ANNEX 1

ITU-R BT. 801

RECOMMENDATION ITU-R BT.801-1

TEST SIGNALS FOR DIGITALLY ENCODED COLOUR TELEVISION SIGNALS CONFORMING WITH RECOMMENDATIONS ITU-R BT.601 (PART A) AND ITU-R BT.656

(Question ITU-R 25/11)

(1992-1995)

The ITU Radiocommunication Assembly,

considering

a) that digital television systems operate in very different ways from analogue systems with the consequence that a quite different set of picture impairments may be introduced;

b) that impairments may occur both from the conversions to and from the digital domain (which include filtering, sampling and quantization), and by degradations of the digital signal itself (such as individual digit errors, timing jitter or loss of frame synchronization);

c) that for measurements of such impairments it is necessary to provide the test signals,

recommends

1 that for measurements of quantization errors and timing errors between analogue and digital active lines in conversion process from and to the digital signals conforming with Recommendation ITU-R BT.601 (Part A), using 8-bit quantization, and for verifying the conformity of the multiplex format with Recommendation ITU-R BT.656, and checking for the correct operation of the associated interfaces, test signals used should be selected from the list given in Table 1, rows No. 1 to 15;

2 that for the verification of cable equalizers and phase-locked loop (PLL) circuits the test signal of Table 1, row 16 should be used.

The test signals are listed in Table 1 and its brief description and precise sample values are annexed in Annexes 1 and 2, respectively.

TABLE 1

List of test signals

No.	Title
1	Grey
2	Alternating white/black at 0.1 Hz
3	End-of-line pulses
4	Black/white ramp
5	Yellow/grey ramp
6	Grey/blue ramp
7	Cyan/grey ramp
8	Grey/red ramp
9	C_B, Y, C_R, Y ramp
10	White, end-of-line porches
11	Blue, end-of-line porches
12	Red, end-of-line porches
13	Yellow, end-of-line porches
14	Cyan, end-of-line porches
15	Digital colour-bar
16	Check field signal

ANNEX 1

Brief description of test signals

The formulae corresponding to the test signals are defined in § 1, and the waveforms are illustrated in § 2.

1 Formulae (see Note 1)

In cases where sample values are derived by computation, an addition of 0.5 is included in the formula to ensure that the appropriate level is obtained by rounding the result.

NOTE 1 – Y, C_R, C_B sample numbering is in accordance with Recommendation ITU-R BT.656.

These digital waveforms are made up of pulses in uniform ranges, ramps between two uniform ranges, and transitions between two uniform ranges, shaped by a filter whose impulse response $R(t)$ is defined as a function of time t as follows:

– for $-3T < t < 3T$, $\quad R(t) = 0.42 + 0.50 \cos(\pi t / 3T) + 0.08 \cos(2\pi t / 3T)$

– otherwise $R(t) = 0$

($R(t)$: Blackman window).

The value of T is 74 ns for digital waveforms $A1$, $A2$, $A3$ and $A4$ and 148 ns for $A5$ and $A6$.

1.1 Test signal No. 1: grey

The active video lines of this signal are defined by:

$Y(i) = A1(i), \qquad C_R = C_B = 128.$

This signal is critical for transmission via a parallel interface, since each of the 8 interface data binary signals then contains a succession of bits 0, 1, 0, 1, 0, 1 ... and attains maximum power concentration at high frequencies (multiples of 13.5 MHz) which often prove difficult to preserve in practical transmission links.

1.2 Test signal No. 2: alternating white/black at 0.1 Hz

This signal produces alternately:

– for 5 s, pictures containing “white” digital active video lines defined by:

$Y(i) = A2(i), \qquad C_R = C_B = 128;$

– for 5 s, pictures containing “black” digital active video lines defined by:

$Y = 16, \qquad C_R = C_B = 128.$

This signal produces a variation of the black level in the corresponding analogue video signals, owing to the suppression of continuous components and very low frequencies by the analogue transmission links. It provides a means of checking the compensation for this variation, as well as black stability and accuracy in digital coding.

1.3 Test signal No. 3: end-of-line pulses

The signal’s digital active video lines are defined by:

$Y(i) = A3(i), \qquad C_R = C_B = 128.$

This four-pulse signal can be used to check the position of the digital active line in relation to the analogue reference, as well as the activity of samples situated at the end of the digital active line. The outside edges of the two internal pulses coincide with the ends of the line, in the 625/50 system.

1.4 Test signal No. 4: black/white ramp

The digital active video lines of this signal are defined by:

$$Y(i) = \text{int}(A4(i)), \qquad C_R = C_B = 128.$$

This signal may be used to test the existence and position of quantization levels 1 to 254 of the luminance signal.

1.5 Test signal No. 5: yellow/grey ramp

The digital active lines of this signal are defined by:

$$C_B(i) = \text{int}(A5(i))$$

$$C_R(i) = \text{int}(128.5 - (0.114 / 0.701)(A5(i) - 128))$$

$$Y(i) = \text{int}(126 - (169 / 224)(A5(i) - 128))$$

This signal can be used to test the existence and position of quantization levels 1 to 128 of the colour difference signal C_B.

1.6 Test signal No. 6: grey/blue ramp

The digital active video lines of this signal are defined by the same formulae as in § 1.5, replacing *A*5 by *A*6.

This signal can be used to test the existence and position of quantization levels 128 to 254 of the colour difference signal C_B.

1.7 Test signal No. 7: cyan/grey ramp

The digital active video lines of this signal are defined by:

$$C_B(i) = \text{int}(128.5 - (0.299 / 0.886)(A5(i) - 128))$$

$$C_R(i) = \text{int}(A5(i))$$

$$Y(i) = \text{int}(126 - (88 / 224)(A5(\mathrm{i}) - 128))$$

This signal may be used to test the existence and position of quantization levels 1 to 128 of the colour difference signal C_R.

1.8 Test signal No. 8: grey/red ramp

The digital active video lines of this signal are defined by the same formulae as in § 1.7, replacing *A*5 by *A*6.

This signal may be used to test the existence and position of quantization levels 128 to 254 of the colour difference signal C_R.

1.9 Test signal No. 9: C_B, Y, C_R, Y ramp

The active video lines of this signal are defined by $A7(i)$ in Table 2 for 1 440 samples of the digital active line multiplex.

This signal is useful for testing the conformity of the digital video signal format at the output of the digital processing equipment carrying out demultiplexing and remultiplexing operations on the components of the digital video signal.

NOTE 1 – This signal produces spurious colours in the *R*, *G*, *B* field.

1.10 Test signal No. 10: white, end-of-line porches

The active video lines of this signal are defined by:

$Y(i) = A8(\mathrm{i})$, $C_B = C_R = 128$.

This signal has no shaping of the transitions on *Y* at the ends of the digital active line and is useful for observing the analogue shaping of the line blankings by the 4:2:2 decoders.

Two integral transitions of the Blackman pulse with a rise time of 300 ns are placed 3 μs from the leading and trailing edges of analogue line blankings for 625-line systems, permitting comparative observation of the transitions and verification of the conformity of the digital-analogue time correspondence on *Y*.

1.11 Test signal No. 11: blue, end-of-line porches

The active video lines of this signal are defined by:

$Y = 41$, $C_B(i) = A9(i)$, $C_R = 110$.

This signal can be used to make the observations described in § 1.10 for high transitions on C_B.

1.12 Test signal No. 12: red, end-of-line porches

The active video lines of this signal are defined by:

$Y = 81$, $C_B = 90$, $C_R = A9(i)$.

This signal can be used to make the observations described in § 1.10 for high transitions on C_R.

1.13 Test signal No. 13: yellow, end-of-line porches

The active video lines of this signal are defined by:

$Y = 210$, $C_B(i) = A_{10}(i)$, $C_R = 146$.

This signal can be used to make the observations described in § 1.10 for low transitions on C_B.

1.14 Test signal No. 14: cyan, end-of-line porches

The active video lines of this signal are defined by:

$Y = 170$, $C_B = 166$, $C_R(i) = A10(i)$.

This signal can be used to make the observations described in § 1.10 for low transitions on C_R.

1.15 Digital colour bar signals

The frequent use of colour bar signals in analogue television suggests the need to define such encoded signals for digital, in order to monitor levels and phasing between components after 4:2:2 decoding.

Tables 3a) and 3b) give a description of 100/0/100/0 and 100/0/75/0 colour bars calculated by means of mathematical equations with the following characteristics:

– shaping of transitions by integral of the Blackman impulse;

– rise time 10% to 90% for $Y = 150$ ns;

– rise time 10% to 90% for C_B and $C_R = 300$ ns.

1.16 Check field test signal

The following description specifies digital test sequences suitable for evaluating the low-frequency response of equipment handling serial digital video signals. Although a range of sequences will produce the desired low-frequency effects, two specific sequences are defined to test cable equalization and phase-locked loop (PLL) circuits.

1.16.1 Equalizer testing

Equalizer testing is accomplished by producing a serial digital sequence with maximum DC content. Applying the sequence C0.0h, 66.0h continuously during the active line portion of at least one-half of a field and forcing the last sample in the first active line of the first field to the value 20.0h accomplishes the desired result. If other data is added to the test signal, an odd number of 1s should be provided in a majority of frames to ensure that both polarities of the test sequence are produced.

1.16.2 Phased-locked loop testing

Phased-locked loop testing is accomplished by producing a serial digital sequence with maximum low-frequency content and minimum number of zero crossings. Applying the sequence 80.0h, 44.0h continuously during the active line portion of at least one-half of a field accomplishes the desired result. Figure 1 gives a brief description of "check field signal".

FIGURE 1

Brief description of "check field test signal"

Vertical blanking interval
First half of active field C0.0h, 66.0h (Note 1) as described by: $Y = A12$ and $C_B/C_R = A14$ For cable equalization testing
Second half active field (Notes 2 and 3) 80.0h, 44.0h as described by: $Y = A13$ and $C_B/C_R = A15$ For phase locked loop testing

<---------------------------- Horizontal active line (only) ---------------------------->

Note 1 – The last sample in the first active line of the first field is 20.0h, or $Y = A11$.

Note 2 – The first half active field is defined as line 20 to $(X – 1)$ where $140 \le X \le 148$ and 283 to $(X – 1)$ where $400 \le X \le 408$ for 525 system and X is integer.

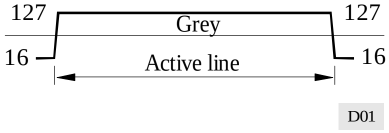
Note 3 – The first half active field is defined as line 23 to $(X – 1)$ where $160 \le X \le 168$ and 336 to $(X – 1)$ where $470 \le X \le 478$ for 625 system and X is integer.

$A11$, $A12$, $A13$, $A14$ and $A15$ in Table 2 describe the exact numerical definitions of "check field signals".

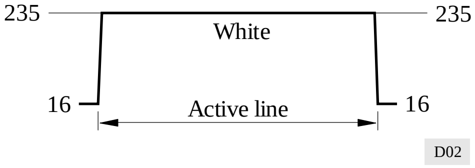
2 Waveforms of test signals

Figures as follows indicate sample levels.

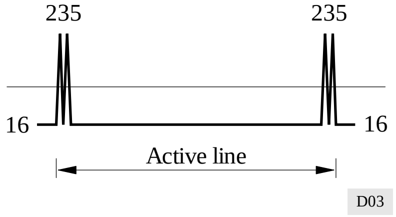
2.1 Grey: *A*1



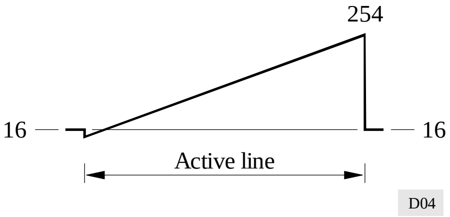
2.2 White: *A*2



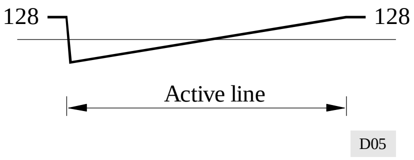
2.3 End-of-line pulses: *A*3



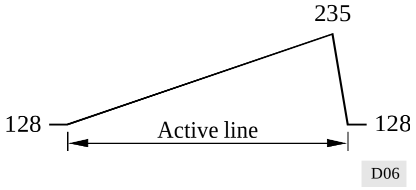
2.4 Black/white ramp: *A*4



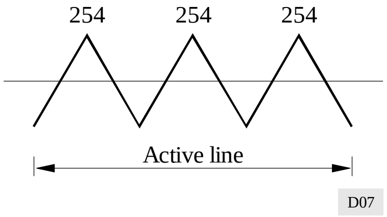
2.5 Yellow/grey and cyan/grey ramp: *A*5



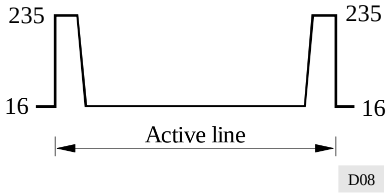
2.6 Grey/blue and grey/red ramp: *A*6



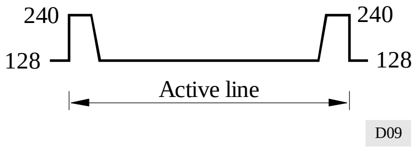
2.7 C_B, *Y*, C_R, *Y* ramp: *A*7



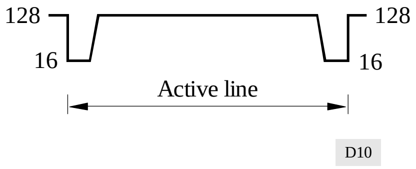
2.8 White, end-of-line porches: *A*8



2.9 Blue and red, end-of-line porches: *A*9



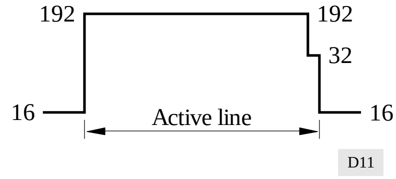
2.10 Yellow and cyan, end-of-line porches: *A*10



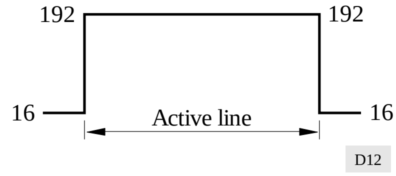
2.11 Check field test signals

2.11.1 *Y* for the first active line of the first field: *A*11

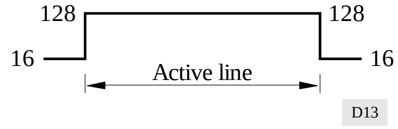
This waveform is used as the line 20 for 525 system and the line 23 for 625 system.



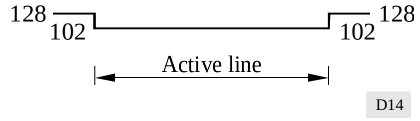
2.11.2 *Y* for equalizer testing: *A*12



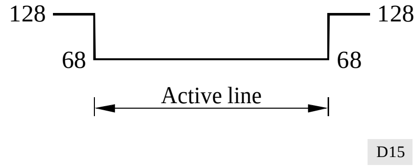
2.11.3 *Y* for phase locked loop testing: *A*13



2.11.4 *C* for equalizer testing: *A*14



2.11.5 *C* for phase locked loop testing: *A*15



ANNEX 2

Sample values corresponding to test signal

TABLE 2

Table of values used for defining digital test signals

A1: Grey

i	0 to 19	20	21	22	23	24	25 to 693	694	695	696	697	698	699 to 719
*A*1(*i*)	16	18	33	72	110	125	127	125	110	72	33	18	16

A2: White

i	0 to 19	20	21	22	23	24	25 to 693	694	695	696	697	698	699 to 719
*A*2(*i*)	16	19	50	126	201	232	235	232	201	126	50	19	16

A3: End-of-line pulses

i	0	1	2	3	4	5	6 to 9	10	11	12	13	14	15	16 to 705	706	707
*A*3(*i*)	16	44	154	235	154	44	16	17	64	185	229	121	31	16	17	64

i	708	709	710	711	712	713	714	715	716	717	718	719
*A*3(*i*)	185	229	121	31	16	16	44	154	235	154	44	16

A4: Black/white ramp

i	0 to 20	21	22	23	24 to 59	60 to 87	88 to 99	100 to 535	536 to 549	550 to 585
*A*4(*i*)	16	14	9	3	1	$((i - 56) / 2)$	16	$((i - 66) / 2)$	235	$((i - 78) / 2)$

i	586 to 599	600	601	602	603	604	605 to 719
*A*4(*i*)	254	250	217	135	53	20	16

i: sample number and takes on values from 0 to 719.

TABLE 2 *(continued)*

A5: Yellow/grey and cyan/grey ramp

i	0 to 19	20	21	22	23	24	25	26	27	28	29 to 39	40 to 95
$A5(i)$	128	126	120	108	89	65	40	21	9	3	1	$((i - 32) / 4)$

i	96 to 119	120 to 563	564 to 719
$A5(i)$	16	$((i - 52) / 4)$	128

A6: Grey/blue and grey/red ramp

i	0 to 19	20 to 563	564 to 579	580 to 631	632 to 659	660	661	662	663	664
$A6(i)$	128	$((i + 396) / 4)$	240	$((i + 384) / 4)$	254	252	246	234	215	191

i	665	666	667	668	669 to 719
$A6(i)$	167	148	136	130	128

A7: C_B, Y, C_R, Y ramp

i	0 to 253	254 to 507	508 to 761	762 to 1 015	1 016 to 1 269	1 270 to 1 439
$A7(i)$	$i + 1$	$508 - i$	$i - 507$	$1\,016 - i$	$i - 1\,015$	$1\,524 - i$

A8: White, end-of-line porches

i	0 to 46	47	48	49	50	51	52	53	54	55 to 667
$A8(i)$	235	232	218	187	139	86	46	24	17	16

i	668	669	670	671	672	673	674	675	676 to 719
$A8(i)$	19	33	64	112	165	205	227	234	235

TABLE 2 *(continued)*

A9: Blue and red, end-of-line porches

i	0 to 23	24	25	26	27 to 333	334	335	336	337	338 to 359
*A*9(*i*)	240	232	191	143	128	130	152	204	236	240

A10: Yellow and cyan, end-of-line porches

i	0 to 23	24	25	26	27 to 333	334	335	336	337	338 to 359
*A*10(*i*)	16	24	65	113	128	126	104	52	20	16

A11: Y for the first active line of the first field

i	0 to 718	719
*A*11(*i*)	192(C0.0h)	32(20.0h)

A12: Y for equalizer testing

i	0 to 719
*A*12(*i*)	192(C0.0h)

A13: Y for phase locked loop testing

i	0 to 719
*A*13(*i*)	128(80.0h)

A14: C for equalizer testing

i	0 to 359
*A*14(*i*)	102(66.0h)

A15: C for phase locked loop testing

i	0 to 359
*A*15(*i*)	68(44.0h)

TABLE 3

Description of encoded colour-bar signals according to the 4:2:2 level of Recommendation ITU-R BT.601

a) *Designation: 100/0/100/0 colour bars*

Definition of Y for digital active line with rise time = 150 ns

i	0 to 13	14	15	16	17	18	19 to 99	100	101	102	103	104	105 to 185
$Y(i)$	16	16	39	126	212	235	235	235	232	223	213	210	210

i	186	187	188	189	190	191 to 271	272	273	274	275	276	277 to 357	358
$Y(i)$	210	206	190	174	170	170	169	167	157	147	145	145	144

i	359	360	361	362	363 to 443	444	445	446	447	448	449 to 529	530	531
$Y(i)$	141	126	110	107	106	106	104	94	84	82	81	81	77

i	532	533	534	535 to 615	616	617	618	619	620	621 to 719
$Y(i)$	61	45	41	41	41	38	28	19	16	16

Definition of C_R for digital active line with rise time = 300 ns

i	0 to 5	6	7	8	9	10	11 to 48	49	50	51	52	53	54 to 91
$C_R(i)$	128	128	128	128	128	128	128	128	130	137	144	146	146

i	92	93	94	95	96	97 to 134	135	136	137	138	139	140 to 177	178
$C_R(i)$	146	133	81	29	16	16	16	18	25	32	34	34	35

i	179	180	181	182	183 to 220	221	222	223	224	225	226 to 263	264	265	266
$C_R(i)$	54	128	202	221	222	222	224	231	238	240	240	240	227	175

i	267	268	269 to 306	307	308	309	310	311	312 to 359
$C_R(i)$	123	110	110	110	112	119	126	128	128

i: sample number and takes on values from 0 to 719.

TABLE 3 *(continued)*

Definition of C_B for digital active line with rise time = 300 ns

i	0 to 5	6	7	8	9	10	11 to 48	49	50	51	52	53	54 to 91	92
$C_B(i)$	128	128	128	128	128	128	128	128	116	72	28	16	16	16

i	93	94	95	96	97 to 134	135	136	137	138	139	140 to 177	178	179	180
$C_B(i)$	31	91	150	166	166	166	154	110	65	54	54	54	69	128

i	181	182	183 to 220	221	222	223	224	225	226 to 263	264	265	266	267
$C_B(i)$	187	202	202	202	191	146	102	90	90	90	106	165	225

i	268	269 to 306	307	308	309	310	311	312 to 359
$C_B(i)$	240	240	240	228	184	140	128	128

b) *Designation: 100/0/75/0 colour bars*

Definition of Y for digital active line with rise time = 150 ns

i	0 to 13	14	15	16	17	18	19 to 99	100	101	102	103	104	105 to 185
$Y(i)$	16	16	39	126	212	235	235	235	227	198	169	162	162

i	186	187	188	189	190	191 to 271	272	273	274	275	276	277 to 357	358
$Y(i)$	161	158	146	134	131	131	131	129	122	114	112	112	112

i	359	360	361	362	363 to 443	444	445	446	447	448	449 to 529	530
$Y(i)$	109	98	87	84	84	84	82	74	67	65	65	65

i	531	532	533	534	535 to 615	616	617	618	619	620	621 to 719
$Y(i)$	62	50	38	35	35	35	33	25	18	16	16

TABLEAU 3 *(continued)*

Definition of C_R for digital active line with rise time = 300 ns

i	0 to 5	6	7	8	9	10	11 to 48	49	50	51	52	53	54 to 91
$C_R(i)$	128	128	128	128	128	128	128	128	129	135	140	142	142

i	92	93	94	95	96	97 to 134	135	136	137	138	139	140 to 177	178
$C_R(i)$	141	132	93	54	44	44	44	45	51	56	58	58	58

i	179	180	181	182	183 to 220	221	222	223	224	225	226 to 263	264	265	266
$C_R(i)$	72	128	184	198	198	198	200	205	211	212	212	212	202	163

i	267	268	269 to 306	307	308	309	310	311	312 to 359
$C_R(i)$	124	115	114	114	116	121	127	128	128

Definition of C_B for digital active line with rise time = 300 ns

i	0 to 5	6	7	8	9	10	11 to 48	49	50	51	52	53	54 to 91
$C_B(i)$	128	128	128	128	128	128	128	128	119	86	53	44	44

i	92	93	94	95	96	97 to 134	135	136	137	138	139	140 to 177	178
$C_B(i)$	44	56	100	145	156	156	156	148	114	81	73	72	73

i	179	180	181	182	183 to 220	221	222	223	224	225	226 to 263	264	265
$C_B(i)$	84	128	172	183	184	183	175	142	108	100	100	100	111

i	266	267	268	269 to 306	307	308	309	310	311	312 to 359
$C_B(i)$	156	200	212	212	212	203	170	137	128	128

ANNEX 2

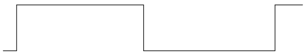
1. Pathological Signals for Cable Equalizers in the Serial Digital Interface

Possible word combinations to generate a stress pattern for cable equalization

. No.	Hex		Validity	
	chroma 1st sample	luminance 2nd sample	4 : 2 : 2 D1	
			10 bit	8 bit
1	200 h	331 h	yes	no
2	300 h	198 h	yes	yes
3	180 h	0CC h	yes	yes
4	0C0 h	066 h	yes	no
5	060 h	033 h	yes	no
6	230 h	019 h	yes	no
7	318 h	0CC h	yes	yes
8	18C h	006 h	yes	no

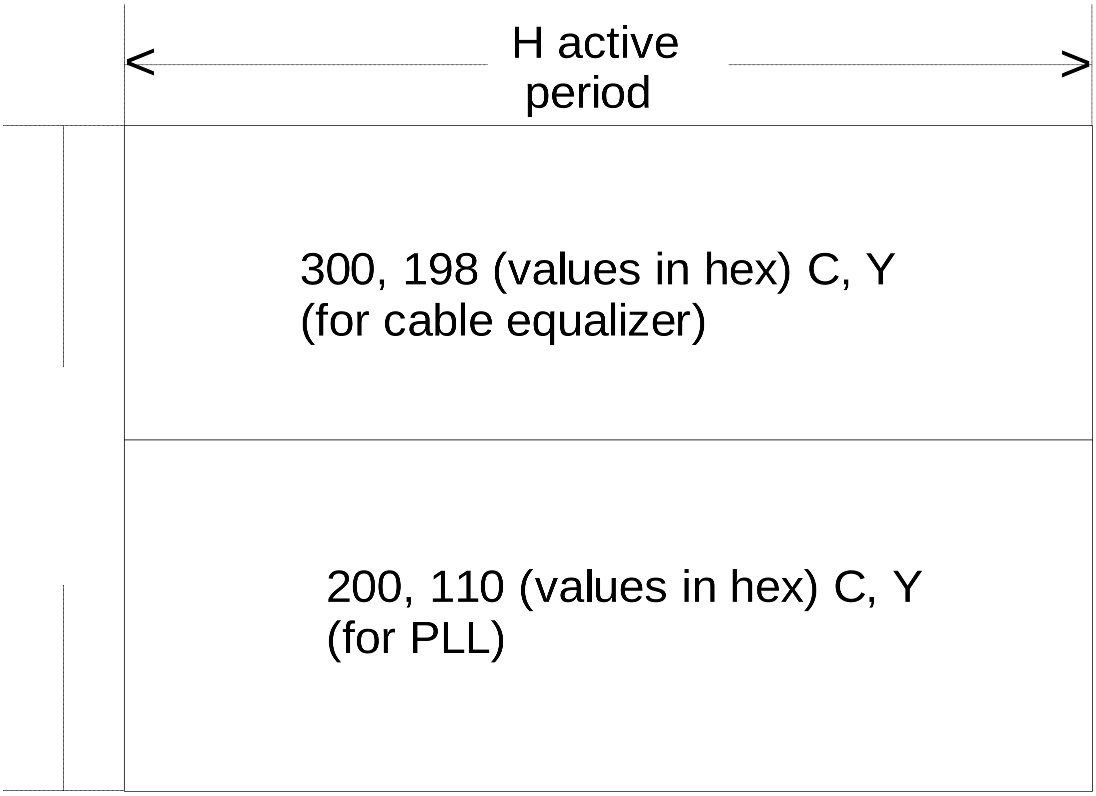
2. Pathological Signals for Genlock of PLL in the Serial Digital Interface

Possible word combinations to generate a stress pattern for genlock of PLL



. No.	Hex		Validity	
	chroma 1st sample	luminance 2nd sample	4 : 2 : 2 D1	
			10 bit	8 bit
1	200 h	110 h	yes	yes
2	100 h	088 h	yes	yes
3	080 h	044 h	yes	yes
4	040 h	022 h	yes	no
5	020 h	011 h	yes	no
6	210 h	008 h	yes	yes
7	108 h	004 h	yes	yes

3. SDI Check Pattern (serial digital interface)



ROHDE&SCHWARZ

BROADCASTING DIVISION

Application Note

ZONE PLATE SIGNALS
525 Lines
Standard M/NTSC

Products:

CCVS+COMPONENT GENERATOR	***SAF***
CCVS GENERATOR	***SFF***

7BM23_0E

ZONE PLATE SIGNALS

525 lines M/NTSC

Back in the early days of television measurements in the baseband, the analog insertion test lines commonly known today were invented and standardized worldwide, constituting an indispensable tool for assessing picture quality. Now the development is beginning to depart from the analog TV world and turn towards digital image processing and transmission. This necessitates new test signals. An important group of signals used in this connection are the zone plate signals which of course also provide valuable information on analog systems and components, eg monitors.

1. Structure of Zone Plate Signal

The zone plate signal in its original form is an optical pattern of alternately black and white concentric circles spaced increasingly closer as their diameters increase .

Fig 1

A section through the centre point of the concentric circles will always reveal the same signal structure no matter at what angle the section is made. A section in the horizontal direction (corresponding to the line structure of a television picture) is referred to as H sweep.

Fig 2 H sweep

Looking for a universally applicable formula describing the zone plate signal, the following equation was found:

$$A\ (x, y, t) = \text{const.} + \sin.\ (k_{\phi} + k_x\, x + k_y\, y + k_{x^2}\, x^2 + k_{y^2}\, y^2 + k_{xy}\, xy + k_{xt}\, xt + k_{yt}\, yt$$
$$+ k_t\, t + k_{t^2}\, t^2)$$

where

x = horizontal distance from a defined zero point, eg the most left point of the screen

y = vertical distance from the defined zero point eg the top of the screen

t = time variable at which the signals change

By setting specific coefficients of the above equation to zero, different types of zone plate signals will be generated, eg:

- H sweep ($k_y, k_{y^2}, k_{xy} = 0$)

- V sweep ($k_x, k_{x^2}, k_{xy} = 0$)

- circular and hyperbolic diagonal zone plate signals depending on the sign of the quadratic coefficient ($k_{xy} = 0$)

- hyperbolic vertical zone plate signal ($k_{x^2}, k_{y^2} = 0$)

If k_t is also set to zero, stationary patterns will be generated.

2 . Example

In the example given below, the coefficients of a circular zone plate pattern moving at a frequency of 1 Hz are to be calculated. The horizontal frequency resolution is assumed to be 5 MHz at the beginning of the line, decreasing to 0 Hz in the centre, and increasing to 5 MHz again at the end of the line. The vertical frequency resolution is assumed to be the same. First, some terms and constants are to be defined:

- Terms:

pw = picture width
ph = picture height

c = cycle (1/13.5 MHz = 74.074 ns to CCIR Rec. 601)
l = line

- Constants for M/NTSC standard:

Complete line: c pw = 63.555619µs / 1 / 13.5 MHz = 858 c pw
Complete picture height: l ph = 525

Visible part
of line: c pw = 858 x 52 µs / 63.555619 µs = 702
of picture: l ph = 525 - (2 x 21) = 483

To clarify the calculation, the meaning of the coefficients is to be explained:

k_x^2 : describes the frequency deviation over one line period,
eg 13.5 MHz / 64 µs

k_x : describes the location of a specific frequency on the active line,
eg 5.5 MHz at the beginning of the line

k_y^2 : describes the frequency deviation over the picture height referred to the
4:3 picture format, eg 10.125 MHz vertical frequency deviation
derived from 525 lines : 13.5 MHz / 4x3.

k_y : describes the vertical frequency at the beginning of the visible vertical
picture range, eg (10.125 MHz * 483) / 525 = 9.315 MHz

The coefficientsk_y^2 and k_y are for the time being applied to a progressively built-up frame, ie without 2:1 interlace.

The coefficients of the circular zone plate signal to be calculated can be determined with the aid of the above definitions:

k_x^2 frequency deviation = 5 MHz per 26 µs = 12.22 MHz per 63.555619µs
= 63.555619µs x 12.22 MHz [c pw^2]
k_x^2 = 776.8 [c pw^2]

k_x = 776.8 * 52 / 63.555619 / 2 = - 317.8 [c pw]
(negative since located left of centre)

k_y^2 = (776.8 / 858) * 3 / 4 * (483 * 525 / 525) = 328.0 [l ph^2]

k_y = 328.0 * (483 / 525) / 2 = - 150.9 [l ph]

As the picture is to move at a rate of 1 Hz, the "coefficients of motion" are to be set as follows: k_t= 1 [Hz], $k\phi = 0°$ and $k_t^2 = 0$ [1/sec^2]
.
Applying the above formulas, the user can fast and easily program any horizontal and vertical starting and end frequencies, as well as linear, circular and hyperbolic, moving and phase-swept zone plate patterns within the 525-line standard.

3. Linear Distortion

The circular zone plate pattern is the most commonly known of the family of zone plate signals. All measurements relevant in practice can be performed using this pattern. For this reason, the considerations made in the following are all based on this signal which is governed by the equation:

$$A (x, y, t) = \text{const.} + \sin. (k_\phi + k_x x + k_y y + k_x^2\ x^2 + k_y2\ y^2 + k_t t)$$

The coefficients of this signal are predefined to have the following values:

k_x = - 317.8
k_y = - 150.9
k_x^2 = 776.8
k_y^2 = 328.0
k_t = 0 (taking a stationary pattern for the sake of simplification)

3.1 Amplitude Frequency Response in Horizontal Direction

When a lowpass filter with a cutoff frequency of approx. 3 MHz is connected between the signal source and the monitor, a pattern of rather unexpected form will appear on the monitor. While the original pattern is circularly symmetric about the centre of the screen, vertical boundary lines will now be seen to the left and right of the centre, and beyond these lines grey level only. The grey level is generated as a result of the sinewave components being suppressed by the lowpass filter. Why vertical lines?

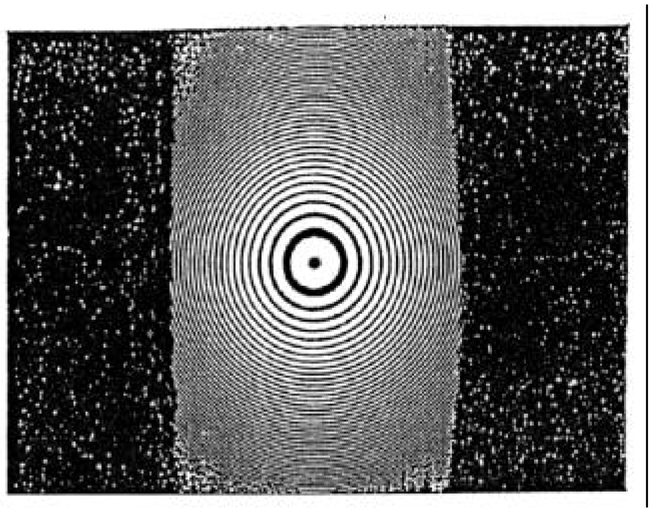


Fig 3 Circular Zone Plate with horizontal bandlimiting at 3 MHz

This can be best understood by looking at the equation. By differentiating the argument ϕ of the sinewave signal partially with respect to x, the frequency variation in the x direction will be obtained:

$$\delta \phi \ (x,y,t) / \delta x = \delta (k_{\phi} + k_x x + k_y y + k_x^2 x^2 + k_y^2 y^2 + k_t t) / \delta x = k_x + 2 k_x^2 x$$

This variation of the frequency is a function of the x coefficient exclusively. This means that at the same x locations the same frequencies will occur across the entire picture. Hence the straight vertical boundary lines described above are formed.

3.2 Amplitude Frequency Response in Vertical Direction

Analogously to the frequency response in the horizontal direction, the symmetrical pattern of the circular zone plate signal makes the vertical signal structure appear as a frequency sweep. In accordance with the 4:3 picture format, the starting and end frequencies at the upper and lower margins of the picture are reduced by a factor of 3/4 compared with those in the horizontal direction. The fine patterns at the upper and lower margins of the picture can be removed by means of a "vertical filter" having a cutoff frequency corresponding to that of the "horizontal filter" and converted accordingly. Grey bars will then appear at the top and bottom of the picture, corresponding to the grey bars obtained right and left of the centre with horizontal filtering. Such a "vertical filter" is not a filter in a conventional sense (that is, made up of coils, capacitors, etc) but a digital filter with a line or frame memory capable of calculating points of identical x locations and variable y loations by employing suitable algorithms (eg FIR filters).

3.3 Diagonal Filtering

The circular zone plate signal considered here has now undergone horizontal and vertical filtering (see sections 3.1 and 3.2). The result is a square window symmetrical about the centre of the screen, with the concentric circles of the zone plate pattern inside the window. It will be seen at a glance that at the margins of the square the resolution is varying: at the corners of the square the resolution is higher by √2 compared with that encountered in the middle of the square sides. To achieve approximately equal resolution along the margins of the square, diagonal filtering can be used employing the same type of digital filter as used for vertical filtering.

3.4 Temporal Filtering

But that's not all there is to filtering. There is still one dimension to be dealt with: time.

With 2:1 interlaced scanning used in today's TV transmissions, large picture areas are reconstructed with a 30-Hz flicker, and fine-structured areas and edges with a 15-Hz flicker. The flicker effects can be eliminated by filtering them out from several consecutive frames. The effects of filtering can again be checked by means of a zone plate pattern, which clearly shows the described flicker effects for the normal interlaced scanning operation.

The calculations in the above example (see section 2) are based on a maximum horizontal frequency of 5 MHz. From this a maximum "vertical frequency" f_V = 12.22 MHz * 3 / 4 = 9.17 MHz, is obtained that can be represented for the vertical 525-line structure. With 2:1 interlaced scanning, however, only 262.5 lines per field are written on the screen, yielding a maximum frequency of only 9.17 MHz / 2 = 4.58 MHz. As a result, aliasing components will be formed at this "vertical frequency", flickering at a rate of 15 Hz since the phase of the aliasing signals is shifted by no more than 180° per frame (also see section 4). Looking at the 2 x 262.5-line-per-frame scanning method, it becomes evident for the first time that television has always had a "digital" character.

3.5 Data Reduction in Digital TV

Fast movements in a TV system can be transmitted at the frame repetition rate as the maximum rate of change. For practical requirements, however, this rate is far too high in the case of a great many, if not all, of the pictures transmitted, or at least in the case of large parts thereof. Temporal filtering, on the other hand, allows stationary picture areas to be transmitted at a lower repetition rate, ie at a reduced bandwidth.

The various types of filtering discussed so far all serve one main purpose:

to achieve maximum data reduction while maintaining optimum picture quality at the receiver end. Data reduction is necessary in the "digital TV era" to enable digital serial transmission of the complete TV signal. Zone plate signals are a suitable, easy-to-handle tool for on-the-screen verification of error-free data reduction in all four filter dimensions. There are data reduction algorithms, eg DCT (Discrete Cosine Transform), which are to be mentioned only briefly in this context. To understand these algorithms, it is necessary to engage in the topic of digital signal processing. As an introduction to this topic we would like to refer the reader to the book "Digitale Filter in der Videotechnik" (Digital Filters in Video Engineering) by H. Schönfelder, published by Drei-R, Berlin.

4. Effects of Nonlinear Distortion

Television has always been a digital system due to its line structure. To sample and reproduce the original signal undistorted within such a system, an antialiasing filter matched to the sampling frequency is required. Since most of the monitors and television receivers do not incorporate such a lowpass filter, aliasing effects occur which are clearly visible on the screen.

In a band-limited system (4.2 MHz in the M / NTSC standard), nonlinear distortion may occur which means that harmonics of the original frequency are generated far beyond the standard bandwidth. The out-of-band signal components are sampled with the digital system clock which produces aliasing effects clearly visible on the screen. Such effects are described in section 3.4 "Temporal Filtering" , for the 2 x 262.5 line structure of the M / NTSC signal; in that example, however, the aliasing components remain within the standard band.

A typical example of nonlinearity is the γ - precorrection ensuring linear brightness variation of the CRT phosphor. CCIR Rec. 624 prescribes γ - to be 2.2 for the M / NTSC standard, ie the camera output voltage is weighted according to the equation $V_P \sim V_C^{0.4545}$ (V_P = precorrected voltage; V_C = camera voltage; 0.4545 = 1/2.2). If this equation is applied to a sinewave voltage, the negative halfwave of the resulting waveform will be relatively flat and the positive halfwave very pointed. The peak of the positive halfwave contains a high proportion of harmonics that may produce aliasing patterns in the digital representation.

5. (Circular) Zone Plate Signal in CCVS Format

A zone plate signal without chroma components, ie generated in the Y channel only, will still show colour components on the screen due to cross-luminance effects. These becomes particularly evident from the M / NTSCcircular zone plate pattern. The locations and movements of the colour components can be explained on the basis of the definitions for the M / NTSC format, using the calculations given above:

*** Horizontal location of cross-luminance components**

As explained in section 3.1, the circular zone plate pattern will have identical horizontal frequencies at identical x coordinates. For this reason, 3.579-MHz colour centres are obtained symmetrically about the centre of the pattern at the left and right margins.

*** Vertical location of cross-luminance components**

There will be identical vertical frequencies at identical y coordinates. The y coordinates are counted in lines per picture height. Where will the "colour subcarrier frequency " in the vertical direction be found?

In M / NTSC, the colour subcarrier is displaced by 180° from line to line. This means that the colour subcarrier will have completed a full cycle in the vertical direction after four lines because of the interlacing. In other words, the "vertical" colour subcarrier frequency will be found where the four-line sequence repeats itself vertically in each field on the circular zone plate pattern. Applied to the line structure and using the above formula the distribution of the colour centres on the screen can be accurately determined:

In our example, K_y^2 = 328.0 [c ph^2] corresponds. to 224.9 [° / l ph]
The colour centres are located where the "vertical line phase" is shifted by 90° per line (four lines for one vertical cycle because of 2 : 1 interlacing) :

l_v = 90 * 525/224.9 = 210.1 lines

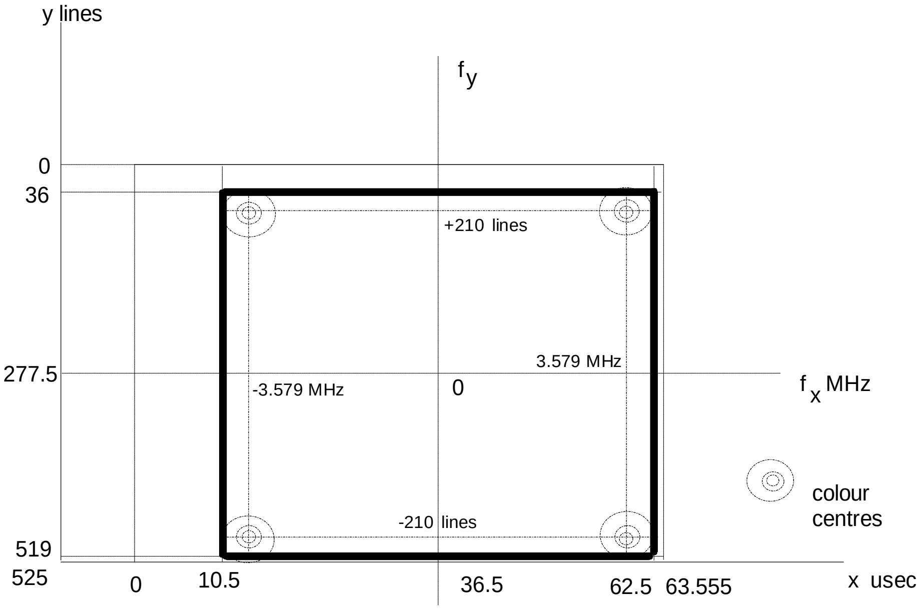


Fig 4 The two dimensional Zone Plate
The visible part of the videosignal is marked by a thick line.

The colour centres, whose locations in the above pattern have been exactly defined, change their phases from which the moving of the coloured concentric circles result. The rate of motion can be best seen from the following diagram:

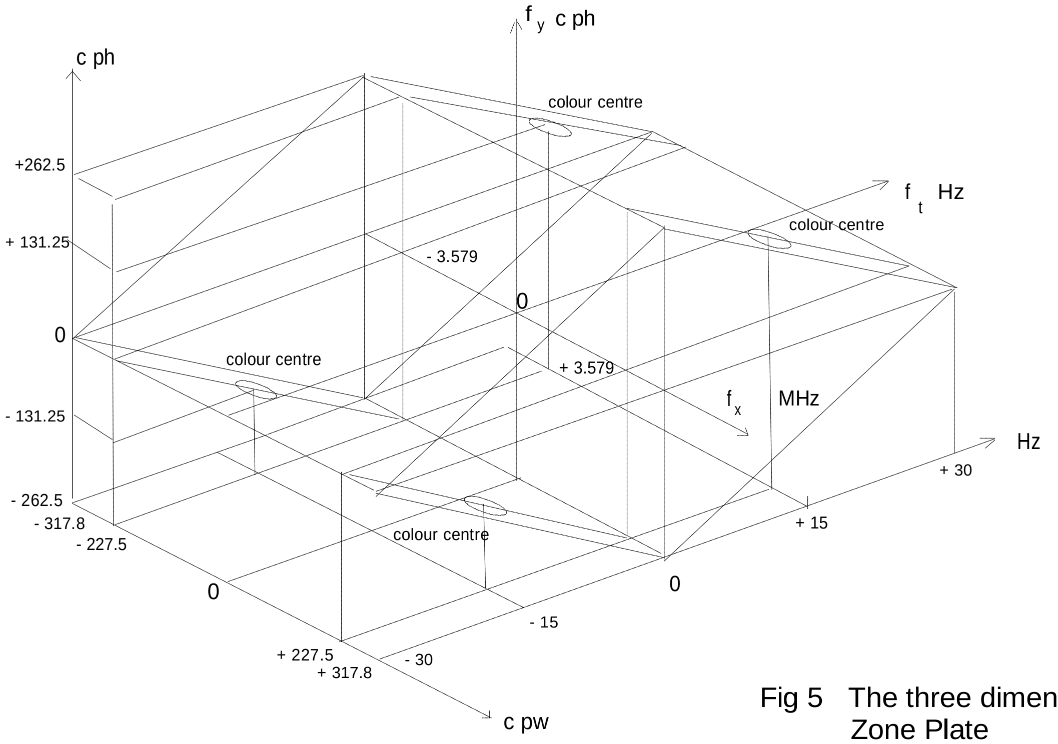


Fig 5 The three dimensional
Zone Plate

The diagram shows that the colour centres change at a rate of
± 15 Hz at ± 210 lines or ± 131.25 c ph
about the centre of the picture.

*** Application**

In addition to the various possibilities of direct on-the-screen evaluation of linear and nonlinear distortion, circular zone plate signals enable another, very important parameter to be measured: cross-colour effects. Zone plate signals are made up of luminance components only, which may also contain frequencies close to the colour subcarrier due to the 5-MHz bandwidth on which our example is based. These frequencies produce the coloured circles generated about the centres whose locations were determined above. The cross-colour effects can be suppressed by means of comb filters more or less effectively, taking into account that movements of the colour components are to be eliminated as well. The efficiency of such filters, which should be provided on all colour TV sets in the upper price range, can be made visible directly and immediately on the screen, again by means of zone plate patterns.

Hyperbolic vertical zone plate signal
(here 625 lines system)

Definiton of the coefficients in the sine argument

$K_\phi + K_x x + K_y y + K_x 2\, x^2 + K_y 2\, y^2 + K_t t + K_t 2\, t^2)$

K_x defines the frequency at field start with a correction factor depending on the frequency deviation per line determined by K_{xy}.

$K_y = 0$

$K_x 2$ and $K_y 2 = 0$, ie there is no additional frequency deviation in the x or y - direction.

K_{xy} defines the frequency deviation per picture height as a factor of the frequency deviation per line. For example: desired frequency deviation
15kHz up to 5 MHz over a 625-line frame
at a field frequency of 50 Hz.

$$K_{xy} = \frac{5\text{ MHz}}{625 \times 50\text{ Hz}/2} = \frac{5\text{ MHz}}{15\,625\text{ Hz}} = 320\ \frac{c}{\text{pw ph}}$$

As an example a zone plate signal corresponding to the V SWEEP of the SAF/SFF signal group SWEEP+BURST is calculated:

V Sweep	Beginning	End
frequency	50 kHz	6 MHz
line in 1st field	48	286
duration in lines	239	

The frequency deviation of (6.000 - 0.050) MHz = 5.95 MHz is to occur in the frame during 2 x 239 = 478 lines:

$$K_{xy} = \frac{5.95\text{ MHz}}{625 \times 50\text{ Hz}/2} \times \frac{625}{478} = 497.7\ \frac{c}{\text{pw ph}}$$

Here 5.95 MHz per 239 lines correspond to a deviation of
5.95 MHz/239 lines = 24.895 kHz/line and the correction factor calculated for K_x is
k = 24.895/15.625 = 1.5933

In line 48, the zone plate signal should have the frequency of 50 kHz. The factor K_x is to be determined accordingly.

The frequency 0 Hz is located in line Z_0:

Z_0 = 48 - (50 kHz / 24.895 kHz)
= 48 - 2.0008 = 45.992

The zone plate signal starts in line 24. Therefore the new reference line is:

Z_0 - 23 = 22.992

The factor K_X is thus obtained from the reference line and the correction factor:

K_X = - 22.992 x 1.5933
K_X = - 36.63 c/pw

K_X is negative as the frequencies of the first 22.992 zone plate lines in the field decrease from 572 kHz in line 24 to 0 Hz in line 45.992.

Due to the zone plate signal pattern with half line offset, the sinewave zero crossing at the upper righthand picture edge is flickering at 25 Hz as opposed to the
V SWEEP since for the latter the half line offset is taken into account.i

Nyquist condition in vertical direction

The highest vertical frequency within the 625 line system is:

$k_{y\ max}$ = 625/2 =312.5 c/ph

If furthermore the value of k_φ
k_φ = 0°
the samples are calculated in the first field at 0° and in the second field at 180°. The (vertical) sinewave has in both arguments the same value:
sin (0°) = sin (180°) = 0. A DC voltage is generated.
The highest vertical frequency with greatest amplitude is only generated, if additional the value of k_φ is
k_φ = 90° or 270°.
Here you recognize at once, that digitizing a sinewave signal is not possible up to half the sampling frequency. Real values arrive at appoximately 0.4 times the sampling rate.