

VIDEO SIGNAL EQUALIZER

This invention concerns apparatus for equalizing a video signal to compensate for irregularities in signal parameters caused by transmission channel characteristics.

The transmission of an image representative signal such as a television signal through a transmission channel may subject the signal to a variety of disturbances which may alter desired parameters of the signal. In particular, transmission channel characteristics may cause the frequency and phase parameters of the signal to deviate from a desired "flat" characteristic. This result may be produced by both terrestrial broadcast and cable channels, for example.

To compensate for such deviations, i.e., to re-acquire a desired flat frequency and phase response of the signal, a signal equalizer may be used at a receiver. The use of such an equalizer is particularly important with the advent of high definition television systems. In digital systems multiple-tap FIR filters are employed by the equalizer apparatus. For removing signal distortions an equalizer may compare a test signal, which is incorporated in the received signal, with a programmed ideal or desired version of the test signal to configure a filter at the receiver so as to remove or compensate for the irregularities in the received television signal. The test signal may be in the form of a pseudorandom number (PRN) sequence as described, for example, in U.S. patent 5,065,242 - Dieterich in the context of deghosting apparatus for a television receiver.

It is herein recognized that an accurate determination of the received signal's average or DC level is important for fast Fourier transform (FFT) ratio equalization. Failure to properly determine the DC level can lead to improperly set DC gain, which can produce what appear to be image "smudges" in a displayed image. Illustratively, this effect will cause a display of a person situated against a flat field background to be surrounded by a "glow" or "shadow". Depending upon equalizer design, this effect



can be centered on the displayed image or offset to one side, and is basically due to a very low frequency signal component produced by an offset in all tap values of the equalizer filter resulting from mis-measured DC characteristics.

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Equalizer apparatus according to the principles of the present invention exhibits improved low frequency operating characteristics. In an illustrated preferred embodiment, this is accomplished by separately calculating the DC response of the
10 signal to be equalized using a non-transform technique, independent of a transform (e.g., a fast Fourier transform) of the signal to be equalized.

In an illustrated embodiment of the invention, a television signal to be equalized to compensate for transmission
15 channel frequency and phase irregularities includes a test signal. In a given embodiment, the test signal is a pseudorandom number (PRN) sequence disposed in a predetermined line of the vertical blanking interval. A sample of 256 points in the PRN test signal sequence is taken. A difference signal is generated, representing
20 the difference between the average (DC) value of the test signal sample and a DC reference component of the television signal (e.g., the horizontal back porch DC level). The test signal sample is frequency transformed by a 256 point FFT unit. A DC frequency sample output of the FFT unit is not used. The remaining 255
25 frequency samples from the FFT output are applied to a frequency ratio unit, another input of which receives the difference signal. This unit develops a value representing a desired-to-actual ratio with respect to the difference signal, and values representing desired-to-actual ratios for each of the remaining 255 FFT
30 frequency samples. The 256 ratio values are inverse FFT transformed to the time domain, and the central 128 transformed values are applied to control taps of a 128 tap FIR filter to determine the operation of the filter for equalizing the television
35 signal.

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Brief Description of the Drawing

FIGURE 1 is a block diagram of a portion of a television receiver including equalizer apparatus according to the present invention.

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FIGURE 2 is a waveform depicting a test signal, comprising a pseudorandom number sequence, incorporated in a television signal to be equalized.

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FIGURES 3 and 4 are block diagrams of alternative equalizer arrangements according to the principles of the present invention.

Detailed Description

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In FIGURE 1 an analog television signal conveyed over a broadcast transmission channel is received by an antenna 10 and is processed initially by an input signal processor 12.

Processor 12 contains conventional circuits including a tuner, radio frequency processor, mixer, intermediate frequency

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processor and demodulator to produce a baseband video signal.

The baseband video signal is converted to digital form by an analog-to-digital converter 14. The digital video signal is applied to inputs of a signal sample selector 16, an average value difference determining network 20, and a signal input of a 128

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tap FIR filter 30.

Unit 16 selects 256 samples of a PRN test signal included in the received television signal. The test signal is disposed in a predetermined line in the vertical blanking interval and comprises, for example, a three repetition PRN sequence.

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Such a test signal is described in detail in U.S. patent 5,065,242, and is illustrated generally in FIGURE 2. The test signal shown in

FIGURE 2 includes a sequence of three pseudorandom number sequences during the active portion of a horizontal line in the

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vertical blanking interval, between successive horizontal blanking "back porch" intervals B1 and B2 and associated sync pulses P1 and P2.

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In this example unit 16, e.g., including a serial input RAM, selects 256 samples S from the central portion of the PRN sequence, i.e., associated with the middle PRN sequence. Other sampling arrangements for sampling additional and/or other sequence portions are also possible. The output 256 samples from selector 16 are applied to a second input of difference unit 20, and to a 256 point Fast Fourier Transform (FFT) unit 18 for converting the sampled information from the time domain to the frequency domain. Difference unit 20 determines the difference between the average value (i.e., the DC value) of the 256 samples from unit 16, and the average value of the input signal from unit 14 during the horizontal blanking intervals. In this example the average value during the horizontal blanking intervals is obtained by averaging the values appearing during horizontal blanking intervals B1 and B2 (e.g., 32 samples each). Using the average of both back porch values improves DC measurement accuracy and immunity from "tilt" due to RF and IF gain changes. A DC difference representative signal DC DIFF is produced at the output of unit 20. Difference unit 20 may include an accumulator with feedback for accumulating values over the desired sampling intervals.

FFT unit 18 develops the Fast Fourier Transform, $F(\omega)$, of the 256 sample PRN test signal. In so doing it produces a plurality of 256 transform coefficients and stores them in a buffer memory. In general these coefficients represent the frequency content of the transformed signal. One of the coefficients represents a DC value of the transformed signal, however this coefficient will not be utilized. Rather, the DC DIFF difference developed by unit 20 is substituted for this coefficient. The remaining 255 coefficients developed by unit 18 and the DC DIFF difference representative signal from unit 20 (which is not FFT transformed) are applied to unit 24.

Unit 24 performs the function $X(\omega)/F(\omega)$, where $X(\omega)$ is the Fast Fourier Transform of an undistorted replica of the PRN test signal. The DC coefficient of the function $X(\omega)$ is selected to correspond to the value DC DIFF for an undistorted signal. The



ratio $X(\omega)/F(\omega)=G(\omega)$ corresponds to the required frequency response of a filter for equalizing the received signal. The inverse FFT of the function $G(\omega)$ is a function $g(t)$, which represents the time domain response of the desired equalizing filter. The reader is directed to "A Tutorial On Ghost Cancelling In Television Systems" by W. Ciciora et.al., published in the IEEE Transactions on Consumer Electronics, Vol. CE-25, February 1979, pages 9-44, for details of the theory of frequency domain processing for determining the characteristics of equalizing (deghosting) filters.

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The function $G(\omega)$ includes 256 coefficients which are applied to an inverse FFT unit 28. Unit 28 develops the function $g(t)$ comprising 256 coefficients. These coefficients correspond to the tap weights of a 256 tap equalizing transversal filter 30 which will correct for transmission channel distortions. Nominally the function $g(t)$ is recurrently calculated in respective signal receivers and the coefficients are used in a known manner to program/update an adaptive equalizing filter 30 of the Finite Impulse Response (FIR) type. If the equalizing filter is to be used for correcting only close-in ghosts for example, the filter may be shortened and realized by using a subset of the coefficients as tap weights. For example to realize a symmetric filter response one may select 128 of the tap values symmetrically about the coefficient representing the DC term and appropriately normalizing or adjusting the selected coefficients to compensate for the amplitude contributions to the filter response of the coefficients that are not utilized.

With the operating characteristics of filter 30 being tailored in response to the signals from unit 28, a frequency and phase equalized video signal appears at the output of filter 30. The equalized video signal may be stored, recorded or displayed. In the illustrative arrangement shown, the video signal is processed by conventional circuits in a video processor 32, e.g., including brightness, contrast and peaking control networks. Finally, the processed video signal is applied to a display stage 36 including an image display device.



FIGURE 3 shows an alternative equalizer arrangement. This arrangement addresses the situation where the test signal is inverted on alternate fields, whereby the mutually inverted test signals can be subtracted from each other (differenced) to improve the accuracy of the 256 selected samples. The DC measurement is not obtained from the differenced signal. Instead, it is obtained as the average of the DC differences computed on each of the signal lines.

10 In FIGURE 3, DC difference representative signal DC DIFF, developed as discussed in connection with FIGURE 1, is applied to a field averager 50. Unit 50 averages signal DC DIFF over the two successive fields over which the test signal inverts. A unit 52, which receives an input signal from unit 16 (FIGURE 1),
15 determines the difference between the value of the test signal during one field, and the value of the inverted test signal during the next field. Since the test signal is inverted in successive fields the test signals add constructively in the differencing operation while the DC level is cancelled. The 256 sample difference
20 representative output of unit 52 is transformed by the 256 point FFT unit 18, the output of which is applied to frequency ratioing unit 24 together with the output signal from unit 50. Subsequent signal processing occurs as in FIGURE 1.

25 The arrangement of FIGURE 4 addresses the fact that, because the test signal sequences are of opposite polarities on successive fields, the DC value can be obtained by adding successive field PRN sequences together. The PRN sequences cancel except for a residue representing a DC error. A sinusoidal
30 type test signal could also be used.

In FIGURE 4 a field summer 60 which adds the test signal from successive fields is added between units 14 and 20. Unit 52 is as shown in FIGURE 3. In FIGURE 4 signal DC DIFF is
35 applied directly to unit 24 together with the output of FFT unit 18. Signal processing otherwise is as in FIGURE 1.



The described equalizer system can operate with other types of test signals (e.g. any waveform with a known DC level) with different waveforms (e.g. sinusoidal) and sequence lengths, and video signal DC information can be derived from other areas of the signal (e.g. averages of active line blank areas and synchronizing information). Also, the input signal to be equalized, e.g., the signal samples from unit 16 in FIGURE 1, advantageously may be provided from the output of a deghoster filter such as disclosed in U.S. patent 5,065,242, to help prevent long ghosts of sync pulses from contaminating the blanking interval DC measurement.

The concept of substituting a measured DC value for a transformed DC value is not limited to FFT DC coefficients, and should not be so construed in the claims. For example in video signal compression apparatus which utilizes Discrete Cosine Transforms (DCT), the DCT DC coefficients of luminance components may be substituted for DC values measured in the time domain to provide greater immunity from noise corruption of the DC level.



CLAIMS:

1. Video signal processing apparatus characterized by:
frequency transform means (18) for generating
spectral coefficients of a portion of a time domain video signal,
said spectral coefficients including a DC coefficient;

5 means (20), exclusive of said transform means, for
measuring a DC characteristic of said portion of the video signal
and providing a DC value representing said DC characteristic;

means (24) for substituting said DC value for said DC
coefficient generated by said transform means; and

10 means (28,30) for processing said spectral coefficients
with said substituted DC value.

2. The apparatus according to Claim 1, characterized
in that

15 said measuring means measures the DC characteristic
of a test signal included in said video signal.

3. The apparatus according to Claim 1, further
characterized by

20 a filter coupled to said video signal and responsive to
said processed spectral coefficients for equalizing said video
signal.

4. Apparatus according to claim 1, characterized in
that

said video signal contains a test signal within a
predetermined interval; and

25 said DC characteristic measuring means and said
transform means respond to said test signal.



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5. Apparatus according to claim 4, characterized in that

said test signal is constituted by a pseudo-random number sequence;

5 said transform means performs a fast Fourier transform (FFT); and

said processing means includes an FIR filter means.

6. The apparatus according to any one of the preceding claims, characterized by

10 ratioing means responsive to said representative signal and to said transformed video signal for providing an output signal containing values representing ratios of desired to actual values for said DC representative signal and for said transformed video signal; and

15 filter means having a signal input for receiving said video signal, and a control input for receiving said output signal from said ratioing means to determine the operation of said filter for equalizing said video signal.



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