CCITT SGXV
Working Party XV/1

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Specialist Group on Coding for Visual Telephony

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Source: BT, NTT

Title: Standards Conversion to and from Single Mode 288, 29.97 Format

1. Introduction

This document details the algorithms used to produce the sequences shown by NTT and BT at the September 1985 meeting in Turin.

It should be noted that it is only the 288 line, 29.97Hz sequential format which is standardised - NOT the means of achieving the conversions. It is not claimed that the algorithms presented here are optimal in terms of picture quality, or that simpler algorithms would not produce acceptable results. In particular, such items as the number of interpolator taps, the quantisation accuracy of coefficients and the number of bits retained at intermediate stages may require additional study. However it is suggested that this should not be undertaken until the coding algorithm has been chosen and resultant picture quality is better known so that the impairments due to the standards conversion are neither too small nor too large in comparison.

2. NTSC to 288, 29.97

The first step is to produce 480, 29.97 sequential. Half of the lines (240) are taken from one field (16.67ms) of the NTSC input. The other 240 interleaved lines come from the sum of half of each of the previous and next fields. This is shown in figure 1(a).

The second and final step is to convert each 480 line sequential frame to 288 lines. This is accomplished by a tranversal filter and interpolator with 5 taps. A low pass characteristic cutting at 144 cycles per picture height is included since the sample density is being reduced. The reduction of 480 to 288 is in the ratio 5:3, so there are three different types of output line, ie there are three phases to be considered. Hence there are 3 sets of the 5 tap coefficients and these are used cyclically from one output line to the next - figures 1(b) to 1(d). (All pels on any one line are formed in the same way. Also, the fact that there is a '5' in the ratio 5:3 and there are 5 taps in the transversal arrangement is just a coincidence.)

3. 288, 29.97 to NTSC

Each 288 line sequential frame is interpolated to 480 lines by a 5-tap transversal arrangement. This ratio is 3:5 so there are 5 output phases and hence 5 sets of coefficients - figures 2(a) to 2(e). Interlace is then introduced by using 240 alternate lines as the active lines of one NTSC field (16.67ms) and the other 240 lines for the next field. The even numbered lines of 480, 29.97 form one NTSC field and the odd numbered lines the other.

This algorithm increases the field rate from 29.97Hz to 59.94Hz by simple temporal repetition, ie each pair of NTSC output fields contains the same temporal information. However, the two fields differ spatially - the 240 lines in one field are not merely repeated to give the second field.

4. PAL to 288, 29.97

This can be done by two methods which although they look different at first glance are in fact equivalent. The method described below is the conceptually simpler one, - it is not the one in figure 3 of Doc. #40.

The first step is to to form 288 line 50Hz sequential. Alternate fields (20ms each) have their lines shifted up and down by 1/4 of line pitch. (Line pitch here refers to spacing between two consecutive lines in one field.) These shifts are performed by a 5-tap transversal arrangement, with two sets of coefficients which are used alternately on a field by field basis - figure 3(a). This process means that the spatial sample positions (ie lines) in all fields are the same. Averaging pairs of fields on a running basis then gives 288, 50 sequential. Spatially, the process is equivalent to a 10-tap low pass filter cutting at 144 cycles per picture height and temporally a slow roll-off with a notch at 25Hz is introduced.

The second and final step is to reduce the frame rate to 29.97Hz (actually 13.5MHz/6/143/525 = 29.9700299....) by linear interpolation between the nearest two 50Hz ones. If the desired output rate had been exactly 30Hz then a simple 5:3 ratio would have applied, ie 3 phases to consider resulting in 3 pairs of coefficients. However, the ratio of PAL and NTSC field rates is precisely 1001:1200 so this conversion theoretically requires 600 pairs of coefficients. In practice, this can be reduced by quantising the output positions to a smaller number of values and accepting some temporal sample position distortion. The demonstration tapes used 32 pairs of coefficients. This step is illustrated in figure 3(b).

5. 288, 29.97 to PAL

The first step is to produce 288, 50 sequential by linear interpolation between the nearest two input pictures - figure 4(a). Again, quantisation to 32 output positions is employed.

Then interlace is introduced by shifting alternate fields (20ms each) up and down by 1/4 line pitch - figures 4(b) and 4(c). The resulting 576 lines from two fields form the active lines of one PAL picture (40 ms).

6. Interpolation of Edge Lines and Sequence Boundary Fields

When the line interpolators and shifters are used at the top and bottom of pictures some of the taps may fall outside the active picture area. This problem may be overcome by any of the following methods:

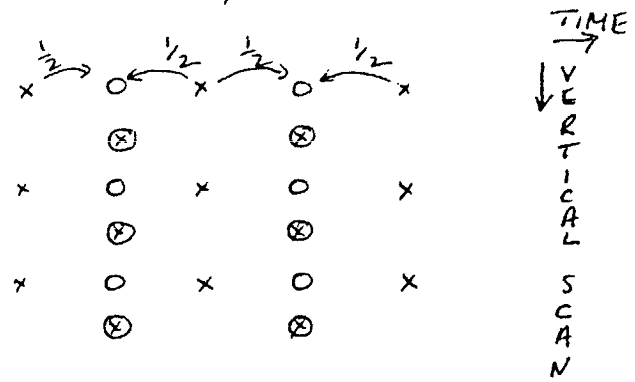
(a) Use dummy lines with Y=127, B-Y=127, R-Y=127 (mid gray without colour).

(b) Repeat the input edge line once or twice as necessary into the blanking interval.

(c) Substitute the first or last output line which can be correctly interpolated.

Concerning the analogous problem with field rate conversion, only pure interpolation should be used, which may result in the shortening of some sequences.

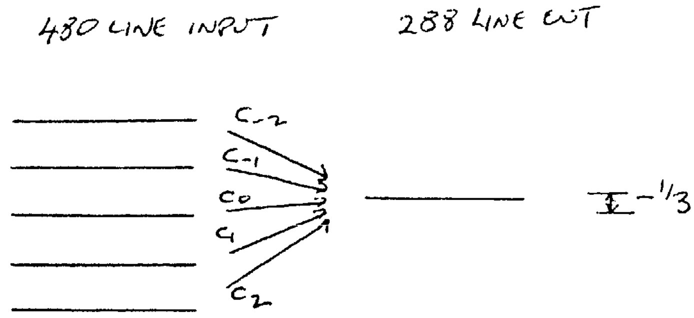
NTSC → 480, 29.97 SEQUENTIAL



× INPUT LINE

o OUTPUT LINE

FIG 1(a)



PHASE DIFF = −1/3

C_{-2} = 0

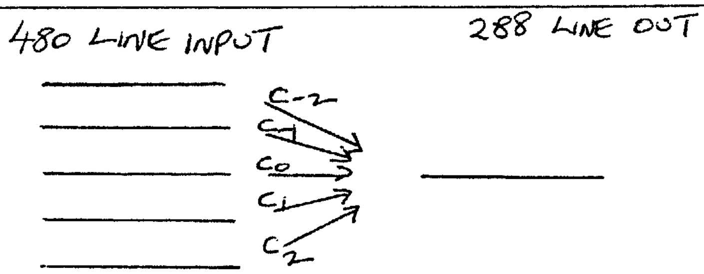
C_{-1} = 113/256

C_0 = 140/256

C_1 = 35/256

C_2 = −32/256

FIG 1(b)



PHASE DIFF = 0

C_{-2} = −24/256

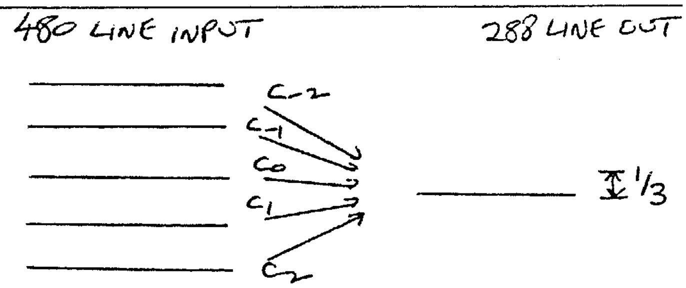
C_{-1} = 76/256

C_0 = 152/256

C_1 = 76/256

C_2 = −24/256

FIG 1(c)



PHASE DIFF = 1/3

C_{-2} = −32/256

C_{-1} = 35/256

C_0 = 140/256

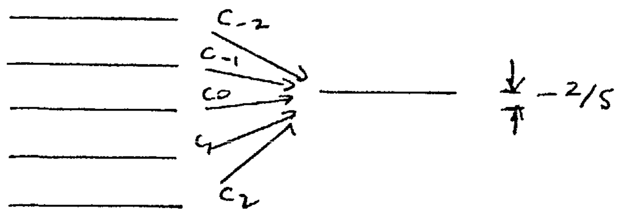
C_1 = 113/256

C_2 = 0

FIG 1(d)

NTSC → 288, 29.97

288 LINE INPUT 480 LINE OUT



PHASE DIFF = $-2/5$

$C_{-2} = -49/256$

$C_{-1} = 131/256$

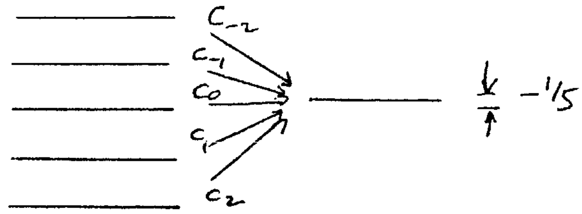
$C_0 = 197/256$

$C_1 = -56/256$

$C_2 = 33/256$

FIG 2(a)

288 LINE INPUT 480 LINE OUT



PHASE DIFF = $-1/5$

$C_{-2} = -27/256$

$C_{-1} = 60/256$

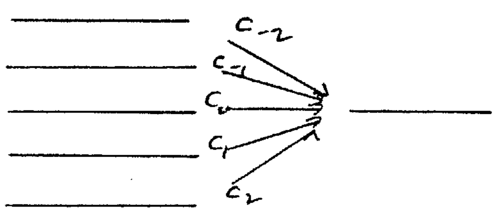
$C_0 = 241/256$

$C_1 = -40/256$

$C_2 = 22/256$

FIG 2(b)

288 LINE INPUT 480 LINE OUT



PHASE DIFF = 0

$C_{-2} = 0$

$C_{-1} = 0$

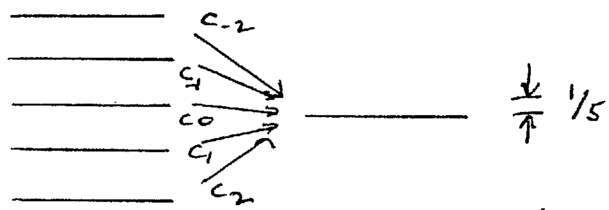
$C_0 = 256/256$

$C_1 = 0$

$C_2 = 0$

FIG 2(c)

288 LINE INPUT 480 LINE OUT



PHASE DIFF = $1/5$

$C_{-2} = 22/256$

$C_{-1} = -40/256$

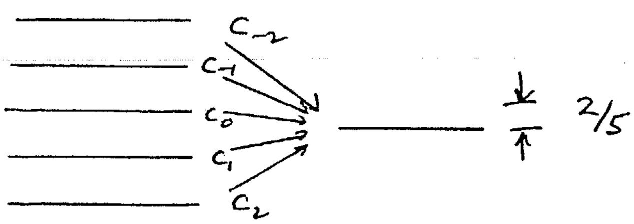
$C_0 = 241/256$

$C_1 = 60/256$

$C_2 = -27/256$

FIG 2(d)

288 LINE INPUT 480 LINE OUT



PHASE DIFF = $2/5$

$C_{-2} = 33/256$

$C_{-1} = -56/256$

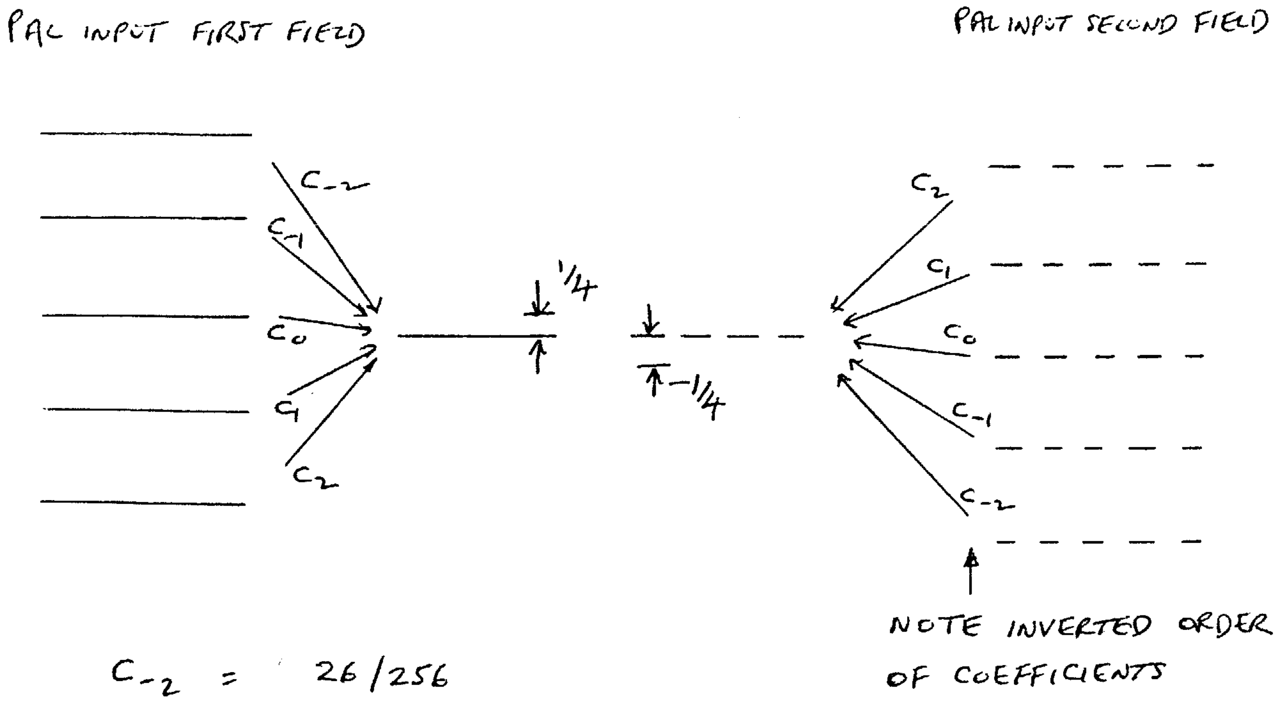
$C_0 = 197/256$

$C_1 = 131/256$

$C_2 = -49/256$

FIG 2(e).

288, 29.97 → NTSC



$C_{-2} = 26/256$

$C_{-1} = -46/256$

$C_0 = 232/256$

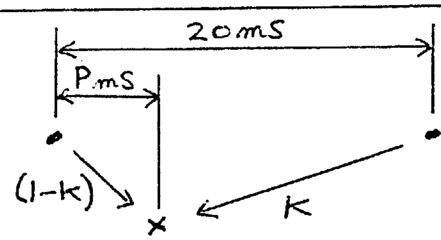
$C_1 = 77/256$

$C_2 = -33/256$

FIG 3(a)

288, 50 SEQUENTIAL INPUT FRAMES

288, 29.97 OUTPUT



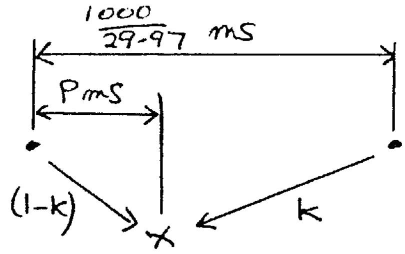
$k = \frac{P}{20}$ ROUNDED TO NEAREST 1/32

FIG 3(b)

PAL → 288, 29.97

288, 29.97 INPUT FRAMES

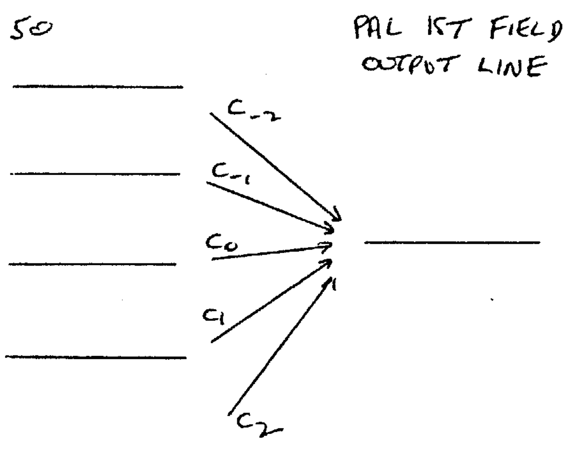
288, 50 INTERPOLATED FRAME



$k = \frac{30P}{1001}$ ROUNDED TO NEAREST 1/32

FIG 4(a)

288, 50



$C_{-2} = -33/256$

$C_{-1} = 77/256$

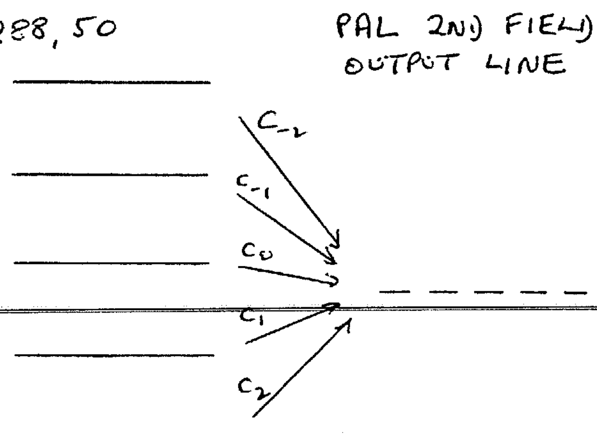
$C_0 = 232/256$

$C_1 = -46/256$

$C_2 = 26/256$

FIG 4(b)

288, 50



$C_{-2} = 26/256$

$C_{-1} = -46/256$

$C_0 = 232/256$

$C_1 = 77/256$

$C_2 = -33/256$

FIG 4(c)

288, 29.97 → PAL