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CIRCUITRY FOR COMB FILTERING PAL AND NTSC VIDEO SIGNALS

This invention is related to comb filters for processing video signals.

5 In processing video signals, it is known to be particularly advantageous to separate the luminance and chrominance components from composite video signal with comb filters. The reason being that the separated luminance component is of full bandwidth, e.g., 4.2 MHz for
10 NTSC signal, and cross components are substantially eliminated from both of the separated luminance and chrominance components. Typical intraframe comb filters for NTSC video signals include circuitry for combining signals which are displaced in time by an odd integral
15 number of horizontal line periods. Because the phase of the chrominance subcarrier changes by exactly 180° from line to line, additively combining NTSC video signals displaced by one line interval produces a signal in which the luminance components from the two lines constructively
20 combine and the chrominance component is cancelled. Conversely, if the signals are subtractively combined the luminance component is cancelled while the chrominance components from the two lines constructively combine. The vertical resolution of the luminance component is
25 compromised but is acceptable.

PAL signals on the otherhand have a chrominance subcarrier which exhibits a 180° phase change every two horizontal line periods. Therefore, typical intraframe PAL comb filters combine video signals which are displaced in
30 time by two horizontal intervals. The PAL comb filter function is basically the same as for the NTSC comb filter however, since the signals that are combined are spatially displaced by two lines, the vertical resolution of the PAL luminance component is significantly impaired, and tends
35 towards not being acceptable.

Yoshimitsu Nakajima et al in an article entitled "Improvement of Picture Quality For NTSC And PAL Systems By Digital Signal Processing," IEEE Transactions on Consumer Electronics, Vol. CE-31, No. 4, Nov. 1985, pp. 642-654

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describe adaptive comb filters which combine samples from three successive lines of video signal. In this system, the NTSC embodiment combines samples which are vertically aligned, similar to the aforescribed typical NTSC and PAL comb filters. The PAL embodiment however combines diagonally aligned samples from adjacent lines. This tends to preserve the vertical resolution of the luminance component, reduces memory requirements for delaying the video signals but tends to have an adverse affect on images containing vertical lines.

Published West German Application DE 3007520 A1 shows a comb filter apparatus for PAL signals including an intraframe comb filter. The intraframe comb filter includes a one line delay element for delaying alternate samples of the video signal from successive lines of signal. The delayed samples are coupled to one input of a combining circuit and intervening samples from the current line are coupled to a second input of the combining circuit. Since the combined signals correspond to alternate samples on alternate lines, the intraframe filter function corresponds to a diagonal rather than a vertical comb filter. Further since the apparatus operates on alternate samples, there is a loss in horizontal resolution.

Richard C. Spiero in U.S. Patent No. 4,480,265 describes a circuit for comb filtering separated PAL chrominance signals by combining signals from adjacent video lines. In this system one of the signals to be combined is first applied to a phase inverter which inverts the phase of the (R-Y) component of the chrominance signal before combining. The line of chrominance which undergoes phase inversion has its components phase aligned with the chrominance components of adjacent lines. The phase inverted line and an adjacent line is additively combined to develop a noise reduced chrominance signal. This system is limited to comb filtering chrominance signal and cannot be utilized to separate the luminance and chrominance components from composite PAL video signals.



The approach of the present invention seeks to provide a comb filter for processing, at least PAL, video signals in which the shortcomings such as discussed above are substantially avoided.

5 The present invention is embodied in a comb filter for video signals, including a delay element for concurrently providing video signal from three successive lines designated Top, Middle and Bottom, and signal combining circuitry for combining signal from the Middle
10 line with signal alternately selected from the Top and Bottom lines, along each line interval.

 In a further embodiment of the invention, detection circuitry is coupled to receive the signals from the Top, Middle and Bottom lines, and generate a control
15 signal if the signal from the combining circuitry potentially includes undesirable artifacts. Substitution circuitry responsive to the control signal, is included to replace the signal from the combining circuitry with alternatively filtered signal from at least one of the Top,
20 Middle and Bottom lines of signal.

Brief Description of the Drawings

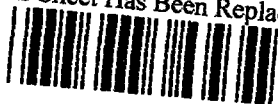
FIGURES 1A, 1B and 1C are pictorial diagrams representing a portion of a field of chrominance components of video signals sampled at four times the chrominance
25 subcarrier frequency, which diagrams are useful in understanding the principle of the invention.

FIGURES 2, 3 and 9 are block diagrams of alternative comb filter circuits embodying the invention.

FIGURES 4-8 are block diagrams or schematics of
30 alternative circuits which may be implemented for element 72 of FIGURE 3.

FIGURE 10 is a block diagram of a further embodiment of a comb filter arrangement for taking into account vertical signal components.

35 FIGURE 11 is a table of samples provided at various signal points in the arrangement of FIGURE 10.



The invention may be practiced in either the analog, e.g., sampled data, or digital signal processing domain, however, it will be described in a digital signal processing environment. As such, except for clock lines
5 and the analog signal input, the interconnecting lines are assumed to be multibit parallel connections.

Referring to FIGURE 1A, a matrix of signal samples are illustrated which are intended to represent successive chrominance components from portions of
10 successive lines of an NTSC video signal sampled at four times the color subcarrier frequency. The signal is presumed to be sampled in phase with one of the axes of the quadrature modulated color difference signal components. Samples designated $\pm I$ represent the in phase component and
15 samples designated $\pm Q$ represent the quadrature phase component. The $\pm$ signs represent the sampling phase relative to the subcarrier and not necessarily the sample polarity. If the sampled video signal is a composite video signal, the samples at each location will include a
20 luminance, Y contribution, e.g., $Y+Q$, $Y-I$, $Y-Q$, $Y+I$, $Y+Q$ etc. however, the Y terms have been excluded in the drawing to avoid confusion. In FIGURE 1A, the in phase and quadrature samples I, Q may represent the (R-Y) and (B-Y) color difference signals or the conventional I and Q color
25 difference signals. The particular sample set is determined by the sampling phase. It is seen from FIGURE 1A that vertically adjacent samples represent like chrominance components. This vertical alignment facilitates comb filtering, i.e., additively combining
30 vertically adjacent samples cancels the chrominance and provides twice luminance while subtractive combining vertically adjacent samples cancels luminance contributions and provides twice chrominance (assuming substantially redundant line-to-line image content). Any line may be
35 combined with either adjacent line to produce a comb filter signal.

FIGURE 1B illustrates a matrix of signal samples which are intended to represent successive chrominance



components from portions of successive lines of a PAL video signal (e.g., PAL/M) sampled at four times the subcarrier frequency. As in FIGURE 1A contributions of the luminance component (for composite signal) have been excluded. The signal is presumed to be sampled in phase with one of the axes of the quadrature modulated color difference signal components U,V. By convention component U represents the (B-Y) color difference signal and component V represents the (R-Y) color difference signal. In the PAL signal the phase of the V component is shifted 90° line-to-line relative to the U component. The result is that vertically adjacent samples represent alternate components. Consequently vertically adjacent samples cannot be combined to produce comb filtered signals representing a particular component. Note however that the samples may be combined diagonally, as indicated by the arrows, to develop comb filtered components. However, errors will occur for horizontal transitions which can occur in the luminance component, resulting in significant cross components in the comb filtered chrominance components.

FIGURE 1C shows the sample distribution resulting from sampling the video signal at 45 degrees off the U or V axes. As in FIGURES 1A and 1B the luminance contributions, if present in the input video signal, have been excluded from the diagram. It is seen from FIGURE 1C that vertically adjacent samples represent like chrominance components. Alternate samples between any pair of lines represent samples of opposite subcarrier phase and may be combined to separate the luminance and chrominance components of composite video signal. The pairs of samples which may be combined for this purpose are indicated by the arrows in the figure. To produce separated luminance and chrominance components representing line N of the video signal, the samples along line N are alternately combined with vertically adjacent samples from line N+1 and line N-1, i.e., sample (l,s) (m,b) (n,u) (o,d) and (p,w). Similarly, to produce separated components representing



line N-1, the samples along line N-1 are alternately combined with samples from line N-2 and line N.

Alternatively, if the input video signal contains only a chrominance component, alternate samples of like subcarrier phase may be additively combined to produce noise reduced comb filtered chrominance signals, i.e., samples (l,a) (m,t) (n,c) (o,n) and (p,e). In this example it is necessary to concurrently provide samples from three adjacent lines. Comb filtered chrominance samples may be produced from signals from only two adjacent lines if alternate samples from one of the lines have their polarity reversed. In this instance, consider developing comb filtered chrominance samples representing line N by combining samples from lines N and N+1. In line N+1 samples s,u and w are inverted to produce samples -,s -u and -w. Then samples (l,-s) (m,t) (n,-u) (o,v) and (p,-w) are combined to produce the comb filtered chrominance component.

FIGURE 2 illustrates circuitry embodying the basic invention. Input video signal which may be sourced from a conventional television tuner is applied to terminal 10. This signal is coupled to the analog input connection of an analog-to-digital converter (ADC) 12, and to the phase-locked-loop (PLL) circuitry 16 and sync separator 14. The sync separator develops a burst gate signal BG which is coupled to the PLL circuitry 16. PLL circuitry 16 is responsive to the burst component of the video signal to develop a clock signal having a frequency of four times the chrominance subcarrier frequency f_{sc} , phase locked to e.g. the U axis of the chrominance component. This clock signal is coupled to a phase shifter 18, which shifts the phase of the clock signal to substantially 45° relative to the U or V axis. The phase shifted clock signal is applied to the sampling clock input terminal of ADC 12 and a divide-by-two frequency divider 20. The PLL 16 also develops a PAL switch signal which represents the relative phase of the V chrominance component. Circuits 14, 16 and 18 may be of conventional design. Circuit 18 may be



incorporated in the PLL 16. In an alternative arrangement, the sync separator 14 and PLL 16 may be designed to process digital samples in which case the input signal to these circuits is derived from the output signal from ADC 12

5 (indicated by the broken line connection).

The PAL switch signal and the clock signal from divider 20 are coupled to respective input terminals of an exclusive OR circuit 22 which produces a two times f_{sc} clock signal of opposite phase on alternate lines. The two
10 times f_{sc} clock signal is coupled to the control input terminal of a switch circuit 32, to alternately couple samples applied to its two signal inputs I1 and I2 to the subtracter 28.

The video signal at terminal 10 is sampled and
15 converted to binary form by ADC 12 to produce samples as illustrated in FIGURE 1C. These samples are coupled to a one horizontal interval delay element 24 and to the input terminal I1 of switch 32. The delayed signal from delay element 24 is coupled to a second one horizontal interval
20 delay element 26, the output of which is coupled to the input terminal I2 of switch 32. If the signal provided by delay element 24 corresponds to line N (FIGURE 1C), then the signals applied to the inputs I1 and I2 of switch 32 correspond to lines N+1 and N-1 respectively.

25 Signal representing line N from delay element 24 is coupled to the minuend input terminal of subtracter 28 and output signal from switch 32 is coupled to the subtrahend input terminal of subtracter 28. Switch 32 is conditioned to couple alternate samples from line N+1 and
30 N-1 to subtracter 28, e.g., the sequence of samples s, b, u, d, w. The chrominance component of the samples are constructively combined in the subtracter 28 to produce a comb filtered chrominance signal. If the input signal includes a luminance component it is substantially
35 cancelled by the subtractive function. Output signal provided by subtracter 28 is coupled to a bandpass filter 30 designed to have a passband encompassing the frequency spectrum normally occupied by the chrominance signal. If



the input video signal includes a luminance component, a separated luminance signal is provided by subtracting the bandpass and comb filtered signal from element 30, from delayed composite video signal from delay element 24 in the subtracter 34.

Delay element 26 provides samples representing line N-1 when comb filtered signal representing line N is being provided by subtracter 28 (and 34). With reference to FIGURE 1C it is seen that only every other sample from line N-1 is utilized. Therefore delay element 26 may be realized with a half-H delay line, e.g., a memory element having half the storage capacity as delay element 24 and cycled or clocked at one-half the sample rate.

FIGURE 3 illustrates an adaptive comb filter of the type shown in FIGURE 2, including additional circuitry to compensate for comb filtered signal artifacts introduced by vertical transitions of the video signal. In FIGURE 3, signal from ADC 12 is coupled to a one-horizontal-interval-delay element 52 and a bandpass filter 50. Output signal from delay element 52 is coupled via a bandpass filter 54 to a second one-horizontal-interval delay element 56. Bandpass filters 50 and 54 have passbands arranged to encompass the frequency spectrum normally occupied by the chrominance component of the input video signal.

Output signal from bandpass filter 54 is coupled to the minuend input connections of subtracter circuits 58 and 60. Output signals from delay element 56 and bandpass filter 50 are respectively coupled to the subtrahend input connections of subtracter circuits 60 and 58. The three signals coupled to subtracters 58 and 60 are all bandpass filtered. If the signal coupled to the minuend input connection of subtracter circuits 58 and 60 corresponds to line N (FIGURE 1C) then the signals coupled to the subtrahend input connections of subtracters 58 and 60 respectively correspond to lines N+1 and N-1.

Subtractor 58 produces samples corresponding to the differences between successive vertically adjacent samples from lines N and N+1. Subtractor 60 produces



samples corresponding to the differences between successive vertically adjacent samples from lines N and N-1. The difference samples from subtracter circuits 58 and 60 are coupled to respective signal input terminals of a

5 two-to-one multiplexer 64. Multiplexer 64 is conditioned by the two-times f_{sc} signal from exclusive OR circuit 22 (FIGURE 2) to alternately couple samples from subtracter circuits 58 and 60 to a delay element 68. The sequence of samples provided by multiplexer 64 corresponds to the

10 sequence of samples provided by subtracter circuit 28 in FIGURE 2 and thus represents a comb filtered chrominance component corresponding to line N.

Delay element 68 provides a compensating delay to the comb filtered chrominance signal, to accommodate for

15 processing delays in the remainder of the circuitry to be described. The comb filtered chrominance signal, since it is the algebraic sum of two signals is of twice amplitude. Therefore the comb filtered signal from delay element 68 is coupled to an attenuator 70 which divides the signal

20 amplitude by two. The divided signal from attenuator 70 is applied to one input terminal of a switching circuit 74. An alternative chrominance signal is coupled to a second input terminal of switching circuit 74. The alternative chrominance signal may be derived by horizontally filtering

25 signal provided by bandpass filter 54 in filter 62. In this instance, horizontal filter 62 may provide narrowband chrominance signal samples corresponding to the comb filtered pixel available from attenuator 70. An exemplary horizontal filter function H is represented by the

30 equation:

$$H = -1 + 2Z^{-P} - Z^{-2P}$$

where Z is the conventional Zee transform variable and the superscript p represents a one sample delay period. Alternatively, the alternative chrominance signal may

35 simply be the bandpass filtered signal available from filter 54, coupled to the switching circuit 74 via compensating delay element 69. For example, if the comb filtered signal corresponds to combined samples n-u (for



line N), the alternative chrominance sample corresponds to sample n (FIGURE 1C). It will be appreciated by those skilled in the art of video signal processing, that other alternate chrominance signals may be derived from the input video signal and applied to switching circuit 74.

Switching circuit 74 is conditioned by a switching signal K to couple either the comb filtered chrominance signal or the alternative chrominance signal or a combination of both to its output terminal to provide a chrominance component signal. The chrominance component signal from circuit 74 may be subtracted (in subtracter circuit 82) from delayed composite video signal from delay element 52 to produce a luminance component signal.

The exemplary switching circuit 74 includes the cascade connection of a subtracter 76, a multiplier 78 and an adder 80. The comb filtered chrominance signal from attenuator 70 is coupled to one input of the subtracter 76. The alternative chrominance signal is coupled to a second input of subtracter 76 and to the adder 80. The control signal K nominally having values between 0-1 inclusive, is applied to the control input of the multiplier. The output produced by circuit 74 corresponds to $(K)S1 + (1-K)S2$ where S1 and S2 correspond to the comb filtered and alternative chrominance signals respectively.

The control signal K is developed as follows. Refer to FIGURE 1C and consider a comb filtered signal corresponding to sample n line N. The comb filtered sample representing pixel n is a combination of samples n and u. If a vertical transition exists between lines N and N+1 there is a high probability that the combined sample will be erroneous, i.e., introduce an artifact in the displayed image. If a transition exists at pixel n between lines N and N+1, it is highly probable that the transition extends to the area between pixels m and t and pixels o and v. The existence of such transitions can therefore be detected by measuring the difference between like phase samples m,t and o,v. These samples are not utilized in developing the comb

filtered sample representing pixel n , but are utilized in determining if the comb filtered sample may be erroneous.

Referring again to FIGURE 3, sample differences from subtracter circuits 58 and 60 are coupled to
 5 respective signal input terminals of a further multiplexer 66. Multiplexer 66 is conditioned by the two-times f_{sc} clock signal from exclusive OR circuit 22 to provide a sequence of sample differences representing the alternate sample differences not passed by multiplexer 64. That is
 10 when comb filtered samples are developed representing line N , the sequence of sample differences passed by multiplexer 66 are derived from samples $(l,a)(m,t)(n,c)(o,v)$ and (p,c) . The samples provided by multiplexer 66 are coupled to the K control signal generator 72 which develops
 15 a K control signal representing the relative goodness of the current comb filtered signal. For example, if a vertical transition is detected or not detected, generator 72 may produce control values of zero and one respectively.

FIGURE 4 is a circuit diagram for a control
 20 signal generator 72 which develops K control signals having one and zero values. In this circuitry, the difference samples from multiplexer 66 are coupled to circuit element 410 which provides the magnitude of the difference samples. The magnitude samples are compared to a reference value REF
 25 in a comparator 412 which provides logic one and zero values for the magnitude samples being greater and lesser than the reference value respectively. The reference value is selected to be at least equal to the nominal expected noise value to preclude false detection of transitions.
 30 The reference value may be increased to a value representing vertical transitions which do not produce unacceptable comb filtered signals, which value will be determined subjectively for each particular video signal processing system.

35 The one/zero values from comparator 412 are coupled to one input terminal of a NAND gate 418, and to the input terminal of the cascade connected delay elements 414 and 416. The output of delay element 416 is coupled to



a second input of the NAND gate 418. The delay elements 414 and 416 each provide a sample delay of one sample period. If the comb filtered sample currently provided by attenuator 70 corresponds to the difference between samples (n,u) then the one/zero values at the input to delay element 414 and output of delay element 416 correspond to differences between samples (o,v) and (m,t) respectively. If a logic "one" is present at both inputs to the NAND gate 418, NAND gate 418 provides a zero value and the alternate chrominance sample is provided by switching circuit 74. Otherwise, NAND gate 418 provides a "one" value and the comb filtered signal is provided by circuit 74.

FIGURES 5-8 show alternative embodiments of the K signal generator 72, each of which provides a variable control signal, K, having values from zero to one. Refer first to FIGURE 8. In this embodiment, sample differences from multiplexer 66 are coupled to a magnitude circuit 810 which provides the magnitudes of the differences. The magnitude values are coupled to cascade connected delay elements 812 and 814 and to one input connection of a sample averaging circuit 816. The output of delay element 814 is coupled to a second input connection of the averaging circuit 816 which provides the average of samples applied to its input connections e.g., the average of the magnitudes of the differences of samples (m,t) and (o,u). The averages provided by circuit 816 are applied to logic circuitry 818 which produces the K control signal. Logic circuitry 818 may conveniently be realized with a memory device, for example, a read only memory (ROM). The average values are coupled as address codes to the ROM which is programmed to produce K values associated with the average values. For example the ROM may be programmed to provide the reciprocal of the average values. Alternatively, the ROM may be programmed to produce a limited number of K values associated with predetermined ranges of the average values. For example, if the average values are represented by seven bit samples having values from zero to 127 the ROM may be programmed to provide K values corresponding to 1,



7/8, 6/8, 5/8, 3/8, 2/8, 1/8 and 0 for ranges of average values of (0-15), (16-31), (32-47), (48-63), (64-79), (80-95), (96-111) and (112-127) respectively.

FIGURES 5, 6 and 7 are alternative circuits which provide K values related to the ratio of horizontal differences H_D to vertical differences V_D of the form $V_D/(V_D+H_D)$. The values provided by multiplexer 66 are vertical differences. Horizontal differences are derived, for example, by taking the differences between vertical differences.

The FIGURE 5 circuit will be described in detail. The operation of the FIGURES 6 and 7 circuitry is similar and will be readily understood with knowledge of operation of the FIGURE 5 circuit.

In FIGURE 5, the difference samples from multiplexer 66 and coupled to the cascade connected one-sample-interval delay elements 510 and 512, to a signal averager 514 and a signal differencing circuit 524. Output samples from the delay element 512 are coupled to respective second input connections of the signal averager 514 and the signal differencing circuit 524. Averager 514 provides the average value, V_D , of two difference samples (e.g., (n-t) and (o-v)) and differencing circuit 524 provides the difference, H_D , between the same two difference samples. The average values V_D are applied to a magnitude detector 516 which provides the absolute value $|V_D|$ of the average value. The differences H_D provided by the differencing circuit 524 are coupled to a magnitude detector 522 which provides the absolute value $|H_D|$ of the difference values. The values $|H_D|$ and $|V_D|$ are summed in adder circuit 518 to form the signal $|H_D|+|V_D|$. The value $|V_D|$ from detector 516 is then divided by the value $|H_D|+|V_D|$ in divider 520, producing the signal sample $|V_D|/(|H_D|+|V_D|)$ which is constrained to have values between zero and one inclusive. The signal samples from the divider 520 are coupled as address codes to a ROM 526 which is programmed to provide the appropriate K value for respective address values. Note that the FIGURE 5



circuitry may be slightly rearranged to have the divider 520 produce the ratios $|H_D|/(|H_D|+|V_D|)$. In this instance the ROM 526 will be appropriately programmed to accommodate these address values. Note also that in either instance
5 the function of the ROM 526 may be provided with alternative logic circuitry.

FIGURE 9 is an alternative adaptive comb filter circuit which switches between line alternating comb filtered output and various other substitute signals. The
10 comb filtered chrominance signal produced by the FIGURE 2 circuitry is an example of line alternating comb filtered signal. In FIGURE 9, circuit elements designated by like numerals as elements in FIGURE 3 are similar and perform like functions. As such, multiplexer 64 produces a line
15 alternating comb filtered chrominance signal and multiplexer 66 produces a sequence of line difference samples, which difference samples do not contribute to the comb filtered signal per se.

Refer to FIGURE 1C and consider a comb filtered
20 signal representing line N pixel n. A line alternating comb filter combines samples n and u. If there is a vertical transition between lines N and N+1, the comb filtered sample will probably be in error. If a vertical transition exists between lines N and N+1, it is highly
25 unlikely that a vertical transition will concurrently occur between lines N and N-1. Therefore, it may be more advantageous to combine sample n with a sample from line N-1, for example sample a or sample e or an average of both. Note samples a and e are sampled at the same
30 subcarrier phase as sample u. The circuitry of FIGURE 9 is arranged to substitute a comb filtered sample, e.g., n-a, or sample n for the line alternating comb filtered sample e.g., n-u, if a probable error exists in the line alternating comb filtered sample.

35 In FIGURE 9, signal from the bandpass filter 50 is coupled to delay elements 910 and 912 to concurrently provide samples u, t and s (FIGURE 1C). Signal from delay element 56 is coupled to delay elements 914 and 916 to



concurrently provide samples c, b and a (FIGURE 1C). The delay elements 912 and 916 are coupled to respective input terminals of a multiplexer 918 which is conditioned by the two times f_{sc} signal from exclusive OR circuit 22 to pass a sample from line N-1 when the multiplexer 64 is passing a sample representing the difference between lines N and N+1 and vice versa. The output of multiplexer 918 is coupled to the subtrahend input of subtracter 920. The minuend input of the subtracter 920 is coupled to the output of the bandpass filter 54. The subtracter 920 provides the difference e.g., n-a concurrently with multiplexer 64 providing the difference n-u. Output samples from the subtracter 920, multiplexer 64 and bandpass filter 54 are coupled to respective signal input terminals A, B and C of a multiplexer 922. Multiplexer 922 is conditioned by a control circuit 940 to pass one of the signals available at its A, B and C input connections as a chrominance signal chroma. The chrominance signal may thereafter be combined with composite video signal to produce a luminance component as in FIGURE 3. Note, compensating delays are provided in each of the input signal paths to the multiplexer 922 to accommodate the processing delay of the multiplexer 922 control signal generating circuitry.

Control signals for the multiplexer 922 are developed from the alternate difference samples provided by multiplexer 66. In the exemplary circuitry shown, sample differences from multiplexer 66 are coupled to circuitry 924 which provides logic one values for difference samples having a magnitude which exceed a predetermined threshold value and provides logic zero values otherwise. The logic one/zero values are coupled to the cascade connected delay elements 926-930. Assuming that the current signals available at multiplexer 922 correspond to line N sample n, the one/zero values representing the alternate difference samples from multiplexer 66 are indicated adjacent the output connections of delay elements 926-930. The one/zero values from delay elements 926 and 928, representing difference values disposed on either side of the current



line alternating comb filter sample, are applied to respective input connections of an AND gate 932. AND gate 932 provides a logic one output value only when both of its input values are a logic 1 and provides a logic zero value otherwise. If AND gate 932 provides a logic one value it is probable that the line alternating comb filtered sample from multiplexer 64 is in error.

The one/zero values from circuit 924 and delay element 930 are coupled to respective input connections of an AND gate 934. The values coupled to AND gate 934 represent differences disposed on either side of the current line alternating comb filter sample removed two sample intervals from the current sample and derived from the current line (N) and the adjacent line (N-1) which is not contributing to the current line alternating comb filter sample. AND gate 934 provides a logic one output value when a vertical transition exists between the current line and the adjacent line not contributing to the current line alternating comb filter sample.

The output logic value from AND gates 932 and 934 are applied to the control logic circuitry 940 which generates control signals for multiplexer 922. If AND gate 932 provides a logic 0 value, control circuit 940 conditions multiplexer 922 to pass the sample available from multiplexer 64. If both of the AND gates 932 and 934 provide logic one values, indicating transitions between the current line and both adjacent lines, control circuitry 940 conditions multiplexer 922 to pass the sample available from the bandpass filter 54. Finally, if AND gate 932 provides a logic one and AND gate 934 provides a logic zero, indicating a vertical transition between e.g., lines N and N+1 but no transition between lines N and N-1, then control circuit 940 conditions the multiplexer 922 to pass the alternate difference sample (e.g., n-a) provided by subtracter 926.

The circuitry of FIGURE 9 can be slightly rearranged to generate a further substitute signal (alternative to the sample n-a). Consider the comb



filtered sample $(n-u)$ representing line N sample n. The sample c, immediately above sample n is of like sampling phase. Both samples n and c have been derived via bandpass filter 54 and thus are primarily chrominance samples. Thus
5 if the samples n and c are additively combined the sum thereof will be primarily a chrominance sample. These substitute samples may be produced in the FIGURE 9 arrangement by substituting an adder circuit for subtracter 926 and coupling the A and B input connections of
10 multiplexer 918 to the output connections of delay element 56 and bandpass filter 50 respectively (i.e., eliminating delay elements 910-916). The remainder of the circuitry of FIGURE 9 can remain intact. The substitute samples, e.g., $(n+c)$, have the advantage of being derived from spatially
15 adjacent samples, but the disadvantage of including high frequency luminance. Conversely the substitute samples, e.g., $(n-a)$, contain substantially no luminance components but are derived from fairly widely separated samples and may include errors due to horizontal transitions.

20 Both alternatives of the FIGURE 9 circuitry may be combined in a single system with appropriate detection circuitry to select the substitute sample least likely to introduce artifacts in the reproduced image.

FIGURE 10 illustrates an adaptive comb filter, of
25 the type shown in FIGURE 2, for processing the sampled video signal produced by ADC 12. In FIGURE 10 a total of three different ways for deriving a luminance signal Y and likewise three different ways of deriving a chrominance signal C, are shown. In each instance the signal paths are
30 evaluated, as a function of the vertical components, to determine which path will provide the best expected signal separation. This is achieved in the following described manner according to the arrangement of FIGURE 10, in which the luminance signal Y2H and the chrominance signal C2H
35 correspond to the signals Y and C respectively in FIGURE 2.

In FIGURE 10, the sampled and digitized input video signal from ADC 12 is provided to the input a' of the series circuit of delay elements 1004 and 1005. At the



center point b' thereof the signal is delayed by one line and at the output point c' the signal is delayed by two lines. Between the input point a' and the center point b' a subtraction stage 1006 is connected. Between the center
5 point b' and the output point c' a subtraction stage 1007 is connected. The outputs of the subtraction stages 1006 and 1007 are applied to respective inputs of a change over switch 1008. The change over switch 1008 is controlled by a switching signal fsw related to the sampling rate and
10 provides at the output d' the extracted chrominance signal. The chrominance signal is provided via amplifier 1012, with an amplification factor of 0.5, to terminal 1009 where it is available as digital chrominance signal separated from the luminance signal. The chrominance signal at point g is
15 also provided to one input of a subtraction stage 1010 whose second input is the combined signal from center point b'. At terminal 1011 there is obtained the difference between the combined signal and the chrominance signal, thus providing the digitized luminance signal separated
20 from the chrominance signal. In addition, in FIGURE 10 at the points a', b', c' the adder stages 1013 and 1014 are connected as shown. The adder stages 1013, 1014 provide respective signals h and k according to the table shown in FIGURE 11.

25 From FIGURE 11 it is evident that for each of the signals at the outputs h and k, during alternate sampling intervals, a pure luminance signal occurs. These signals h, k are supplied respectively to interpolation filters 1015 and 1016. These filters, through division by two of the
30 sampling rate, processes the alternate samples having the pure luminance signal and generate interstitial samples via interpolation. Thereby two additional luminance signals YD, YU are provided respectively responsive to the outputs h and k. Correspondingly the chrominance signals from
35 outputs e' and f are additionally supplied to two interpolation filters 1017, 1018 and are there converted in the same manner into two further chrominance signals CD and CU. It is evident that now three luminance signals,



specifically Y2H, YD, YU and also three chrominance signals C2H, CD, CU are available which differ in their composition from lines $n-1$, n , and $n+1$. This means that these signals are dependent on the vertical components present in the picture which are the difference between signals of successive lines.

It is now determined, as a function of the presence of vertical components, which of the three luminance and chrominance signals available should be used in further signal processing, picture display or recording such that the best separation of luminance and chrominance information is provided. As criterion for the selection, the chrominance signals at the outputs e' , f of the subtraction stages 1006, 1007 are evaluated. These signals are supplied to two subsampler stages 1019, 1020. These subsampler stages effect through a division by two of the sampling rate, an evaluation of the signals only during the sampling intervals according to FIGURE 11, in which their amplitudes e' , f in the absence of vertical components are zero, thus for example with the chrominance signal at the output e' , during the sampling intervals 2 and 4. The amplitudes e' and f are evaluated in the stages 1019, 1020 and through filtering and rectification converted into two voltages with the values A' and B' . In the presence of vertical components the amplitudes A' and B' are not zero but rather increase corresponding to the amplitude of the vertical components. These voltages are supplied to comparator circuit 1021 and there compared with a threshold value S . As a function of this comparison at the output 1022 a setting value originates which effects a selection between the luminance signals and the chrominance signals at the outputs in FIGURE 10 in such a way that, for particular vertical components, an optimal separation takes place. This selection takes place according to the following rule:

Result of case comparison	Output luminance	Output chrominance
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1. $A' < S, B' < S$	Y2H	C2H
2. $A' > S, A' > B'$	YD	CD
3. $B' > S, B' > A$	YU	CU

According to case 1 the amplitudes A' and B' depending on the vertical components lie below the threshold value S . This means that in the signal no significant vertical components are present. Then the signals Y2H and C2H are used. If according to case 2, the amplitude A' lies above the threshold value S and also above the amplitude B' , the signals YD and CD are used. Thus the signal from the output of the stage in which the amplitude A' or B' is large, is analogously switched over to the other stage. If according to case 3 the amplitude B' lies above the threshold value S and above the amplitude A' , the signals YU and CU are correspondingly used. With low vertical components, thus small amplitudes A' and B' , the circuit operates, with the signals CU, CD, YU, YD not being used.

Through the adaptation of the circuit to the vertical components present in each instance, a significantly better signal separation and an improved picture display is achieved.

While the description provided hereby with reference to the circuitry illustrated in FIGURES 2-11, has been primarily in terms of PAL video samples, it will be appreciated by those skilled in the art of video signal processing, that the concepts are equally applicable to NTSC video signals, and the claims should be considered in this light.





CLAIMS

1. Comb filter apparatus comprising:
a signal input terminal (10) for providing an
input video signal; characterized by:
 - 5 first means (24,26) coupled to said signal input
terminal for concurrently providing video signals from
three successive horizontal lines designated top, middle
and bottom;
means (32) including combining means (28)
10 responsive to said video signals from said top, middle and
bottom lines for providing a comb filtered signal
representing said middle line, said comb filtered signal
including said video signal from said middle line
alternately combined at regular intervals less than a line
15 interval, with said video signals from said top, and bottom
lines.
2. The comb filter apparatus set forth in
claim 1 wherein said input video signal includes a
chrominance component having a carrier of frequency f_c
20 modulated with chrominance information and characterized in
that said means including combining means alternately
combines said video signal from said middle lines with said
video signals from said top and bottom lines at a rate
which is a multiple of said frequency f_c .
- 25 3. The comb filter apparatus set forth in claim
2 for comb filtering a video signal including a carrier
signal of frequency f_c quadrature modulated along first and
second axes by first and second chrominance components (I,Q
or UV), said apparatus characterized by:
 - 30 sampling means coupled to said signal input
terminal for sampling said video signal at a rate equal to
a multiple of said carrier signal frequency and at
intervals disposed substantially 45 degrees relative to
said first and second axes, to produce video signal
35 samples;





said first means is coupled to said sampling means for concurrently providing said video signal samples from three successive horizontal lines of said video signal designated top, middle and bottom; and

5 said means including combining means provides a line alternating comb filtered video signal including said video signal samples from said middle line alternatively combined with said video signal samples from said top and bottom lines.

10 4. The comb filter apparatus set forth in Claim 3 characterized in that said means including combining means also provides a sequence of samples representing differences between said video signal samples from said middle line and alternate samples from said top
15 and bottom lines located between said video signal samples contributing to said line alternating comb filtered video signal;

 means coupled to said signal input terminal for generating a substitute video signal;

20 means responsive to said sequence of samples for determining probable occurrences of errors in said line alternating comb filtered video signal and substituting said substitute video signal therefor.

 5. The comb filter apparatus set forth in Claim 3 wherein said video signal conforms to PAL standards
25 and said comb filter apparatus is further characterized by:

 means coupled to said signal input terminal for generating a PAL switch signal having first and second states indicating the relative phase of one of said
30 chrominance components; and

 wherein said means including combining means is responsive to said PAL switch signal for determining which video signal samples from said top and bottom lines are combined with video signal samples from said middle line.





6. The comb filter apparatus set forth in Claim 5 characterized in that said means including combining means also provides a sequence of samples representing differences between said video signal samples from said middle line and alternate samples from said top and bottom lines located between said video signal samples contributing to said line alternating comb filtered video signal;

means coupled to said signal input terminal for generating a substitute video signal;

means responsive to said sequence of samples for determining probable occurrences of errors in said line alternating comb filtered video signal and substituting said substitute video signal therefor.

7. The comb filter apparatus set forth in Claim 5 characterized in that said means including combining means comprises:

first and second subtracter circuits having respective minuend input terminals coupled to receive said video signal samples from said middle line, having respective subtrahend input terminals coupled to receive said video signal samples from said bottom and top lines respectively, and having respective output terminals;

a first multiplexer having first and second input terminals coupled to the output terminals of said first and second subtracter circuits, having a control input terminal and an output terminal for providing said line alternating comb filtered signal;

a second multiplexer having second and first input terminals coupled to the output terminals of said first and second subtracter circuits, having a control input terminal and an output terminal for providing said sequence of samples;

means, coupled for receiving said PAL switch signal, for providing a control signal to the control input terminals of said first and second multiplexers, said control signal having a frequency equal to one half the





sample rate and a relative phase determined by the state of the PAL switch signal.

8. The comb filter apparatus set forth in Claim 4 characterized in that said means for determining probable errors and substituting comprises:

means, coupled for receiving said line alternating comb filtered video signal and said substitute video signal, and responsive to a control signal for proportionally combining said line alternating comb filtered and substitute video signals;

means, coupled for receiving said sequence of samples, for developing a first value representing a vertical transition between lines from which samples for the current comb filtered sample is derived;

means, coupled for receiving said sequence of samples, for developing a second value representing a horizontal transition occurring proximate the sample for which the current comb filtered sample is produced; and

means, coupled for receiving said first and second values, for providing said control signal representing the ratio of one of said first and second values divided by the sum of said first and second values; and

means for coupling said control signal to said means for proportionally combining.

9. The comb filter apparatus set forth in Claim 4 characterized in that the means for determining probable errors and substituting comprises:

means, coupled for receiving said line alternating comb filtered video signal and said substitute video signal, and responsive to a control signal for proportionally combining said comb filtered and substitute video signals;

means, coupled for receiving said sequence of samples, for generating said control signal as a function of the magnitude of samples of said sequence representing





differences between the middle and top lines relative to the magnitude of samples of said sequence representing differences between the middle and bottom lines.

10. The comb filter apparatus set forth in claim
5 2 characterized in that said comb filter further includes means for combining video signal from said middle line with video signal from one of said top and bottom lines to provide a further comb filtered signal representing said middle line, and including means responsive to video signal
10 from said middle line and video signal from said one of said top and bottom lines for selecting one of said comb filtered signal and said further comb filtered signal as an output comb filtered signal.

11. The comb filter apparatus set forth in claim
15 10 characterized in that said comb filter further includes means for combining signal from said middle line and the other of said one of said top and bottom lines to provide a still further comb filtered signal representing said middle line, and means responsive to video signal from said top,
20 middle and bottom lines for selecting one of said comb filtered signal, said further comb filtered signal and said still further comb filtered signal as an output signal.

12. The comb filter apparatus set forth in claim
25 10 characterized by said means for combining video signal from said middle line and said one of said top and bottom lines to provide said further comb filtered signal, provides combined samples of alternately available samples, and includes interpolating means for generating intervening samples.

30 13. The comb filter apparatus set forth in claim 11 characterized by said means responsive to video signal from said top, middle and bottom lines for selecting one of said comb filtered signal, said further comb filtered





signal and said still further comb filtered signal includes:

- 5 first means for providing a first difference signal representing the difference in amplitudes of video signal from said top and middle lines;
- second means for providing a second difference signal representing the difference in amplitudes of video signal from said middle and bottom lines;
- means for providing a threshold value; and
- 10 means for comparing the first and second difference signals and the threshold value, and selecting said comb filtered signal if said first and second difference signals are less than the threshold value, selecting the further comb filtered signal if the first
- 15 difference signal is greater than both the second difference signal and the threshold value, and selecting the still further comb filtered signal if the second difference signal is greater than both the first difference signal and the threshold value.
- 20 14. The comb filter apparatus set forth in claim 1 characterized in that said means for concurrently providing video signals from three successive horizontal lines includes a first sampled data delay line for storing samples at a predetermined rate, and a second sampled data
- 25 delay line having half the storage capacity as said first sampled data delay line and operated at half said predetermined rate, and means for coupling said second sampled data delay line to said first sampled data delay line.

