Rec. 601 — the move to components

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In the late 1970s it was clear that the time was right to standardize the sampling parameters for digital video signals. This would allow the emerging digital "islands" to be connected over the course of time, to form a complete digital programme chain. However, many broadcast engineers preferred composite digital video standards, with the sampling frequency linked to the PAL or NTSC subcarrier, while others looked forward to a universal standard based on sampling separate luminance and colour difference components.

The resolution came from work at BBC Research Department on standards conversion. The BBC became convinced that digital component standards were the way forward and was able to demonstrate how composite signals can be accommodated in a component world – based on line-locked orthogonal sampling patterns.

How things were

Cast your mind back to the 1970s. Or if you weren't around then, try to imagine what it might have been like. No, not the music, the revolting students, or the mad flared trousers and long floating skirts. Rather: *what was the state of broadcasting technology in those days?* In particular, *how much broadcasting equipment was digital, and what was it used for?*

In the 1970s, most of Europe used television based on 625/50 scanning, with the **PAL** colour system predominant in much of Western Europe, while France, the Soviet Union and Eastern Europe used **SECAM**. There were differences in luminance bandwidth: 5.0 MHz for B/G PAL, 5.5 MHz for the UK's PAL system and nominally 6 MHz for SECAM. There were also legacy monochrome systems, such as 405/50 scanning in the UK and the 819/50 system in France. North America, Japan and South America mostly used 525/60 scanning with the **NTSC** colour system and a luminance bandwidth of 4.2 MHz.

NTSC and PAL coding are both linear processes and so analogue signals in either format can be mixed and cut in studio processing, provided their subcarrier phases are the same. In analogue NTSC and PAL studios it was normal to code to composite form as early as possible in the signal chain – so that each signal required only one wire rather than the three needed for RGB. The poor stability of analogue circuitry meant that matching separate channel RGB or YUV component signals was impractical except in very limited areas. SECAM, with its frequency-modulated chrominance, does not allow any processing of composite signals, so the very robust composite signal was used only on videotape recorders and point-to-point links, with decoding to component signals for mixing. Some broadcasters avoided the problem by operating their studios in PAL and recoding to SECAM for transmission.

Pioneers Peter Raigner, Herbert Mayer and Val Lord take coffee while attending a meeting in London

In those days, international contacts – particularly at engineer level – were much less common. However, there were many more local players. BBC Research Department at Kingswood Warren had home-grown competition in the form of the IBA Experimental and Development Department at Crawley Court, Winchester and also contributions from the ITCA in London. The IBA had won international acclaim for their DICE standards converter and were continuing with a strong showing in digital television recording, using modified helical-scan machines. Just across the Channel in Rennes, France, there was the CCETT who, not surprisingly (because of SECAM), were putting more emphasis on digital components for studios and digital bitrate reduction for distribution and links. The EBU then, as now, played a strong role in promoting and coordinating contacts between broadcasters. Even closer to home, there was very substantial friendly rivalry with our own sister department, BBC Designs Department at Western House.

These establishments had a huge influence on the work that we did at Kingswood Warren. Making a case for a new area of work simply on its own merits was much harder and less likely to be successful than simply to say: *"The IBA is working on this"* or *"The CCETT is very prominent in that area"* in which case it would almost certainly be approved!

As you might expect, digital techniques were first applied to audio, because of its lower bandwidth. By the early 70s in the UK, audio was being distributed from studios to transmitters in digital form for both radio and TV – in the case of TV, in the form of "sound-in-syncs" [1] (digital audio pulses in the line sync pulses of the analogue TV waveform). A prototype digital audio recorder had been demonstrated [2]. An investigation by Guy McNally of commercial microprocessors in the late 70s concluded that performance needed to improve by a factor of three to perform digitally all the functions of an analogue mixing desk [3]; but by 1979, he had built an experimental computer for processing audio signals called COPAS [4].

Although digits were initially used in audio only for point-to-point transmission, early studies of the application of digital techniques for television pointed mainly to applications for signal processing. George Monteath and Vic Devereux picked out standards conversion as a potential application in 1967 [5] – no doubt because BBC RD was then working on an analogue standards converter, and the problems of analogue quartz delay lines were uppermost in their minds. By the time of IBC-1972, Gordon Parker was already pricing up the components needed for an all-digital studio [6].

Experimental analogue-to-digital converters, when applied to the composite PAL signal, showed an advantage in sampling at or near a harmonic of the colour subcarrier frequency (f_{sc}) because the visibility of quantizing distortion was reduced [7]. Thus early digital equipment found a benefit in $3f_{sc}$ sampling (about 13.30 MHz for PAL). In some applications, this had the disadvantage that samples were offset horizontally from one line to the next and were not locked to the picture. When this was a problem, the nearest harmonic of the line frequency (f_h) to $3f_{sc}$ was used instead (i.e. $851f_h$). As analogue-to-digital converters improved, it became possible to sample at $4f_{sc}$ (about 17.73 MHz for PAL), which retained the advantages of $3f_{sc}$, but with a picture-locked structure in which the samples were almost in register, vertically.

Evolution of the digital studio standard

Early views

In the earliest days of the search for a digital studio standard, European broadcasters held a variety of views. For SECAM countries, a ***digital component*** standard was an obvious choice. Most PAL countries, while appreciating the potential benefits of components for signal processing, were put off by the effect that multiple decode/recodes would have on picture quality when dealing with PAL contribution and distribution networks – although Gordon Parker does suggest [6] that in a digital studio, PAL coding may not be necessary within at least part of the studio centre.

It was also natural that SECAM countries – where repeated coding and decoding, with its attendant notch filtering, was the norm – would have less regard for luminance bandwidth. In PAL countries, however, “clean” coding with reduced artefacts was being researched, and luminance bandwidth was considered important for improved picture quality.

And finally, some broadcasters were relaxed about the choice because they could never see themselves going digital!

The EBU operated an international exchange network and, being used to the practicalities of dealing with PAL and SECAM, would ideally have liked just one standard for the exchange of digital signals.

Things must have been easier for NTSC users because the subcarrier frequency is a multiple of half the line frequency, so $4f_{sc}$ gives the advantages of line-locked and subcarrier-locked sampling at the same time. Also $4f_{sc}$ for NTSC is a more manageable 14.318 MHz. However, signal processing would have shared the decode/recode problems in common with those for PAL broadcasters.

Evolution of the BBC view

The evolution of the BBC's position during the mid to late 1970s was quite involved and requires some of the supporting work to be explored.

Despite the early optimism about digital studios, digital studio equipment was slow to appear (apart from timebase correctors on video recorders). The big breakthroughs seemed to come in compression, with the main applications being for use in transmission links and in tape recording. The biggest win was the discovery by Geoff Phillips that PAL signals could be sampled at a sub-Nyquist rate of $2f_{sc}$ (about 8.87 MHz); after the first ***sub-Nyquist sampling***, further conversions between the non-standard $2f_{sc}$ PAL and $4f_{sc}$ PAL were lossless. Two further strands of work had come to the fore: ***transform coding*** and ***differential PCM*** (DPCM).

Colour matte testing requires a model, a blue screen and a pen

The transform coding work was based on the Hadamard transform [8] (rather than the discrete cosine transform later used in MPEG) and tended to favour line-locked sampling (13.5 MHz was used to support the inherent block structure) and component signals. The DPCM methods [9] were better matched to subcarrier-locked sampling of composite PAL, making use of defined subcarrier phase relationships between neighbouring samples in the picture. DPCM was particularly efficient when combined with the sub-Nyquist $2f_{SC}$ sampling technique [10].

BBC Pioneer, Alan Roberts, checks the picture-processing capability of the digital options

In about 1975, we held what became known locally as "the shoot-out". This was a side-by-side comparison, which compared the results obtained using transform coding and using DPCM. Everyone agreed that DPCM was the clear winner, giving better quality pictures at a lower bitrate. We could see that transform coding would require much more development and complexity to achieve, with real-time hardware, the 1-bit per pixel results reported in the literature for computer simulations.

This added weight to the support for using digital PAL sampled at $4f_{SC}$ for processing, and using $2f_{SC}$ for links. A further factor was the development of the Weston system [11], also based on $2f_{SC}$, but with the prospect of controlling the effect of PAL impairments through multiple PAL/YUV conversions. The Weston PAL decoding technique also provided a gateway to picture-locked (and almost line-locked) component signal processing at $4f_{SC}$. As a result, the BBC officially favoured the ***composite digital*** view until the late 70s. However, this was not the whole story. $4f_{SC}$ sampling of PAL had one overwhelming disadvantage: it was too fast.

At a clock frequency around 13 MHz, the clock period is 75 ns; at $4f_{SC}$ it is 56 ns. However, when designing practical circuits, the difference in speed is much more significant than those numbers would suggest: for a low-power schottky (LS series) TTL D-type flip-flop (as commonly used at the time), the setup time (the time the data must be stable before the clock pulse) is about 20 ns and the maximum propagation delay from clock pulse to output is 25 ns. Thus the time remaining for the actual processing circuitry is 30 ns at 13 MHz but only 11 ns at $4f_{SC.}$ More expensive and power-hungry schottky logic was needed to do any processing at $4f_{SC}$.

A survey of digital video projects at Kingswood showed that most designers found a line-locked frequency around 13 MHz best suited their purpose, although they knew the official line was to use $4f_{SC}$. This was particularly the case for standards conversion.

In 1976, the BBC decided to replace its ageing 625/50 PAL - 525/60 NTSC standards converters (based on quartz analogue field delays). The BBC had been greatly impressed by the IBA's digital DICE converter and wanted its own equivalent. This development was started by Chris Clarke and Nick Tanton in the early days, and later Nick moved on to be replaced by Pete Fraser. Fortunately, we were able to make use of the understanding of interpolation gained by John Drewery for the 625/50 to 405/50 digital line rate converters [12], required when the UK moved to 625/50 signal distribution in the early 70s.

Originally, the BBC's new four-field ACE converter [13] was engineered only for luminance operation at 13.5 MHz. This was a ruse devised by John Chambers to prevent successful prototype equipment being hijacked and pressed into use prematurely by the television service. Unfortunately the outcome was that we had to convert the original prototype to colour operation by over-clocking it at about 16 MHz (beyond the specification of the digital multiplier chips) to accommodate a YUYVY multiplex. During one important series of demonstrations, as one set of visitors was filing out and

Abbreviations

CCETT	(France Telecom's) *Centre Commun d'Etudes de Télédiffusion et de Télécommunications*	**ITU**	International Telecommunication Union
CCIR	(ITU) International Radio Consultative Committee	**LCD**	Liquid Crystal Display
CRT	Cathode Ray Tube	**NTSC**	National Television System Committee (USA)
DPCM	Differential Pulse Code Modulation	**PAL**	Phase Alternation Line
IBA	Independent Broadcasting Authority (UK, but now defunct)	**PTT**	Post, Telephone and Telegraph administration
IRT	*Institut für Rundfunktechnik GmbH* (German broadcast engineering research centre)	**RGB**	Red-Green-Blue (colour model)
ITCA	Independent Television Companies Association (UK, but now defunct)	**SECAM**	*Séquentiel couleur à mémoire*
		SMPTE	Society of Motion Picture and Television Engineers (USA)
		TTL	Transistor-to-Transistor Logic
		YUV	The luminance (Y) and colour difference (U and V) signals of the PAL colour television system

the next was coming in, Pete Fraser had to discharge a CO_2 fire extinguisher into the fan inlets. This cooling was just sufficient to keep the timing errors under control for the duration of the following demonstration [1]. The equipment was then properly engineered for service use by BBC Designs Department and subsequently made under licence by GEC-McMichael.

However, in the present context, the important feature was that the standards converter contained fully digital PAL and NTSC decoders, and coders based on line-locked sampling of the composite signals [14]. The PAL decoder used $816f_h$ (12.75 MHz) and the NTSC decoder used $800f_h$ (12.587 MHz), although any line multiples in the 12 to 15 MHz frequency range could have been used. This was in contrast to all previous digital decoders in which the colour demodulation and modulation depended on taking the samples at defined phases of the colour subcarrier – in other words, it was the analogue sampling process doing most of the demodulation rather than the digital processing. Although this appeared to be a simpler process than line-locked PAL decoding, in fact the complexity was elsewhere – in the precise phase stabilisation of the sampling clock and in the generation of line-locked waveforms such as syncs and blanking.

These new techniques provided a straightforward gateway between analogue PAL and digital components and released the process from any link to the colour subcarrier frequency. Also they were compatible with the clean PAL filtering advantages of the Weston system. When combined with the advantages for studio signal processing that line-locked components provided, line-locked PAL decoding allowed a very rapid turn-around in the BBC position on the studio standard. This change occurred in the first half of 1979, so that the BBC was able to join other EBU members in agreeing that YUV components and line-locked sampling were the only contenders in the search for a digital studio standard. At this stage (August 1979), the BBC preference was for $816f_h$ (12.75 MHz) and with a 3:1:1 YUV ratio.

Nevertheless, sub-Nyquist PAL systems were developed further in the BBC and briefly went into trial service for PAL programme distribution.

Other views in Europe

Although there was now a broad consensus supporting components and line-locked sampling, there was still a wide range of views on the more detailed parameters of a digital studio standard. Views in other labs in Europe had been evolving, but not necessarily converging. The main considerations were to have a high enough sampling frequency to ensure that picture quality was maintained, while keeping the data rate low enough to allow practicable recorders / distribution links and signal

1. This is a recurring experience for digital video engineers: Andrew Oliphant gave a demonstration to the European Parliament on a hot day in June 1993 which was kept going using an aluminium teapot full of ice cubes!

processing. Part of the problem was that with then-current technologies, these two constraints did not provide a region where they met and overlapped in the middle!

Sensing that the PAL countries preferred a $4f_{sc}$ / $2f_{sc}$ approach, Jacques Sabatier and Francis Kretz of CCETT had proposed a component-sampling scheme with luminance sampled at $568f_h$ (8.875 MHz) and colour-difference components sampled at $284f_H$ [15]. The total word rate would thus be $1136f_h$, just above $4f_{sc}$. To preserve some luminance bandwidth above the Nyquist frequency of 4.43 MHz, they proposed to use a line-quincunx (half-line offset) sampling structure, bringing the vertical/temporal compromise of interlace into the horizontal/vertical domain as well. The word "quincunx" is not very commonly used in English, so the proposal was generally known by its French name, *quinconce.*

At first sight, *quinconce* has similarities with $4f_{sc}$ / $2f_{sc}$ PAL (since $2f_{sc}$ is very nearly a multiple of half line frequency). For some time it was thought that it might be possible to find a mathematical "bridge" linking $2f_{sc}$ PAL, the Weston system and *quinconce*, thus connecting the composite and component worlds – but the mathematical complexity of the search for that elusive bridge caused it to be christened the « *pont des soupirs* ».

The IBA was still keen to retain a link to the PAL subcarrier and suggested $908f_h$ (14.19 MHz, about $3.2f_{sc}$) for sampling the luminance. To keep within bitrate constraints, they proposed sampling the colour-difference signals at a quarter of the luminance rate.

German broadcasters – represented by FTZ, the research institute of the PTT, as well as by the IRT – were particularly concerned about bitrates for transmission and recording.

The EBU standards process *(attended by Andrew Oliphant)*

To meet the challenge of the digital future, the EBU reorganized its technical groups, creating a new Working Party V dealing with new systems and services, with a sub-group V1 (digital coding of sound and television) and a specialist group V1-VID (parameters, quality and digital coding of television), chaired by Howard Jones from the BBC.

V1-VID met in June 1979 and again in November 1979 when it was finally faced with nine different proposals to choose from, with luminance sampling frequencies ranging from $568f_h$ (8.86 MHz) to $910f_h$ (14.22 MHz), ratios of luminance to colour-difference sampling frequencies of 2:1, 3:1 or 4:1 and with orthogonal or quincunx sampling structures. There had been a number of small meetings between June and November that had helped organizations to assess each others' priorities and it was fairly easy to agree that all could accept, albeit with reservations, the proposal put forward by the German FTZ institute for a system with orthogonal sampling of luminance at $768f_h$ (12.0 MHz) and colour-difference at $256f_h$

Howard Jones (far left) and Peter Rainger (far right) in debate at Winchester

(4 MHz). The low luminance sampling frequency, which created some reservations, was to meet the constraint of packaging the whole signal into the 140 Mbit/s telecom hierarchy and taking account of the recorder manufacturers' view that 160 Mbit/s represented the current limit of the technology. Other reservations were around the colour-difference bandwidths and the feasibility of colour keying.

So it was that the EBU decided on practical demonstrations to explore the issues, presented to coincide with a meeting of the *Bureau* of the Technical Committee in London. These were held at BBC Designs Department, Western House, in April 1980. BBC Designs Department provided the facilities and high-quality source material, while other broadcasters – including the IBA, ITCA and CCETT – provided digital recording, mixing and chroma-key facilities.

We had prepared basic analogue RGB/digital YUV interface equipment for the demonstrations, but also included the PAL decoder from the standards converter modified to work at 12 MHz sampling. This was coupled with the frame stores from the standards converter to form a picture-based comb filter, which on still pictures gave perfect separation of chrominance and full bandwidth luminance. This was such an eye-catching demonstration that one delegate refused to believe that the PAL-decoded pictures were not sourced directly as RGB. Of course, the PAL cross-colour effects returned on moving pictures, but the point had been made.

The Western House demonstrations were a great success. The general view was that higher sampling frequencies were needed to preserve quality, particularly for signal processing applications such as chroma-key. So the EBU decided to hold further demonstrations to consider higher basic sampling frequencies and particularly with half-rate colour-difference sampling, rather than the one-third rate used in 12:4:4.

In the run-up to the new demonstrations, scheduled for January 1981 at the IBA's Crawley Court centre near Winchester, we were preparing interfaces working at 12, 13, 13.5 and 14.25 MHz and with YUV sampling in the ratios 4:2:2 (referred to as 4:2:2 rather than 2:1:1 because one-quarter ratio luminance, that is, 4:1:1, was still favoured by some). What we really needed was some signal processing as well. So we found ourselves designing a horizontal zoom processor, allowing the digital component pictures to be stretched horizontally in any ratio.

Thanks to careful worst-case synchronous design (Chris Clarke insisted that monostables should never be used for anything more complicated than making a light flash), the BBC equipment was totally reliable. Each evening during the setup, we set the switches to produce moving colour bars, then turned off. The next morning we turned on, and when we saw moving colour bars we knew we could put our feet up.

The IBA invited all the participants to a lavish entertainment in the Great Hall of Winchester Castle, where a round table, once believed to be King Arthur's, hangs on the wall. Boris Townsend officiated, magnificent in medieval robes, and Sir Brian Young, the IBA's Director-General gave a speech of welcome. He started by promising to be brief – always a bad sign – then went on for what seemed an eternity to the hungry engineers waiting to attack the buffet. But we had to wait longer: when he finished, an interpreter robed to match Boris Townsend translated the whole oration into French. It was all quite unnecessary; our French colleagues had already laughed politely at Sir Brian's jokes in English.

After supper, the choir of Winchester Cathedral trooped in to entertain us with madrigals, and we all joined in the chorus of a specially-written *Ode of the Winchester Code*. Despite this harmony, the Winchester Code was not to be: the demonstrations and presentations added a lot to our understanding of the issues, but agreement on a world standard would have to wait until the SMPTE meetings in San Francisco the following month.

Chris Clarke graduated from Imperial College, London and joined BBC Research Department in 1970. In addition to the standards conversion, composite decoding and digital YUV standards work referred to here, he has been involved in many other aspects of digital television in the 1970s and 1980s, including video data compression, error protection, test signal generation and video scrambling.

In the mid-1990s he led the team that developed the first modulator and demodulator for DVB-T digital terrestrial TV broadcasting. This culminated in the first DVB-T compliant TV broadcast in April 1996, from the BBC's Crystal Palace transmitter, thus paving the way for digital terrestrial TV services around the world. Subsequently, he has worked to apply the COFDM modulation techniques of DVB-T to a new generation of digital wireless cameras.

Still involved in engineering, Chris Clarke is currently working on low-delay coding of video for production applications.

Andrew Oliphant joined BBC Research Department in 1972. He contributed to the development of teletext, then worked on digital processing for telecine and on PAL decoding. Since the work described in this article, he has been involved with satellite broadcasting and has led European projects on optical routeing in broadcast production and on verifying the DVB-T specification. He is currently Head of Transmission Systems Group at BBC R&D.

The SMPTE meetings *(attended by Chris Clarke)*

The SMPTE had also recognized the benefit of evaluating real equipment and had scheduled a programme of tests to precede the SMPTE Winter conference held in San Francisco, February 1981. In this case, however, the format was that of formal subjective tests in which the participants graded the pictures that they were shown without it being revealed what they were. In contrast, participants at the EBU demonstrations had been told what they were seeing and had the opportunity to draw each other's attention to particular features and discuss the impairments. The benefit of the SMPTE approach was that it had the potential to give an authoritative answer to the question of which parameters were good enough.

The BBC provided a paper on line-locked composite decoding for the SMPTE conference, this time with the emphasis on NTSC and 525/60 frequencies [16]. Our zoom processor proved invaluable in this, as it allowed us to prepare a U-matic NTSC tape which, by zooming in on the resolution bars of a test card, showed the reduction in cross-effects, in spite of the NTSC distribution system in the conference hall.

In common with probably everyone in Europe, it came as a complete surprise to us that you could choose a common line-locked sampling frequency for the 625/50 and 525/60 line standards. From a European perspective, 625/50 scanning gave simple numbers: the line frequency was 15625 Hz, or 1 MHz divided by 64, and the field rate was 50 Hz exactly. In comparison, NTSC had a line frequency of 15734.265 Hz and a field rate of 59.94 Hz. It was not appreciated in Europe that the line frequency was simply 4.5 MHz divided by 286.

As it had been with PAL, it was suddenly important for NTSC to be decoded/coded at a frequency with no simple relationship to the colour (or in this context, perhaps we should say *color*) subcarrier, that is, at $858f_h$ or 13.5 MHz.

On the basis of this, I was invited to accompany Phil Laven (who, as the BBC's resident engineer in North America, represented the BBC at the SMPTE) to a meeting of the SMPTE Working Group on Digital Video Standards. There was some discussion on the practicality of NTSC decoding at frequencies other than $4f_{sc}$ (14.318 MHz) and also digital interpolation from 14.318 to 13.5 MHz was considered. I was able to tell them that I had actually built a digital NTSC decoder three years earlier based on line-locked sampling at 800-times line frequency and this could easily be modified to work at $858f_h$. This proved that however different people's views might be in an academic discussion, these differences melted away when presented with practical hardware experience. As a result, an SMPTE subcommittee (NTSC interface) was formed under the chairmanship of Stan Baron, which I attended to further explain and document the techniques involved. This group held two meetings in New York, May and September 1981.

Filling in the details

Active line length, coding ranges, overshoots/undershoots and filtering

V1-VID met in June 1981 in Munich to agree subsidiary parameters, such as the number of samples per active line. We all started with the belief that 720 was the right number to go for, but it took a long time to prove it, looking at the specifications for the analogue signals in different countries and the very wide tolerances they allowed. In the USA at that time, the FCC was very concerned about blanking width, because the number of different processing equipments in the signal chain was increasing, with each of them re-blanking the signal so the picture tended to get narrower and narrower. So we concentrated on the line-blanking interval specifications. It didn’t help that the Green Books of the CCIR had the wrong specification for NTSC – according to John Rossi, who was representing the SMPTE. The authoritative specifications, said Rossi, were those of the FCC and the EIA – but they were expressed in different terms and not entirely compatible. After most of a day spent counting fractions of a microsecond and arguing over rails and fenceposts, we came to the conclusion that we all wanted: 720 was indeed the right number.

Finalising the standard was not without its pitfalls. Perhaps one of the least satisfactory areas of the standard was that of coding ranges. Initially, during the demonstrations, everyone had used 16 to 240 coding with a mid-level of 128 for digital Y, U and V, that is 225 coding levels. However, when the time came to write this down, someone became confused between coding levels and steps and wrote down 224 levels when they meant 224 steps. Once embodied in the CCIR standard, this was very difficult to change, even though it gave a non-symmetrical coding range (+111 to -112, relative to zero) for the inherently symmetrical colour difference signals.

While the mistake was rectified for U and V (or C_B and C_R as they became), the issue was less clear cut for the non-symmetrical Y signal. Once the discussion was opened, several parties – led by John Rossi for the SMPTE – wanted to increase the headroom. Also, there were representations from Japan that signals could exceed a nominal white level by up to 10%, and from other sources who suggested that clipping a white-going overshoot was more visible than at black. As a result, the final agreement was made with 235 for white and retaining 16 for black, although the resulting lack of a mid-grey level annoyed purists for a while.

More satisfactory was the consideration of chrominance filtering which recognized the need for sharp-cut filters at all conversions except the last one. This allowed the bandwidth needed for chroma-key and other processing to be retained through the system; however, the inclusion of a slow roll-off in the composite coder for analogue broadcasts or in the picture monitor for direct component signals avoided the dreadful chrominance ringing that would otherwise occur.

Historical perspective

To an extent. the Rec. 601 standard represented a leap of faith. It probably depended more than we recognized at the time on future developments but, in due course, all the important linking technologies arrived to make it all happen. A measure of the success of the standard was how quickly and how universally it became accepted. The equipment builders never looked back and the possibility of studio equipment that would be compatible anywhere in the world became a reality.

Certainly the standards process had very wide support throughout the broadcasting industry. Keith Lucas, then of the IBA, presented a graph at a lecture showing the number of broadcasting engineers involved in standardization committees plotted against time. Through the mid seventies this graph showed a healthy exponential growth. But Keith pointed out that, by extrapolating to the end of 1980 (was this by chance?), all the engineers in broadcasting would spend all their time working in standardization committees! This may help to explain why Rec. 601 was a great success and went on to form the basis of other standards (such as the core interface for MPEG-1 & 2), whereas subsequent standardizations, such as MAC/packet and the attempts to define a universal HDTV standard have had less happy outcomes.

It is interesting to consider what might have happened had the early thoughts on standardization in the UK been carried through to a standard. The $4f_{sc}$ PAL sampling at 17.73 MHz might have been carried through to the component signals, so we would still be left with this residual echo of the past, needlessly complicating the broadcast system of the UK – it is presumed here that we would not have been able to persuade other Europeans to see the merits of such a system. In fact, it would be a bit like using interlace (a technique devised to disguise the line structure and flicker in CRT displays) when everyone uses progressively-scanned LCD or plasma panel displays. But perhaps the standardization process has not quite come to terms with that issue yet!

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