COMB FILTERING TV SIGNALS

2130840

This invention relates to comb filtering TV signals. An embodiment of the invention concerns frame-to-frame comb filters for separating the luminance (Y) and chrominance (C) components of composite television signals and more particularly to means for correcting signal distortion due to the occurence of motion between successive video frames in such a comb filter system.

Electronic signals which are periodic in nature may be processed advantageously by storing replicas of the signal which are separated in time by the repetition period and then combining the stored replicas to enhance information content of the signal. For example, conventional television broadcast systems (and most video record/playback systems) are arranged so that much of the brightness (luminance) information contained in an image is represented by signal frequencies which are concentrated about integral multiples of the horizontal line scanning frequency. Color (chrominance) information is encoded or inserted in a portion of the luminance signal spectrum around frequencies which lie halfway between the multiples of line scanning frequency (i.e., at odd multiples of one-half the line scanning frequency).

Chrominance and luminance information can be separated and detail information may be enhanced by appropriately combing the composite signal spectrum. Known combing arrangements take advantage of the fact that the odd multiple relationship between chrominance signal components and half the line scanning frequency causes the chrominance signal components for corresponding image areas on successive lines to be 180° out of phase with each other (so-called interlaced frequency components). Luminance signal components for corresponding image areas on successive lines are substantially in phase with each other (and comprise non-interlaced components).

In a comb filter system, one or more replicas of the composite image-representative signal are produced which are time delayed from each other by at least one

line scanning interval (a so-called 1-H delay). The signals from one line are added to signals from a preceding line, resulting in the cancellation of the interlaced frequency components (e.g., chrominance) while reinforcing the non-interlaced frequency components (e.g., luminance). By subtracting the signals for two successive lines (e.g., by inverting the signals for one line and then adding the two), the non-interlaced frequency components are cancelled while the interlaced frequency components are reinforced. Thus, the luminance and chrominance signals may be mutually combed and thereby may be separated advantageously.

The foregoing combing process is possible because of the inherent high level of signal redundancy line-to-line in a typical video scene. If one considers a stationary picture, and a particular pixel of that scene, it will be appreciated that the level of redundancy of the signal representing that pixel on a frame-to-frame basis will be substantially one hundred percent. Thus, if combing were performed on a frame-to-frame basis, the percentage of residual luminance signal in the combed chrominance signal will be significantly reduced over a line-to-line combed signal. Similarly, the percentage of residual chrominance signal in the combed luminance signal will be significantly reduced over a line-to-line combed signal.

More particularly, there will be, for example, no vertical detail accompanying the combed chrominance signal. By design, the chrominance signal of an NTSC composite signal is synchronized to have a 180 degree phase relationship from frame to frame permitting comb filtering on a frame basis. The luminance component may therefore be extracted by linear addition of the composite signal from successive frames and the chrominance component may be extracted by linear subtraction of the composite signal from successive frames.

The response characteristic of a line-to-line comb filter has nulls or teeth spaced at line frequency or

15.734 KHz intervals while the frame-to-frame filter response has teeth at 30 Hz intervals. The closer teeth or null spacing of the frame comb gives rise to a more complete combing process in all spatial directions than the interline comb.

In the frame-to-frame combing process, non-stationary objects give rise to distortions in the reproduced images. These distortions are due to incomplete cancellation of the luminance and chrominance components in the combed chrominance and combed luminance signals respectively (cross components) as well as an effective bandwidth reduction of the luminance signal in the regions of motion. Differences in scene content due to object motion or panning, that occur in the time frame of one-thirtieth of a second or faster are characterized as being visual motion of the scene content.

The motion induced distortions created by the frame-to-frame combing process are two dimensional and are due entirely to interframe scene motion. The distortions are observable in both the horizontal and vertical directions in the plane of the image and are manifested as dual or phantom images in the reproduced scenes. The dual images are separated by an amount corresponding to the rate of motion and may be accompanied by incorrect hue at the edges of the moving objects.

In contrast, interline comb filters create one dimensional distortions which are due to vertical structure within a scene even if stationary. Distortions accompanying the interline combing process appear as an effective lowering of the bandwidth of the signal representing vertical scene structure and a softening of vertical edges of the scene content.

It is an object of the present invention to reduce the objectionable effects produced by motion in an image period-to-image period combing system.

One aspect of the present invention includes a comb filter for processing television (TV) signals including a delay means for delaying the TV signal

by one image period. First means are provided for combining the TV signal and delayed TV signal from the delay means to produce the sum thereof corresponding to a first component from the TV signal. Second means are provided for combining the TV signal and the delayed TV signal from the delay means to produce the difference thereof corresponding to a second component from the TV signal. A linear phase, low-pass filter is provided having an input coupled to the second combining means for receiving the second component of the TV signal. The low-pass filter has an output and substantially rejects the frequency spectrum normally occupied by the second component of the TV signal. Third means are provided coupled to the first combining means and to the output of the low-pass filter for combining the first component and the TV signal with the low-passed filtered signal to correct the first component of signal for errors therein due to inter-image motion.

In accordance with an embodiment of the invention, motion detection means are coupled to the output terminal of the low-pass filter and are responsive to the low-pass filtered signal for detecting the occurrence of inter-frame scene motion. The motion detection means generates a control signal responsive to such motion. Fourth signal combining means are provided having a first input coupled to the second combining means to receive the second component. The fourth signal combining means has a second input and an output . Switching means are coupled to the motion detection means and are responsive to the control signal for selectively coupling the first component to the second input of said fourth signal combining means when inter-frame scene motion is detected.

In accordance with another embodiment of the invention, a linear phase bandpass filter is serially coupled to the output of the fourth signal

combining means. The bandpass filter is designed to pass only the chrominance signal frequency spectrum.

In the Drawings:

FIGURE 1 is a block diagram of a frame-to-frame comb filter known in the art of TV signal processing;

FIGURES 2a-d are amplitude versus time waveforms associated with the FIGURE 1 circuit, while FIGURE 2e is a waveform resulting from a modification of the FIGURE 1 circuit;

FIGURE 3a, is a block diagram of a illustrative frame-to-frame comb filter embodying the present invention and Figures 3b and 3c illustrate optional modifications of it. Referring to FIGURE 1, there is shown a frame-to-frame comb filter known in the prior art. For purposes of illustration, the apparatus will be described in terms of separating luminance and chrominance signals from a composite TV signal. However, the apparatus is not limited to this particular application. For example, the apparatus of FIGURE 1 may be used to comb filter luminance signal for insertion of chrominance signal therein in the formation of a composite video signal.

In FIGURE 1, a storage element 10 has the capacity to store the electrical manifestation of one frame (e.g., two fields of NTSC video format) of video signal. Storage element 10 sequentially accepts input signal at input terminal 11 and outputs the same signal onto output terminal 14 delayed by the duration of one frame period. The element 10 may comprise a digital memory, e.g., a random access memory (RAM) with the appropriate support electronics or an analog memory, e.g., a serial charge transfer device (CTD) such as a charge coupled device (CCD) with its necessary supporting circuitry. Conceptually it does not matter whether element 10 is a digital or analog circuit, however, it will be assumed that it is digital in nature. The remaining circuit elements incorporated therewith will therefore be considered to be digital in nature to avoid

digital-to-analog signal conversion between the circuit elements.

Input signal from connection 11 and delayed signal from connection 14 are summed together in the ADDER circuit 12. The luminance components of signal, being in phase, add while the chrominance components, being 180 degrees out of, phase cancel to produce a substantially chrominance free luminance signal Y at connection 15. Input signal and delayed signal are also applied to the SUBTRACTOR circuit 13 wherein the chrominance components of the two frames sum constructively while the luminance components cancel to produce a substantially luminance free chrominance signal on connection 16 (at least when successive frame signals are records of the same stationary scene).

Referring to FIGURE 2, the effects of motion on the aforedescribed frame-to-frame combing process is graphically illustrated. FIGURE 2a represents a portion of the composite signal applied to terminal 11 at an arbitrary time interval. FIGURE 2b represents the composite video signal from the same scene exactly one frame period later in time and wherein some motion has occurred in the scene. In waveform 2a, assume that the signal component between times T1 and T3 represents an object having luminance and chrominance signal parameters L2 and C2 respectively. The object is assumed to be located in an area of uniform scene content having luminance and chrominance signal parameters L1 and C1 respectively.

Between frames, the object moves spatially causing the video signal representation of the object to translate in time, i.e., to fall between times T2 and T4 in FIGURE 2b. The relative signal parameters L and C of the luminance and chrominance components of the signal remain the same between the FIGURE 2a and 2b waveforms though there exists a time shift with respect to the object represented by L2, C2. The chrominance component of the signal, however, has a 180 degree phase

relationship between waveforms 2a and 2b (i.e., between frames).

The sum and difference of the FIGURE 2a and 2b waveforms are represented by the waveforms 2c and 2d respectively. It is seen that for those segments of time in which the absolute value of the chrominance vector component between the 2a and 2b waveforms is the same, substantially complete cancellation of the chrominance component results from summing the two waveforms (FIGURE 2c). Similarly, where the amplitude of the luminance component of the signal is the same between the two waveforms (2a and 2b) substantially complete cancellation of the luminance component results from a subtraction of the two waveforms (FIGURE 2d). FIGURES 2a, 2b, 2c and 2d are representative of signals occurring respectively at connections 11, 14, 15 and 16 of the FIGURE 1 circuit.

Over the period where motion occurs between frames, i.e., between times T1 and T2 and times T3 and T4, unequal signals are being differentially summed, and incomplete cancellation of the undesired component occurs.

In addition, motion distorts the desired signal. The motion causes an averaging of the signal over the periods where motion occurs. These averages are represented in FIGURE 2c by the signal segments denoted (L1+L2) which is equivalent to (2L1+2L2)/2. Normally the signal from the two frames will be weighted by a factor of ½ before being combined. The amplitude of the combed signal will be ½ the values shown and the signal during the motion period will be (L1+L2)/2. The averages (L1+L2) in the luminance signal tend to replicate the signal transitions to produce a double or phantom image which surrounds the moving object. The averages (C1+C2) in the combed chrominance signal during periods of interframe motion tends to distort the hue around the moving object.

If a low-pass filter is provided at connection 16 of FIGURE 1, the combed chrominance signal of FIGURE 2d produces the signal shown in FIGURE 2e. In FIGURE 2e, the chrominance signal spectrum has been removed, leaving only

the uncancelled luminance component resulting from the interframe motion. If the signal of FIGURE 2e is added or subtracted to the signal of FIGURE 2c, the edges of the luminance signal will be restored, producing a luminance component equivalent to one which has not been combed. Addition of the FIGURE 2e signal will restore the luminance signal of FIGURE 2c between the times T1 to T2 to the level of 2L2 and reduce the luminance signal between times T3 and T4 to the value of 2L1 as indicated by the broken lines.

The circuitry shown in FIGURE 3a is a frame-to-frame comb filter arranged in accordance with the principles of the present invention with facility for correcting distortions such as double images or smearing due to motion between successive frames. In FIGURE 3, elements designated with the same numerals as elements in FIGURE 1 perform identical functions. Thus, at the connections 15 and 16 of the FIGURE 3a circuit, combed luminance and combed chrominance signals are respectively produced, which signals contain cross components as well as imperfectly combed signal components due to interframe motion.

The combed chrominance signal at connection 16 is applied to a linear phase low pass filter 27 to remove the chrominance signal spectrum leaving the uncancelled low frequency luminance components. The low pass filtered signal from filter 27 is added back, in ADDER circuit 31, to the combed luminance signal from connection 15 to produce corrected luminance Y_c at connection 32. Thus, the corrected luminance signal is developed at the connection 32 in accordance with the principles of the present invention. The residual uncancelled chrominance component in the combed luminance signal from connection 15 tends only to create a second order distortion which is not observable except on close inspection of the displayed image.

The low pass filter 27 must be linear phase in order to reinsert properly the motion detail into the

combed luminance signal. Transient response will be adversely affected if the motion detail is not properly reinserted, due to phase differentials between the motion affected segments of the combed luminance signal and the motion detail extracted from the combed chrominance signal.

The residual chrominance (C2-C1, C1-C2) in the luminance channel, due to interframe motion, does not produce significant distortions in the reproduced image. However, the averaged or transitional chrominance signal (C1+C2) in the combed chrominance signal component, occurring during motion periods, may produce objectionable color distortions. The chrominance signal is a vector quantity. Thus, the vector sum C2+C1 during motion periods may produce colors completely different from those represented by either of the signals C1 or C2. To retain color purity at the edges of moving objects, it is often desirable that the chrominance component be corrected for motion induced errors generated in the comb filtering process.

The information necessary for correcting the combed chrominance signal resides in the combed luminance signal. This information may be reinserted in a manner similar to the method for restoring the motion detail to the combed luminance signal. However, the chrominance restoration should not be a continuous process, but should only be performed during motion sequences. The reason for this is the relatively large energy density of the luminance signal compared to the cross components of the chrominance signal. Continuous addition of the combed luminance signal to the combed chrominance signal would effectively defeat the combing process. However, the addition of the combed luminance signal to the combed chrominance signal during periods of motion produces a preferable signal to no chrominance reinsertion.

It is normally necessary to bandpass filter the combed chrominance signal to eliminate the residual luminance signal, i.e., luminance motion detail, the

combed luminance component added to the combed chrominance is substantially eliminated from the corrected chrominance signal. Only the luminance components residing in the spectral band of the chrominance signal remain in the corrected chrominance signal and the energy of the luminance signal in this band is relatively low.

The luminance signal is comprised of constituents of the chrominance signal, i.e., red, blue and green signals, and therefore the amplitude of the luminance signal is indicative of the amplitude of the chrominance signal. The occurrence of signal in excess of a predetermined value emanating from low pass filter 27 indicates the occurrence of motion and the amplitude of this signal is indicative of the amplitude of the chrominance errors. Chrominance signal errors large enough to cause objectionable distortions in the reproduced image can therefore be detected by measuring the amplitude of the luminance signal passed by the low pass filter 27.

In FIGURE 3a a motion detector 28 coupled to the output connection of low pass filter 27 compares the low pass filtered combed chrominance signal against a threshold value. The threshold value is set at a level corresponding to a signal level which has been established to cause objectionable chrominance distortions. When the low pass filtered signal from filter 27 exceeds the threshold value, the motion detector 28 generates a control signal which closes the switch 29.

FIGURES 3b and 3c are illustrative examples of analog signal and digital signal motion detectors respectively. The analog version 28' comprises a high gain differential amplifier 40 and a source of reference potential 41. Signal from filter 27 is applied to a non-inverting input terminal 42 of amplifier 40 and signal from reference source 41 is applied to the inverting terminal of amplifier 40. When the potential at terminal 42 exceeds the reference, the output signal from amplifier 40 goes high, otherwise it remains low. Coupled

to the output terminal of amplifier 40 is an N-type field-effect transistor 29' which may be used as the switch 29 of FIGURE 3a. A high potential applied to the gate (G) of the transistor closes the switch and a low potential opens the switch.

In FIGURE 3c, the digital version 28" of the motion detector comprises a binary reference source 45, a subtraction circuit 43 (comparator), a sign detector 44 and an AND circuit switch 29". (In the drawing double line interconnections indicate parallel bit lines.) Subtractor 43 subtracts the reference number (45) from binary signal at the output 42 of filter 27. The difference value is examined by a sign circuit 44 to determine if it is positive or negative. If the difference is positive, the SGN circuit produces a positive output pulse which enables AND circuit 29" to pass the signal on its data lines. Note, if the subtractor performs twos complement arithmetic, the sign circuit may be eliminated and replaced with an inverter circuit directly connected between the most significant bit, i.e., the sign bit, of the subtractor output connections and the AND circuit.

The FIGURE 3b and 3c circuits as shown are only responsive to input signals of one polarity, however, it is well-known in the circuit arts to parallel two such circuits to be responsive to both polarity signals. Alternatively, the comparator may be of the "window comparator" type.

Switch 29 selectively couples the combed luminance signal from connection 15 to one input of ADDER circuit 30. A second input of ADDER circuit 30 is directly coupled to receive the combed chrominance signal from connection 16. When motion detail exceeding the threshold value is detected, switch 29 is closed and the combed chrominance and luminance components are added in the ADDER circuit 30. When no motion detail is detected, switch 29 remains open and the combed chrominance signal

from connection 16 is passed unaltered by the ADDER circuit.

The output signal from ADDER circuit 30 is coupled to a linear phase bandpass filter 34 which passes only the chrominance signal frequency spectrum at its output terminal 35.

Circuit elements 31 and 30 may be either ADDER or SUBTRACTOR circuits as indicated by the (±) signs at their input terminals in FIGURE 3a. However, they must both be the same type circuit, that is, both ADDERS or both SUBTRACTORS. Whether they are ADDERS or SUBTRACTORS determines whether the leading trailing motion distorted signal segments are restored or cancelled respectively.

CLAIMS:

1. A comb filter for processing television (TV) signals including:

a delay means for delaying said TV signal by one image period;

first means for combining said TV signal and delayed TV signal from said delay means to produce the sum thereof corresponding to a first component from said TV signal;

second means for combining said TV signal and delayed TV signal from said delay means to produce the difference thereof corresponding to a second component from said TV signal;

a linear phase low pass filter having an input coupled to said second combining means for receiving said second component of the TV signal, and having an output said low pass filter substantially rejecting the frequency spectrum normally occupied by said second component; and

third means coupled to said first combining means and to said output of said low-pass filter for combining the first component of signal with the low pass filtered signal to correct the first component of signal for errors therein due to inter-image motion.

2. A comb filter as claimed in Claim 1, further comprising

motion detection means coupled to said output of said low-pass filter and responsive to said low-pass filtered signal, for detecting the occurrence of inter-frame scene motion and generating a control signal responsive to such motion;

fourth signal combining means having a first input coupled to said second combining means to receive said second component, said fourth

signal combining means having a second input and an output and

switching means coupled to said motion detection means and responsive to said control signal for selectively coupling said first component to said second input of said fourth signal combining means when inter-frame scene motion is detected.

3. A comb filter set forth in Claim 2, wherein said TV signal is a composite signal including chrominance and luminance constituents, said first component corresponding to the luminance signal, said second component corresponding to the chrominance signal and said delay means comprises a memory device for storing at least one frame of video signal.

4. A comb filter as claimed in Claim 3, futher comprising a linear phase bandpass filter serially coupled to said output of said fourth signal combining means, said bandpass filter being designed to pass only the chrominance signal frequency spectrum.

5. A comb filter as claimed in Claim 2, wherein said motion detection means includes:

said low-pass filter ,

a reference , and

comparison means for comparing signal passed by said low-pass filter against said reference and generating said control signal whenever the low-pass filtered signal differs from said reference by a predetermined amount.

6. A comb filter as claimed in Claim 2, wherein said third combining means and/or said fourth combining means is a signal adding circuit.

7. The comb filter set forth in Claim 2, wherein said third combining means and/or said fourth combining means is a signal subtracting circuit.

8. A method of comb filtering TV signals to separate chrominance and luminance components, comprising steps of:

delaying the TV signal by the duration of one frame of information;

subtractively combining delayed and non-delayed TV signal to produce a comb filtered chrominance component;

additively combining delayed and non-delayed TV signal to produce a comb filtered luminance signal;

low-pass filtering said combed chrominance component with a linear phase filter to substantially eliminate the chrominance signal therefrom; and

combining said low-pass filtered combed chrominance signal with said combed luminance signal during periods of inter-frame motion to produce a combed luminance signal substantially free of distortion due to inter-frame scene motion.

9. A method as claimed in Claim 8, further comprising the steps of

detecting the occurrence of inter-frame scene motion;

generating a control signal responsive to such motion, and

combining said comb filtered chrominance signal with said comb filtered luminance signal in response to said control signal.

10. A method as claimed in Claim 9, further comprising the steps of

bandpass filtering said combined comb filtered chrominance and comb filtered luminance signals to pass only the chrominance spectrum.

11. A comb filter substantially as hereinbefore described with reference to Figure 3a optionally as modified by Figure 3b or 3c.

12. A method of comb filtering substantially as hereinbefore described with reference to Figure 3a optionally as varied by Figure 3b or 3c.