Line numbering and synchronization in digital HDTV systems

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In contrast to analogue television systems where line numbering is conventionally linked to the vertical synchronization, digital television offers the possibility of incorporating line–by–line numbering embedded within the data stream.

The article proposes a new numbering sequence for digital HDTV, based on the active lines. The scheme offers several advantages, in particular in respect of the time taken to achieve synchronization in digital equipment.

1. Introduction

One of the basic characteristics of any television system is the line numbering associated with the picture signal. Conventionally, the numbering has always been connected in some way to the field synchronization and it provides a means of distinguishing the active lines forming the picture from the lines of the field blanking intervals which contain non–picture information. In interlaced scanning systems, the line numbering also distinguishes between the lines of the first and second fields. These conventions have been carried over from conventional 4:3 analogue television to the analogue HDTV systems (1250/50/2:1 and 1125/60/2:1), where the field synchronizing pulse of the first field marks the start of the sequence (*Figs. 1 and 2*).

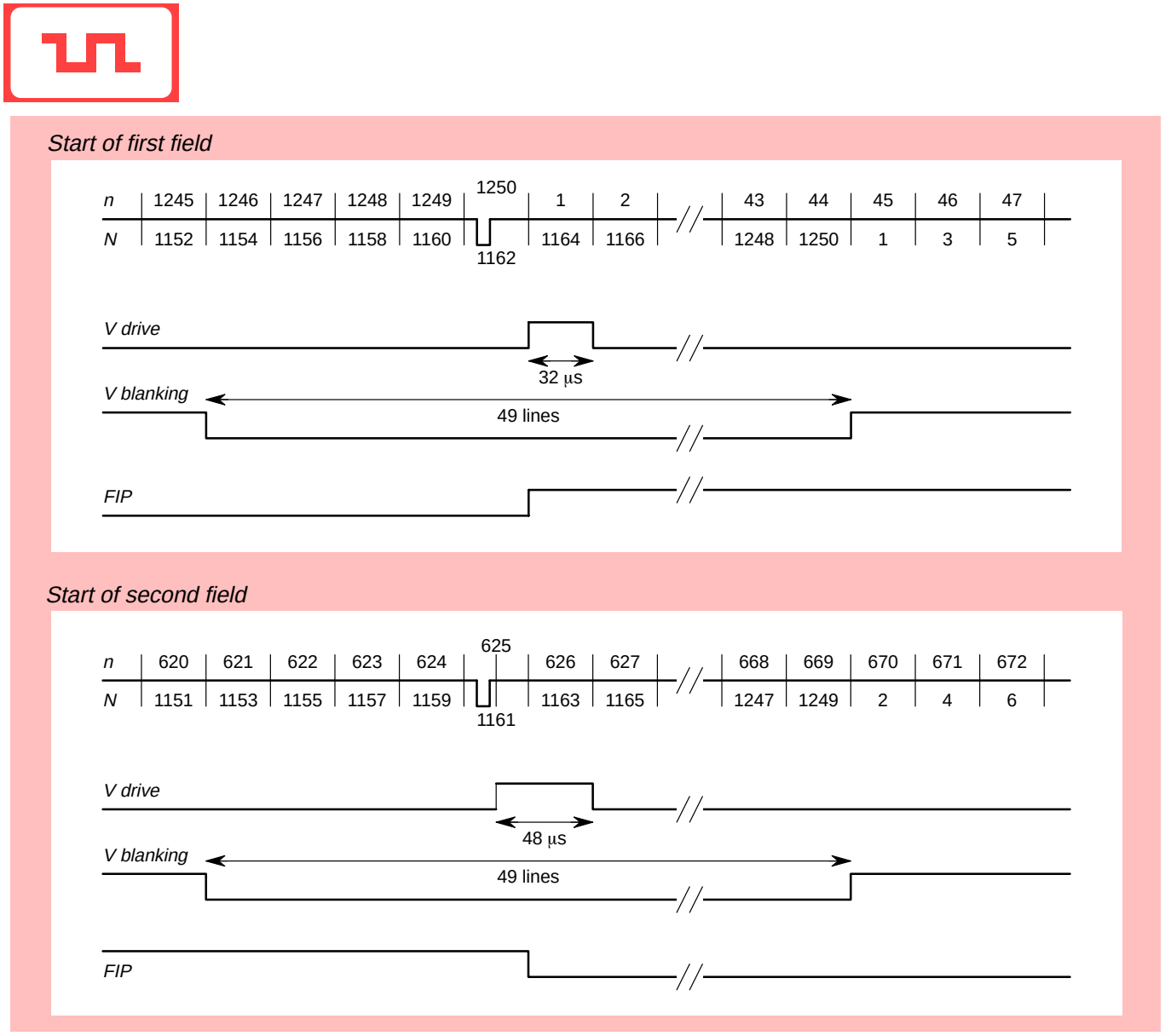
The inclusion of permanent line numbering embedded within the data stream is not, so far, being considered for digital television, although line numbers may be transmitted as ancillary data in the line–blanking interval. The structure of the digital picture signal is dependent on the analogue signal which is still in use in display hardware. Digital synchronization is based on the transmission of three synchronization bits [1, 2]:

H which distinguishes between the start and the end of the active line;

V which indicates the field–blanking interval;

F which distinguishes between the first and second fields.

Two of these synchronization bits, *V* and *F*, are unambiguously related to the line number, so if the line numbers are included as a permanent feature of the picture data stream, this might influence techniques for digital synchronization, as discussed below.



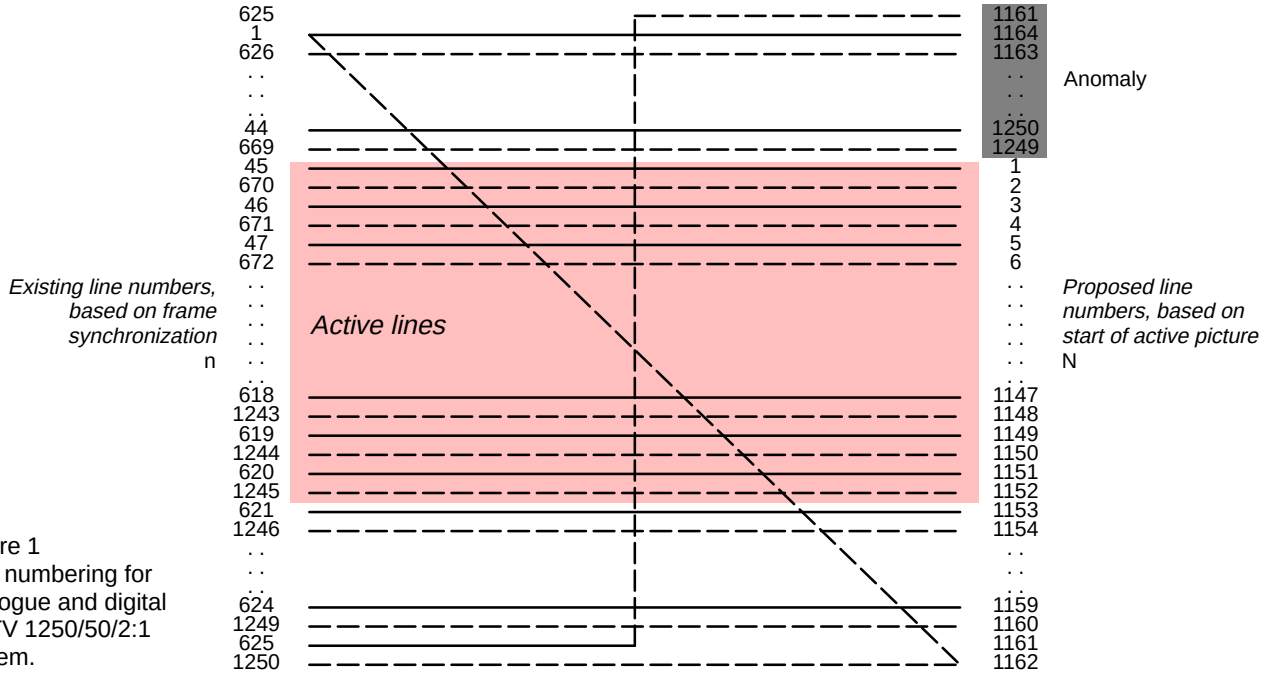
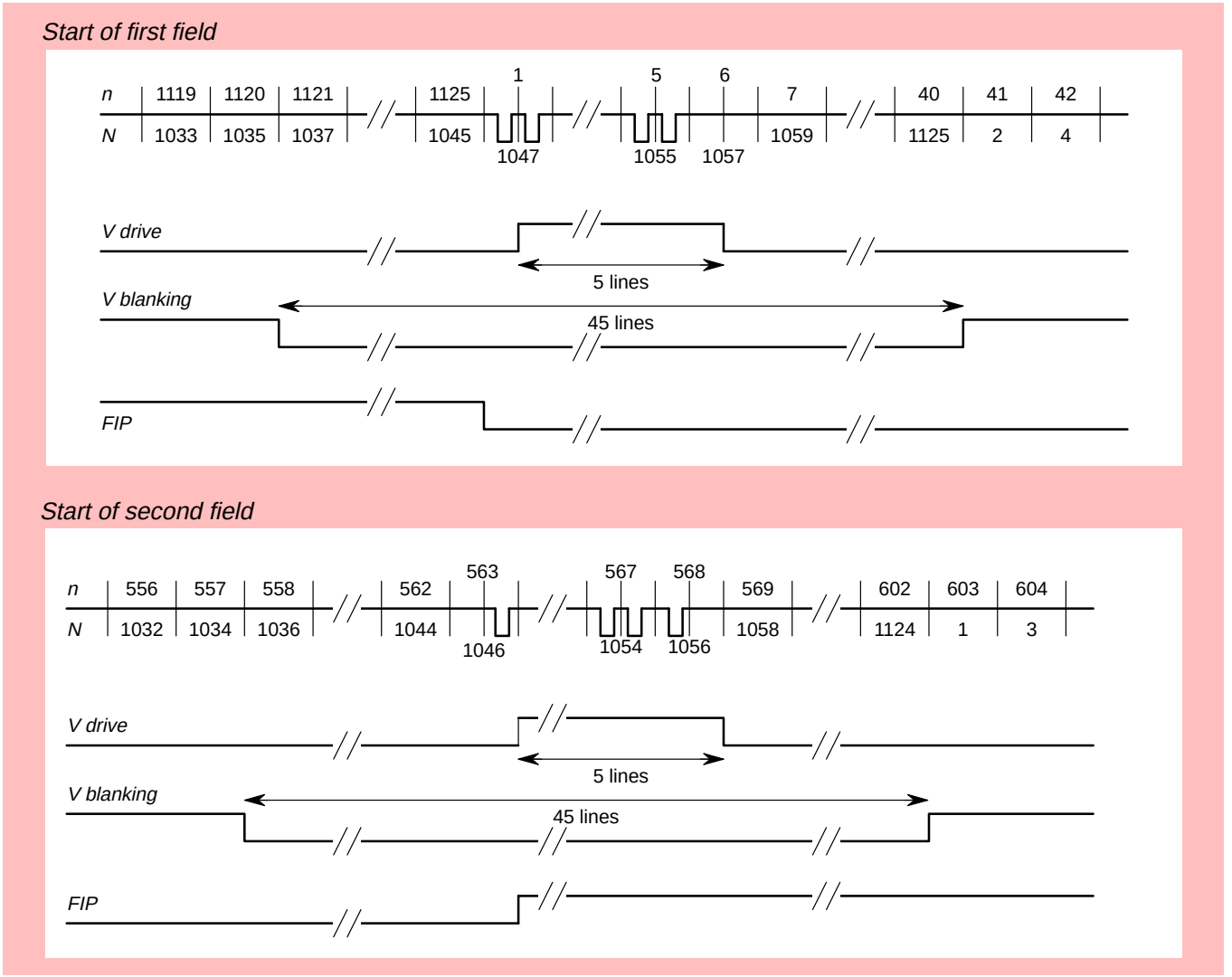


Figure 1
Line numbering for analogue and digital HDTV 1250/50/2:1 system.



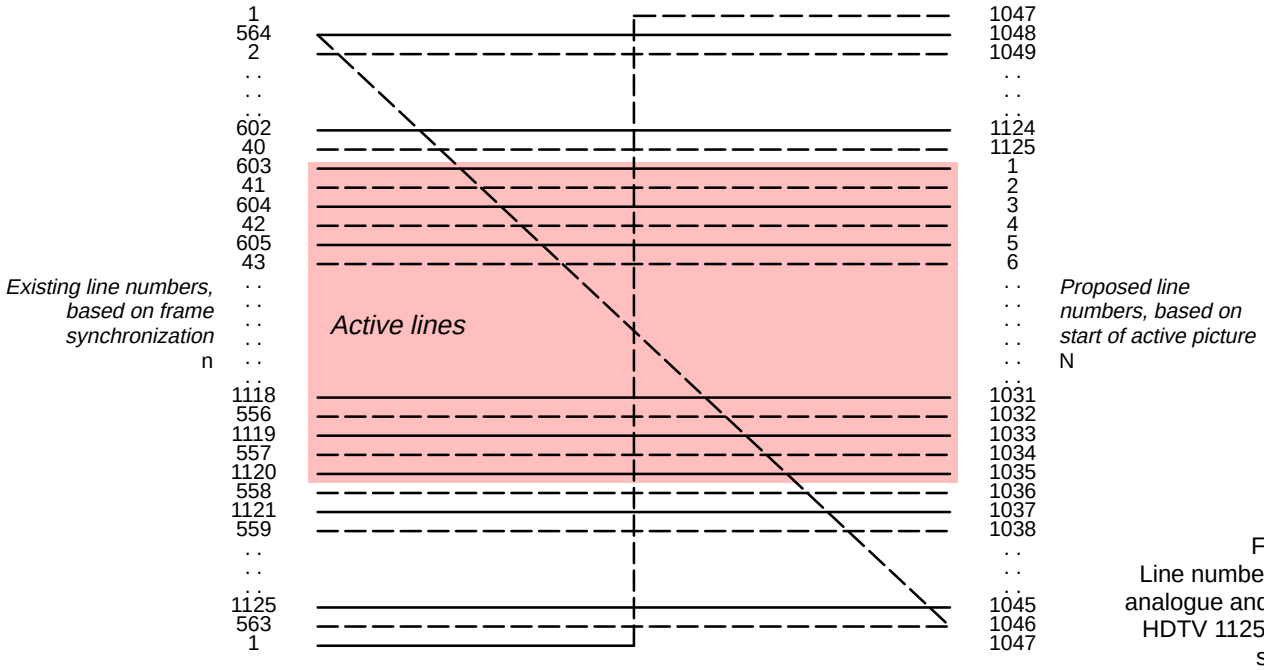


Figure 2
Line numbering for analogue and digital HDTV 1125/60/2:1 system.

2. Line numbering in digital systems

Line numbering can be introduced in various ways. With the development of solid–state scanning and diplay devices, the time is drawing near when the concept of electron beam flyback, and the consequent need for line and field blanking intervals, will loose their original meanings. In an all–digital world, it would seem irrational to have a numbering sequence that begins in the vertical blanking interval. If digital technologies were being developed without the back–drop of the analogue past, it would be more convenient to start with the first active line in the field. Two basic ways of numbering for 625/50/2:1 and 525/60/2:1 digital television were proposed in [3]. With a view to harmonizing the various systems in use, any such change implies also making changes to the conventional practices in analogue television and this is no doubt one of the main reasons why a new line numbering sequence has not yet been adopted in the 4:2:2 "conventional" television systems.

The numbering concept proposed for digital HDTV is based on a sequence of lines in the whole television frame, in the order in which they are displayed on the receiver screen. Apart from the benefits of clarity, this method has the merit of distinguishing simply between interlaced and progressive scanning, a requirement of decisive importance in modern systems where conversion from interlaced to progressive scanning, and vice versa, may be required. In progressively–scanned signals the line numbers increase steadily from one line to the next whereas in interlaced scanning the numbers of successive lines in the transmitted signal differ by two and the parity of the line number (even, odd) defines unambiguously the first and second fields.

In addition, the choice of the point of origin of the coordinate system of the active picture (upper left corner) is of great importance, notably in video effects systems and bit–rate reduction systems. If there is a requirement to shift the point of origin to a different position (for example, to the centre of the picture), it is necessary merely to apply a simple coordinate transformation.

The relationship between the original line numbers n and the new numbers N, for the 1250/50/2:1 system is shown in *Fig. 1*. The upper part of the figure shows the signals in the region of the field–blanking intervals, while the lower part shows individual lines in the analogue scanning raster.

The relationships between the old and new systems can be expressed mathematically:

$N =$	$2n+1162$	for	$1 \leq n \leq 44$	
$N =$	$2n-89$	for	$45 \leq n \leq 669$	
$N =$	$2n-1338$	for	$670 \leq n \leq 1250$	
$n =$	$(N+89)/2$	for	$1 \leq N \leq 1249$	N odd
$n =$	$(N+1338)/2$	for	$2 \leq N \leq 1162$	N even
$n =$	$(N-1162)/2$	for	$1164 \leq N \leq 1250$	N even

The old and new numbering in the 1125/60/2:1 system is shown in *Fig. 2* and the relationships are as follows:

$N =$	$2n+1045$	for	$1 \leq n \leq 40$	
$N =$	$2n-80$	for	$41 \leq n \leq 602$	
$N =$	$2n-1205$	for	$603 \leq n \leq 1125$	
$n =$	$(N+1205)/2$	for	$1 \leq N \leq 1045$	N odd
$n =$	$(N-1045)/2$	for	$1047 \leq N \leq 1125$	N odd
$n =$	$(N+80)/2$	for	$2 \leq N \leq 1124$	N even

It is evident from *Figs. 1* and *2* that the new line numbering is more lucid than the old one. An anomaly occurs in the region of the blanked analogue lines following after the field synchronizing pulse (*Fig. 1* lines 1161 to 1250) where, in the absence of suitable precautions, the even and odd lines will overlap. In interlaced scanning the first analogue field in fact has 624.5 lines and the second field 625.5 lines; these details are insignificant in the digital domain.

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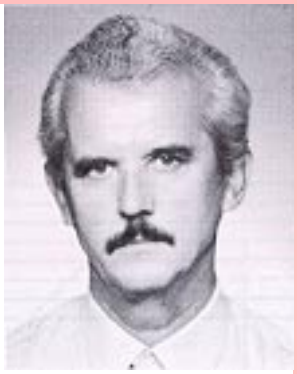

3. Line number transmission and synchronization in digital HDTV systems

If line numbers are to be carried in the digital video data stream, they must evidently be inserted in the line–blanking intervals. The transmission of line numbers as ancillary data, however, is of no practical significance; the information must be present permanently and must be easily accessible. The ancillary data decoder will be a multi–purpose unit and its direct utilization for line number extraction would not be economical. Nor would it be economical to use a special ancillary data extractor which would be unnecessarily complicated and would offer only limited protection.

The most convenient solution is therefore either to place the line number immediately after the synchronizing signal EAV (end of active video) [3], or its incorporation within the EAV and SAV (start of active video) signals. The information *F* can be derived simply from the line number, assuming the whole of the following field–blanking interval is associated with the active lines of the respective field. In these circumstances the information *F* is identical with the "units" bit of the line number (LSB – even/odd).

Similarly, the *V* information can be derived as follows:

if $N > 1152$ then $V = 0$ for 1250/50/2:1

if $N > 1035$ then $V = 0$ for 1125/60/2:1.

For reasons of uniformity it is logical to associate the whole of the line–blanking interval with the active part of the *preceding* line. If that is done, it is necessary to transmit the number of the next–following line in each blanking interval.

It is necessary to code the line numbers with at least eleven information bits ($N < 2048 \equiv 2^{11}$) in the currently–proposed HDTV systems. If the extended Hamming code (16,11) is applied, a one–bit error can be corrected and a two–bit error detected in every codeword. The line number transmission therefore requires a 16–bit code, either after the EAV or directly after the preamble (FF_h, 00_h, 00_h or FF_h, 00_h). Examples of potential arrangements of line number transmission in the digital synchronizing signals, for 8–bit and 10–bit digital video, are shown in *Fig. 3*.

	EAV							SAV			
D7	1	0	0	1	N10	P4	. . .	1	0	0	1
D6	1	0	0	F	N9	P3	. . .	1	0	0	F
D5	1	0	0	V	N8	P2	. . .	1	0	0	V
D4	1	0	0	H	N7	P1	. . .	1	0	0	H
D3	1	0	0	P3	N6	P0	. . .	1	0	0	P3
D2	1	0	0	P2	N5	N2	. . .	1	0	0	P2
D1	1	0	0	P1	N4	N1	. . .	1	0	0	P1
D0	1	0	0	P0	N3	N0	. . .	1	0	0	P0

a) 8–bit video, prefix FF_h, 00_h,00_h

	EAV					SAV		
D7	1	0	N10	P4	. . . . .	1	0	1
D6	1	0	N9	P3	. . . . .	1	0	1
D5	1	0	N8	P2	. . . . .	1	0	1
D4	1	0	N7	P1	. . . . .	1	0	1
D3	1	0	N6	P0	. . . . .	1	0	1
D2	1	0	N5	N2	. . . . .	1	0	1
D1	1	0	N4	N1	. . . . .	1	0	1
D0	1	0	N3	N0	. . . . .	1	0	1

b) 8–bit video, prefix FF_h, 00_h

	EAV					SAV			
D9	1	0	1	1	. . . . .	1	0	1	1
D8	1	0	N10	H	. . . . .	1	0	N10	H
D7	1	0	N9	P5	. . . . .	1	0	N9	P5
D6	1	0	N8	P4	. . . . .	1	0	N8	P4
D5	1	0	N7	P3	. . . . .	1	0	N7	P3
D4	1	0	N6	P2	. . . . .	1	0	N6	P2
D3	1	0	N5	P1	. . . . .	1	0	N5	P1
D2	1	0	N4	P0	. . . . .	1	0	N4	P0
D1	1	0	N3	N1	. . . . .	1	0	N3	N1
D0	1	0	N2	N0	. . . . .	1	0	N2	N0

c) 10–bit video, prefix FF_h, 00_h

Figure 3
Examples of the insertion of 11–bit line numbers in EAV and SAV.

The choice of an agreed method will depend on particular conditions and the consensus of all the parties involved. Further studies will be needed to this end and consideration will also have to be given to protection of the preamble transmission carried in the EAV and SAV signals.

4. Conclusions

If the inclusion of line numbering in digital HDTV systems as outlined here is adopted internationally, the new structure should be reflected also in changes to the numbering of analogue HDTV systems. The basis of the new approach is the numbering of lines in the order in which they appear on the screen; this is not just for the sake of change – the new structure is clearer and more logical and if the numbers are used for synchronization the lock-

ing–up of digital equipment may be achieved more rapidly and with no transient effects. In effect, almost immediately after any cut to a non–synchronized signal (i.e. at the beginning of the first complete line) it will be possible to store the incoming signal directly in the correct memory location, using the line number as a memory address.

Making the numbering sequence start with the first line of the active picture also simplifies some forms of signal processing, such as video effects: for example, a simple tranformation is sufficient to displace the origin of the coordinates to the centre of the active picture area. The proposed scheme is simpler than those beginning in the field blanking interval and does not require the use of a sign bit.

A question that remains open is the most convenient time to implement such a fundamental change. It would seem best to do it when new systems are introduced and from this point of view the present time would appear suitable. The future advantages should richly compensate for the difficulties in the transition period . . .

Bibliography

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[2] EBU document Tech 3271 (1993): **Interlaced version of the 1250/50 HDTV production standard**

[3] Liska, D. et al: **Line numbering in the digital television systems**
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