgroup studied various compression schemes, their options and quality ceilings. As we wanted to base our decisions on experimental evidence, not just on gut feeling and a crystal ball, there had to be underlying evidence as to how these proposed schemes would be usable within a broadcast environment (we did request formal written commitments for standardization in a number of areas). In addition to this, given that VTR and disk will continue to coexist for a long while yet, only compression schemes which would also address the problem of recording on a VTR were considered.

The subgroup was eventually confronted with six different compression schemes, ranging from professional MPEG, to DV-based, Motion-JPEG, Digital Betacam, wavelet encoding and fractal encoding. Applying our user requirements, we had to eliminate a number of these schemes because they simply did not comply (see *Fig. 2*).

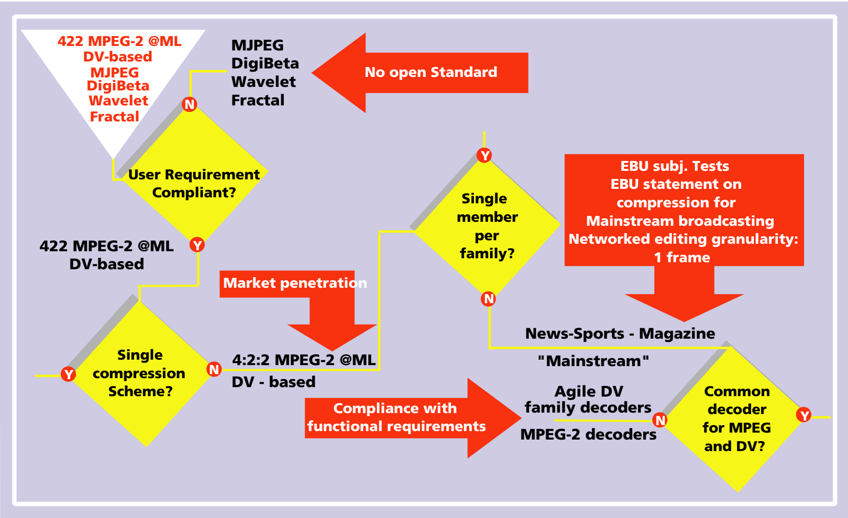


Figure 2
Flow chart used to select suitable compression schemes.

Motion-JPEG was not standardized, and consisted of many variants – although recently an effort has begun within the SMPTE to have M-JPEG made compliant within itself and interoperable with M-JPEG equipment from other manufacturers, but that enterprise is just starting.

We approached the proponents of Digital Betacam, which has a very successful compression format hidden away within the equipment. However, they said that they would not open the compression system to the public domain for standardization, and that they had no intention of using this compression format for networked operation. That rendered Digital Betacam a non-contender.

Wavelet compression is something which works, but is not yet standardized.

Fractal compression is successfully used in environments where the imbalance between encoding and decoding complexity can be tolerated – in graphics, for instance. However, it is not something that could be universally used in a post-production environment.

So what we were left with were:

- MPEG-2 4:2:2 P@ML (abbreviated to "Professional MPEG" in the accompanying figures), which is an adaptation of the MPEG-2 MP@ML;
- a range of DV-based compression schemes.

At the time, there were only two commercial systems on the market we could base our decisions on – one was Betacam SX and the other was DVCPRO.

So the question then arose - *is it going to be just one of those two systems, or is it going to be both?*

It was quite clear from information about market penetration that this idea of a single system covering the whole range of different applications within post-production was a non-starter. So we had to recognize that we would be facing two different compression families in the future, one based on MPEG and the other based on DV.

This lead us to another important question – *will these two systems, SX and DVCPRO, cover the whole range of quality expectations we normally have in television production?*

4. EBU subjective tests

The EBU has carried out a range of tests to try to answer that question. It has found that for applications such as news, sports and magazine programming, these two formats deliver *almost* equal quality. Hence, for news, sports and magazine programmes, we can happily live with MPEG- or DV-based compression in the range 18 - 25 Mbit/s.

This could have led us to the conclusion that we would need just one member of either compression family, but this was not to be. We identified a second quality area – the whole area of mainstream television – which demands compression at around 50 Mbit/s.

Wouldn't it have been nice to have a *common decoder* for these schemes! But the manufacturers at that time said "no, it's not going to happen" so we have ended up with two families of com-

Abbreviations

4:2:2P@ML	(MPEG-2) 4:2:2 Profile at Main Level (Professional MPEG)
GoP	Group of pictures
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
ITU-R	International Telecommunication Union, Radiocommunication Sector
JPEG	(ISO/IEC) Joint Photographic Experts Group
M-JPEG	(ISO) Motion - Joint Photographic Experts Group
MP@ML	(MPEG-2) Main Profile at Main Level
MPEG	(ISO/IEC) Moving Picture Experts Group
NLE	Non-linear editing
SDI	Serial digital interface
SDTI	Serial data transport interface
SMPTE	(US) Society of Motion Picture and Television Engineers

pression and two different *agile decoders*, both of them able to handle the compression members of their own family only.

Fig. 3 shows the subjective performance of the SX system when tested at 18 Mbit/s in accordance with the well-known ITU-R Recommendation BT.500. It clearly shows that, at the seventh generation under worst-case conditions, we end up with conspicuous artefacts. However, studies are still going on to find how we can mitigate these aberrations by aligning macroblocks throughout the post-production process, by means of auxiliary information carried within the bitstream. Perhaps, this will provide a solution in the future – for both MPEG and DV compression.

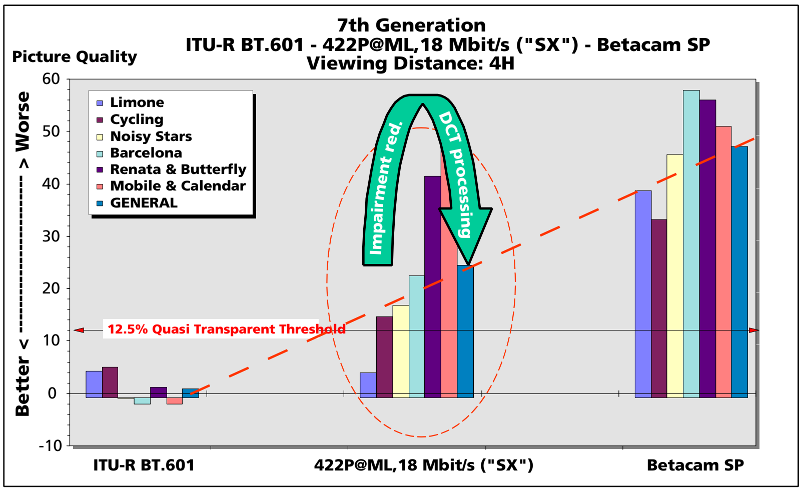


Figure 3
7th generation picture quality at a viewing distance of 4H: 4:2:2P@ML, 18 Mbit/s ("SX").

Fig. 4 shows the subjective performance of what we call the mainstream television profile, running at 50 Mbit/s. As you can see, the average quality obtained at the seventh generation, under worst-case conditions, is just slightly above the level of visibility. Once again, in the future we may be able to reduce these artefacts by aligning macroblocks throughout the post-production process but, until then, our final television products will be maimed with the artefacts caused by multiple coding and decoding.

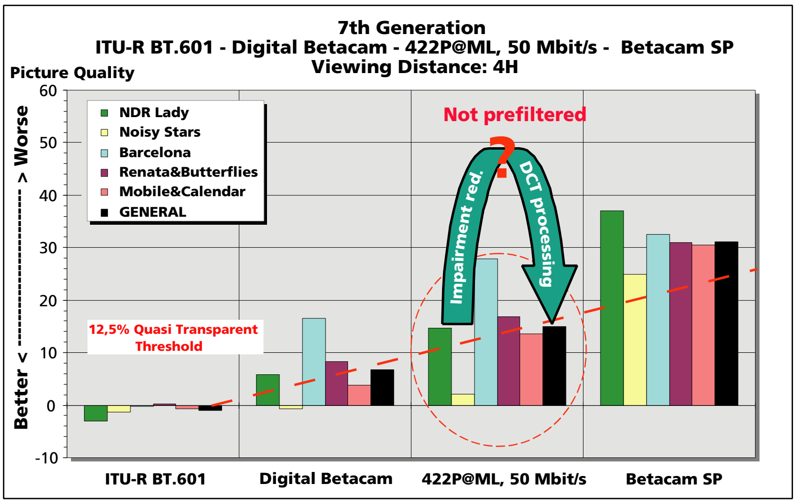


Figure 4
7th generation picture quality at a viewing distance of 4H: 4:2:2P@ML, 50 Mbit/s ("Professional MPEG").

NOTE: The different behaviour of Betacam SP that is apparent in *Figs. 3* and *4* is due to the fact that two different versions of the SP equipment – in different states of (mis)alignment – were used for these tests. It thus indicates, to some extent, the practical quality range of the Betacam SP format.

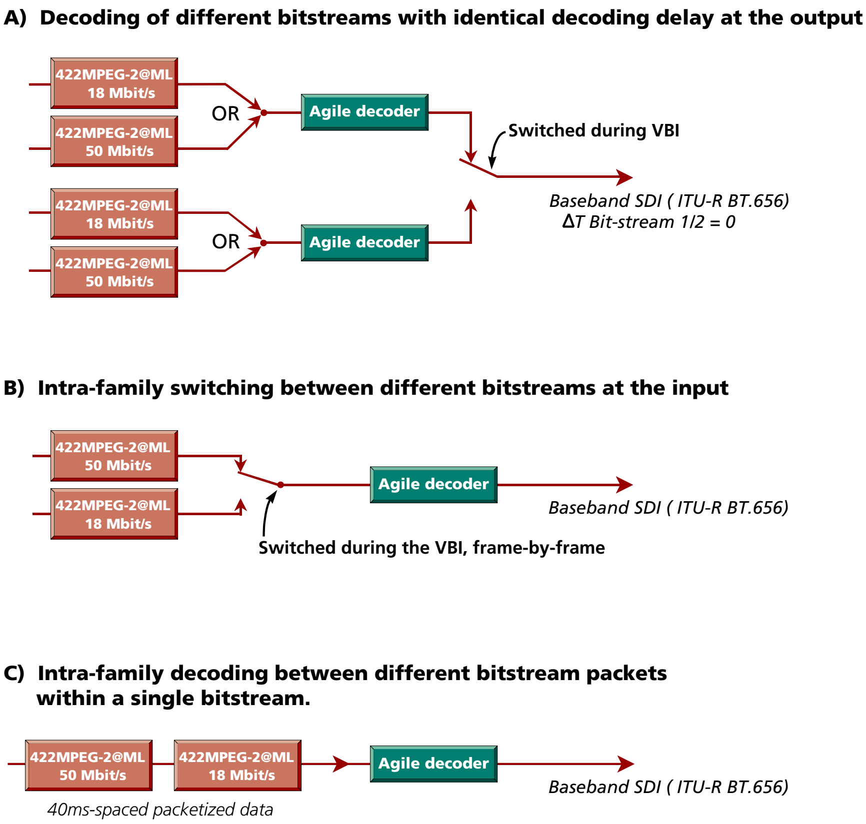
One other option that both families can exploit – at least those compression formats which use temporal redundancy – is the fact that you can alter the GoP structure along the post-production process, in an attempt to maintain some of the original coding information. For example, you can change to a different GoP structure in order to reduce the datarate for increased storage efficiency and then revert to the original GoP when loading this content from the storage device into a different device. This technique is currently being investigated in various places – there is a degree of enthusiasm about it – but we still have to await the results before making a positive public statement about it.

The subgroup's deliberations were very conservative because we had to establish a base-line commonality. It is a worst-case scenario – which can only be improved upon. As technology evolves, some of the differences that we noticed between the two systems will possibly disappear, or will at least be smaller than we originally thought they would be.

5. Agile decoders

An *agile decoders* is any decoder within a particular family, be it MPEG or DV, that could cope with a range of compressed input signals (see the examples shown in *Fig. 5*). In some cases it would be necessary to use interframe switching between the different bitstreams at the input, in which case we would then end up with different data packets within a single SDTI bitstream. The agile decoder would have to be able to output that bitstream for further multiplexing, without causing any hiccups.

It must be acknowledged that agile decoders will only be able to work with fairly standard bitstreams. They will not, for example, be able to cover things like faster than real-time playout, pictures in shuttle or stunt modes and other similar applications which require a different arrangement of the packets in order to optimize the visualized result. These specialist applications will require *native decoders*, designed by the equipment manufacturer for optimum decoding quality.



Native Decoders

Native decoders which have been designed to operate on non-standard bitstreams, e.g. for optimized stunt-mode performance (shuttle, slow-motion) or for special functions, are acceptable. The decoder chip-set should be available on a non-discriminatory basis on fair and equitable conditions. Details of possible deviations from the standardized input datastream should be in the public domain.

Figure 5
Some applications of agile decoders within a single compression family

Fig. 6 (shown below) gives a visual representation of the problems encountered through the use of two different compression families. There are three distinct planes on the diagram:

- a DV plane which represents the whole DV family, and this is not just one company and one tape – there are at least three tape formats currently in use;
- an MPEG plane which covers the range of available GoP structures;

➪ a processing layer.

Ideally the two compression layers should interoperate at an SDTI compressed bit-rate level. However, that is not happening just yet and it is necessary to transmigrate from the SDTI layer into the processing layer which is still SDI. Taking into account the artefacts that are normally caused by coding from A to B and from B to A, what we are trying to achieve as time goes by is to carry out a number of these processes within the compressed area itself. Thus, if there is an economic implementation that will allow us to do this, then that is certainly the way to move forward. At the moment we are still handicapped by having to go from the compressed to the uncompressed state in quite a high number of cases, leaving us with a very conspicuously impaired result at the end.

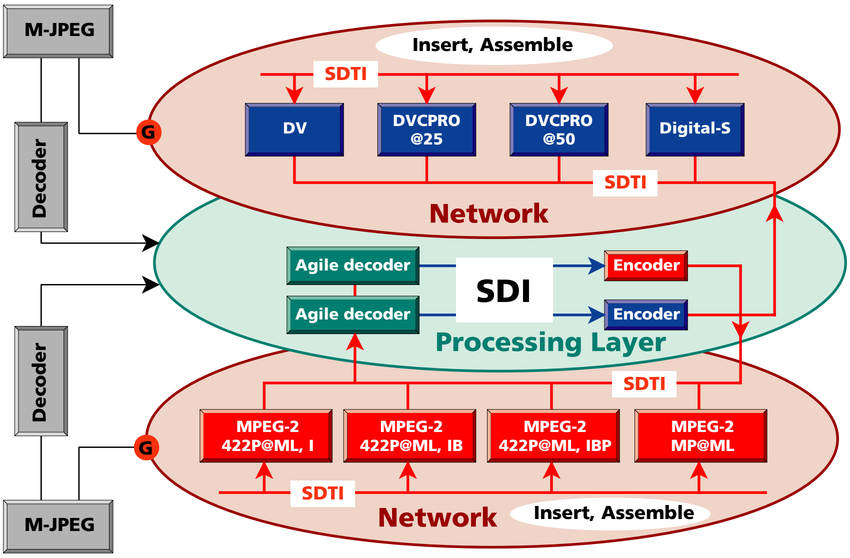


Figure 6
Model showing the two chosen compression families and the need for a processing layer.

There are gateways for M-JPEG which we have not promoted as having a future in a fully-networked environment. This has astounded and surprised some people because it is obvious that Motion-JPEG is everywhere in applications based on hard disks, and NLE in particular. It is now up to the proponents of M-JPEG to provide the appropriate gateways into the networked environment – either into DVCPRO or into MPEG. The way into SDI is open for everybody, that is quite clear.

As time goes by, the differences between the DV and MPEG formats will hopefully disappear. Devices will be provided to enable the agile decoding of both formats, thus allowing a controlled mixture of both formats whilst giving a predictable output signal at the end of the production process.

Horst Schachlbauer *graduated in Telecommunications from the University of Munich in 1967 and has since worked for the IRT, the central Research Laboratory of German, Austrian and Swiss public broadcasters.*

Mr Schachlbauer been very involved in the development of standards for digital television on national as well as international platforms, e.g. ITG, EBU, CCIR and ETSI. In particular he was involved in the specification of CCIR Rec. 601, the D-1 recording format, the ***S****erial* ***D****igital* ***I****nterface and PALplus.*

Currently, Horst Schachlbauer heads the EBU MAGNUM committee which closely liaises with manufacturers in the area of recording technology for television. He also chairs a number of national and international Project Groups dealing with digital television production technology and archiving. He served as the European co-chairman of the EBU/SMPTE Joint Task Force and has recently been elected a Fellow of the SMPTE.