

VIDEO SIGNAL NOISE REDUCTION APPARATUS 2181322

This invention relates to recursive filter circuitry for enhancing the signal-to-noise ratio of video signals.

5 It is well known in the video signal processing arts that the signal-to-noise ratio of video signals can be enhanced by recursive filtering. Recursive filtering is the process of integrating a portion of current video signal with a complementary portion of video signals from
10 previous frames or fields of video signals. A typical recursive filter includes a storage element for delaying substantially one field/frame of video signals, a subtracter, a scaler and an adder. Current video signal, and delayed video signal from the storage element are
15 applied to respective input ports of the subtracter. The differences output by the subtracter are coupled to the scaler which weights the differences by a coefficient, the value of which is dependent on interscene content. The weighted differences and delayed video signal from the
20 storage element are combined in the adder to produce noise reduced video signal which is applied to the input port of the storage element.

 Recursive filtering may be performed on component video signals or on composite video signals. If
25 the process is performed on component video signals, i.e., on luminance signal and chrominance signals separately, using known recursive filters significantly more storage circuitry is required than if the process is performed on composite video signals. On the other hand, if the
30 process is performed on composite video signals, the phase of the chrominance signal of either the current or delayed composite signal must be inverted before the current and delayed signals are combined. In this latter mode a single scaling circuit is employed to weight the composite
35 signal differences resulting in like integration of the luminance and chrominance components of the composite signal.

P.C. Michael et al. in U.S. Patent 4,240,106 recognized that it is advantageous to recursively process luminance and chrominance components with different weighting factors because viewer sensitivity to noise differs for the noise in different bands of the video signal frequency spectrum.

It is an object of the present invention to provide a recursive filter which separately processes the luminance and chrominance components of composite video but which requires a storage element no larger than storage elements required for recursively filtering composite video signals.

In the present invention component video signals, derived for instance from a first signal separator supplied with a composite video signal, are provided to respective first input terminals of a plurality of scaling/combining circuits having also

respective second input terminals. Summing circuitry is coupled to the outputs of said scaling/combining circuits to produce a combined video signal. A delay element is coupled to said summing circuitry for delaying the combined signal by at least substantially one field interval. And a second signal separator has its input coupled to the output of said delay element and having first and second output terminals respectively coupled to the second input terminals of the scaling/combining circuits.

In the accompanying drawings

FIGURE 1 is a block diagram of a recursive filter embodying the present invention.

FIGURES 2 and 3 are block diagrams of alternative Y/C separation circuits which may be implemented in the FIGURE 1 circuitry.

FIGURE 4 is a block diagram of an alternate embodiment of the FIGURE 1 recursive filter.

In the various figures, elements designated with the same numbers correspond to identical or functionally similar circuits. The invention may be practiced on either analog signals or digital representations of analog signals with the appropriate choice of circuit elements. As such, the invention will be described in terms of general functional circuit elements.

Referring to FIGURE 1, composite video signal to be processed for noise reduction/signal-to-noise enhancement is applied to terminal 10. The composite signal is coupled to a chroma/luma separator 12 which produces chrominance component signals, C, and luminance component signals, Y. The chrominance and luminance component signals are coupled to scaling/combining circuits 13 and 19 respectively. Delayed chrominance and luminance component signals C_D , Y_D (from chroma/luma separator 32) are coupled to second input connections of scaling/combining circuits 13 and 19 respectively. The scaling/combining circuits 13 and 19 effectively combine the delayed and non-delayed component signals in predetermined proportions to produce noise reduced component signals C_{out} and Y_{out} . The noise reduced signals are applied to an adder circuit 28 which produces noise-reduced composite signals that are applied to the input connection of a delay element 30. Delay element 30 delays the composite signal applied to its input connection by an interval corresponding to substantially a field period or an integral number of field periods. Delayed composite signal from delay element 30 is coupled to the chroma/luma separator 32 which produces the delayed chrominance and luminance component signals C_D , Y_D .

If FIGURE 1 is configured as a frame recursive filter the signal delay provided by delay element 30 is designed so that the delayed and non-delayed component signals applied to adder 14 and subtracter 20 correspond to the same picture elements (pixels) in succeeding video frames. In addition, the respective delayed component

signals and scaled signals from scaling circuits 16 and 24 applied to subtracter 18 and adder 26 correspond to like pixels from succeeding video frames. In order to satisfy both conditions, compensating delay elements may be required to be inserted between the chroma/luma separator 32 and subtracter 18 and adder 26 respectively. One skilled in the art of signal processing will readily recognize these requirements and know to provide such timing compensation.

If the FIGURE 1 circuit is configured as a field recursive filter, delay element 30 will be designed such that the delayed and non-delayed signals correspond to substantially like pixels from succeeding fields. Exemplary circuitry for performing composite signal field recursive filtering is described in detail in U.S. Patent Application Serial No. 793,734, filed November 1, 1985 and entitled "Apparatus For Noise Reducing Composite Video Signal". (See also UK application 8615923.)

The scaling/combining circuits 13 and 19 are exemplary of numerous circuits which may be implemented to perform the recursion algorithm. Briefly, the circuitry 19 functions as follows. Delayed luminance Y_D is subtracted from incoming luminance Y in subtracter 20. The luminance differences are applied to the scaling circuit 24 which weights the differences by a weighting coefficient K_Y . Delayed luminance Y_D is then added to the weighted luminance differences in adder 26 to produce noise reduced output luminance Y_O . The output luminance Y_O is described by the equation:

$$Y_O = K_Y Y + (1 - K_Y) Y_D. \quad (1)$$

The value of Y_D is equal to the value Y_O produced one frame interval earlier and can be described in Z transform notation

$$Y_D = Y_O Z^{-1} = (K_Y Y + (1 - K_Y) Y_D) Z^{-1}. \quad (2)$$

Expanding equation (1) by successively substituting Y_D from equation (2) in equation (1)

$$Y_O = K_Y Y + K_Y Y (1 - K_Y) Z^{-1} + K_Y Y (1 - K_Y)^2 Z^{-2} + K_Y Y (1 - K_Y)^3 Z^{-3} + \dots \quad (3)$$

If there is no interframe image motion, equation (3) converges to

$$Y_O = K_Y(1/(1-(1-K_Y))) = Y. \quad (4)$$

Thus, the output luminance signal equals the input luminance signal.

Noise components occurring in the luminance signal, however, do not add linearly but rather sum according to the squares of the RMS noise value. It can be shown that the RMS noise output N_O attendant the luminance output is reduced by the factor $\sqrt{K_Y/(2-K_Y)}$, i.e.,

$$N_O = N_{RMS} \sqrt{K_Y/(2-K_Y)}. \quad (5)$$

The scaling/combining circuit 13 is similar to circuit 19 except that the adder and subtracter are interchanged. The interchange accounts for the 180° phase change of the chrominance component from frame-to-frame. With the 180° chrominance phase difference the adder 14 functions as a subtracter and the subtracter functions as an adder.

Typically it is not desirable to recurse the signals when interframe image motion occurs. Therefore motion detectors are included in the recursion circuitry to vary the weighting coefficients when motion occurs. In FIGURE 1 a single motion detector, 22, responsive to the interframe luminance difference signal from subtracter 20, generates the weighting coefficients K_C and K_Y for both the chrominance and luminance scaling circuits

respectively. In an alternative embodiment, separate motion detection - scale factor generating circuitry may be provided for the separate signals. This is indicated by the motion detector 15 drawn in phantom. Exemplary motion detectors may be found in U.S. Patent 4,275,418.

Circuitry for separating the luminance and chrominance components from composite video is illustrated in FIGURES 2 and 3. The FIGURE 2 circuitry is preferred when the luminance component may not occupy the entire standard luminance bandwidth such as occurs in the recovered composite signal from many VTR's. The FIGURE 3 circuitry will provide full band luminance but requires more total circuitry.

In FIGURE 2, composite video is applied to a filter 40 which attenuates signals in the band of frequencies normally occupied by the chrominance component and produces luminance signals, Y, occurring in the band of frequencies below the chrominance band. The composite video signals are also coupled to one input of a subtracter 44, through a delay element 42 which compensates for the group delay of filter 40. The filtered luminance signals are coupled to a second input of subtracter 44 wherein the luminance component is subtracted from composite video signal to produce the chrominance component C.

The FIGURE 3 chroma/luma separator 12" is a line comb filter. In FIGURE 3 composite video signal is coupled to the input of a one horizontal line delay element 46, and respective inputs of adder 48 and subtracter 50. Delayed composite video signal from delay element 46 is coupled to respective second input terminals of adder 48 and subtracter 50. In adder 48, in-phase signal components, i.e. luminance, sum constructively, and antiphase components, i.e. chrominance, cancel to produce the luminance signal Y. In subtracter 50 in-phase signal components cancel and antiphase components sum constructively to produce the chrominance component C. It will be appreciated that either the signals applied to the adder 48 and subtracter 50 or the signals from the adder 48 and subtracter 50 will be halved to normalize the Y and C signals.

FIGURE 4 illustrates another embodiment of a composite signal recursive filter. The FIGURE 4 circuit is similar to the FIGURE 1 circuit, except for the scaling/combining circuitry. The scaling/combining circuitry 13' and 19' performs a similar algorithm to the circuitry 13 and 19 of FIGURE 1. In FIGURE 4, luminance signal from chroma/luma separator 12 is coupled to the scaling circuit 60 wherein it is weighted by the luminance scaling coefficient K_Y . Delayed luminance signal from the chroma/luma separator 32 is applied to the scaling circuit

62 wherein it is weighted by the factor $(1-K_Y)$. The scaled luminance and the delayed and scaled luminance signals from scaling circuits 60 and 62 are coupled to respective input terminals of adder 58, which produces the noise reduced luminance signal. The luminance signal, Y_O , produced by adder 58 is described by the equation:

$$Y_O = K_Y Y + (1-K_Y) Y_D \quad (6)$$

which is identical to equation (1).

The chrominance scaling/combining circuitry 13' is similar to the luminance scaling/combining circuitry 19' with the exception that the delayed chrominance is weighted by a negative factor $-(1-K_C)$, where K_C is the chrominance weighting coefficient. A negative weighting factor $-(1-K_C)$ is used here to account for the antiphase relationship between current and delayed chrominance signals. The weighting factors K_Y , $(1-K_Y)$, K_C and $-(1-K_C)$ may be constants or they may be variable in response to image motion detection as in the FIGURE 1 embodiment.

The invention may also be practiced in, for example, a color video camera system which develops composite video signals. In this instance, the current luminance and chrominance components are available as separate signals, and the chroma/luma separator 12 is not required. The separate chrominance and luminance signals from the camera processing circuitry are applied directly to the scaling/combining circuits 13 and 19 respectively. Composite video signal produced by the camera is formed in adder 28.



CLAIMS:

1. Recursive filter apparatus for enhancing the signal-to-noise ratio of a video signal comprising:

5 a plurality of scaling/combining circuits, having respective first input terminals and respective second input terminals, each for combining signals applied to its said first and second input terminals in predetermined ratios;

10 input means for applying, to the respective first input terminals of said scaling/combining circuits, signals occupying substantially exclusive portions of the frequency spectrum of said video signal;

15 means coupled to said plurality of scaling/combining circuits for summing signals produced thereby to produce a combined recursively filtered video signal;

20 a delay element coupled to said means for summing, for delaying said combined video signal by at least substantially one field interval;

25 filter means, having an input coupled to said delay element and having a plurality of output terminals for providing at respective ones of said plurality of output terminals, signals occupying substantially exclusive portions of the frequency spectrum of delayed combined video signal, the frequency bands occupied by respective ones of the signals provided by said filter means substantially corresponding to frequency bands of the respective signals applied to the first input terminals of said scaling/combining circuits; and

30 respective means for coupling the output terminals of said filter means to the respective second input terminals of said scaling/combining circuits with the signals applied to the first and second input terminals of each scaling/combining circuit occupying substantially similar frequency bands.



2. Apparatus according to Claim 1 for recursive filtering of a composite video signal wherein:

5 said input means comprises a second filter means providing separated luminance and chrominance signals from said composite signal to the first input terminals of a first and a second of the scaling/combining circuits;

10 and said first filter means is a chroma/luma separator coupled to an output terminal of said delay element and itself having first and second output terminals respectively coupled to the second input terminals of said first and second scaling/combining means, said first scaling/combining means receiving
15 chrominance signals from said second filter means and said chroma/luma separator, and said second scaling/combining means receiving luminance signals from said second filter means and said chroma/luma separator.

20 3. Apparatus according to Claim 2 wherein said second filter means comprises:

25 a further chroma/luma separator having an input terminal coupled to a source of composite video signals and having first and second output terminals at which to provide said separated chrominance and luminance signals respectively.

30 4. The apparatus set forth in Claim 2 or 3 wherein each of said first and second scaling/combining means combines signals applied to its input terminals in predetermined proportions.

35 5. Recursive filtering apparatus substantially as hereinbefore described with reference to Fig.1 or Fig.4 of the accompanying drawings.
