TV APPARATUS CAPABLE OF FREEZE FIELD DISPLAY

This invention relates to a television (TV) receiver having an apparatus for generating two non-identical, interlaced fields from the same field of video signal.

It is sometimes desirable to freeze the television picture. A frozen picture, for example, may be transmitted over a narrow bandwidth channel to a remote location. Or a particular moment in a sequence of action being transmitted may be frozen on the TV screen.

The basic approach taken to the production of a still picture in a TV receiver is to store either a field or a frame of video signal in a memory device. Once a field or a frame of video signal is stored, one can produce a frozen picture by stopping or inhibiting the memory writing operation and by repeatedly displaying the contents of the memory on the television screen.

The processing of the composite video signal CVS before its storage in the memory can vary in the amount ofY/C separation performed on the incoming signal. A notch filter may be used in the luminance (Y) channel of the TV receiver to remove the chrominance component therefrom. A bandpass filter may be employed in the chrominance (C) channel to remove the low frequency luminance component from the composite video signal CVS. After the composite video signal CVS is processed in this manner, the component signals CS are then stored in the respective component memories - so that they may be processed electronically to produce special effects (such as - still picture, zoom, pix-in-pix, etc).

It will be noted that the Y/C separation in the notch-filtered and bandpass-filtered video signals is incomplete or partial in the high frequency region of the video signal frequency spectrum. This is so because the luminance and chrominance components of the composite video signal CVS share the upper portion (i.e., 2.5 to 4.1 MHz) of the frequency spectrum.

Returning to the various techniques for the production of a still picture, one possible approach is the freeze frame approach. A frame of video signal can be stored in a frame memory, and read out repeatedly to generate two interlaced fields on the TV screen. The display of two interlaced fields in this manner may produce motion-induced artifacts (i.e., causes moving portions of the picture to jitter back and forth when interfield motion is present).

Another approach to the production of still pictures is to store a field of video signal in a field memory, and to display the same field of stored signal in both of the interlaced fields (i.e., produce two identical interlaced, non-interpolated or real fields). One problem with this approach is that the diagonal edges of the picture on the TV screen appear jagged. Another drawback is that the two fields have unequal spatial offsets. One field has zero offset, and the other field has a half-line offset. A half-line offset means that the signal elements are displayed on the TV screen at positions which are spaced from their true relative positions by one-half of the line spacing.

Still another approach is to display two different interlaced fields - each produced from the same stored field of video signal. The stored field is displayed as one of the two interlaced fields. The second interlaced field is generated by averaging or interpolating two adjacent lines of the stored field to produce a line that is spatially located half-way between the two lines. This approach has a number of disadvantages. The diagonal edges of the TV picture still appear somewhat jagged as in the previous approach. A further disadvantage of this approach is that the two fields may have unequal Y/C separation.

In accordance with this invention, an apparatus is disclosed for providing two non-identical fields suitable for interlaced display, and in a manner that overcomes the afore-mentioned deficiencies in the

production of a freeze picture. Over a low frequency portion of the frequency spectrum of the incoming television signal, one of the interlaced fields is generated by adding three-fourths of a line-delayed television signal L_1 to one-fourth of a non-delayed television signal L_2 (i.e., $F_1 = 3/4\ L_1 + 1/4\ L_2$), and the other interlaced field is generated by adding one-fourth of the line-delayed television signal L_1 to three-fourths of the non-delayed television signal L_2 (i.e., $F_2 = 1/4\ L_1 + 3/4\ L_2$). For high frequency signals (luma highs and chroma signal), however, both F_1 and F_2 are substantially identically proportional to the sum of L_1 and L_2 - i.e., $F_1 = F_2 = 1/2\ L_1 + 1/2\ L_2$. The first and second interpolated signals F_1 and F_2 will be repeatedly displayed on the TV screen during odd and even fields respectively to generate a frozen picture.

In the drawings:

FIGURE 1 shows a frequency independent interpolating apparatus for generating from a single stored field of video signal a pair of non-identical interlaced fields having the relationship $F_1 = 3/4\ L_1 + 1/4\ L_2$, $F_2 = 1/4\ L_1 + 3/4\ L_2$ indicated above;

FIGURE 2 is a graphical representation of a raster produced on a TV screen to illustrate the operation of the FIGURE 1 interpolating apparatus; and

FIGURE 3 illustrates a frequency responsive interpolating apparatus for generating a pair of fields having, pursuant to an embodiment of this invention, a different relationship over different portions of the frequency spectrum.

In the drawings, the lines interconnecting various blocks represent either single conductor connections carrying analog signals or multi-conductor

buses carrying multi-bit parallel binary digital signals, as the case may be.

It will be readily appreciated by those skilled in the television signal processing art that the invention may be practiced on either digital or analog representations of the composite video signal. For the purposes of the detailed description, however, it will be assumed herein that the composite video signal is an 8-bit binary digital signal unless otherwise stated, and that the video signal is in the NTSC format.

It will be further assumed that the composite video signal is decoded without the use of a comb filter. A notch filter, having its center frequency located at the unmodulated color subcarrier frequency, is inserted in the luma channel to remove the chrominance component from the output signal prior to its storage in a component memory. In the similar vein, the incoming composite video signal is bandpass filtered in the chroma channel to remove the low frequency luma from the output signal, and then stored in a component memory.

In the FIGURE 1 freeze field apparatus 100, the luma or chroma component signal CS, present at the input port 102, is applied to a field store 104. The field store 104 is capable of storing one field (or 263 horizontal lines) of an 8-bit video signal. With the incoming video signal sampled at the rate of 4 Fsc (i.e., 4 x 3.58 MHz or 14.32 MHz), the field store 104 is provided with a storage capacity of about 2 M bits.

The video signal L_2 at the output of the field store 104 is applied to a delay element 106, which produces a line-delayed video signal L_1 at its output. The line-delayed video signal L_1 is displaced in time with respect to the incoming video signal L_2 by one horizontal line period (i.e., 1-H).

The line-delayed and non-delayed video signals L_1 and L_2 are applied to first and second divide-by-four circuits 110 and 130 respectively (hereinafter - dividers 110 and 130). The output of the divider 110 is coupled to

a first multiply-by-three circuit 112 (hereinafter -multiplier 112), and to a second input terminal 118 of a multiplexor 114. The output of the multiplier 112 is applied to a first input terminal 116 of the multiplexor 114. The output of the multiplexor 114 is coupled to an adder 150.

The output of the second divider 130 is coupled to a second multiply-by-three circuit 132 (hereinafter - multiplier 132), and a first input terminal 136 of a second multiplexor 134. The output of the multiplier 132 is applied to a second input terminal 138 of the multiplexor 134. The output of the multiplexor 134 is coupled to the adder 150. The interpolated signals F_1 and F_2 are developed at the output terminal 152 of the adder 150.

The dividers 110 and 130 may be simple arrangements to shift the bit positions of the respective samples to two lesser significant bit positions to effect division by four.

The multiplexor 114, responsive to a control signal C, couples the first input terminal 116 to its output terminal 120 during the first one of the interlaced fields (i.e., when C is high) and couples the second input terminal 118 to its output terminal 120 during the second one of the interlaced fields (i.e., when C is low). Similarly, the multiplexor 134, responsive to the same control signal C, couples the first and second input terminals 136 and 138 thereof to its output terminal 140 during the first and second interlaced field periods respectively.

It will be seen that the adder 150 produces an output signal F_1 during the first interlaced field period, where -

$$F_1 = 3/4\ L_1 + 1/4\ L_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

During the second interlaced field period, the adder 150 produces an output signal F_2, where -

$$F_2 = 1/4\ L_1 + 3/4\ L_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

In the FIGURE 1 apparatus, the two divide-by-four circuits 110 and 130 may be replaced by a single

divide-by-four circuit coupled to the output of the adder 150.

The operation of the FIGURE 1 apparatus 100 will be explained with reference to FIGURE 2, which shows a television raster 160. The raster 160 is defined by a pair of interlaced fields - an odd field OF and an even field EF. The odd field OF is formed by a first plurality of horizontal scan lines - indicated by solid lines OF/L_1, OF/L_2 ... OF/L_{263}. The even field EF is formed by a second plurality of horizontal scan lines, which are represented by dash-dot lines - EF/L_0, EF/L_1, EF/L_2 ... EF/L_{262}. The second plurality of the horizontal scan lines are spatially disposed half-way between the respective ones of the first plurality of horizontal scan lines.

As previously indicated, the incoming video signal is sampled at the 4 Fsc rate. The successive samples of the video signal define successive picture elements or pixels. The picture elements of the odd field OF and the even field EF are respectively identified in FIGURE 2 as circular and square elements.

The addition of three-fourths of the earlier line's amplitude (e.g., 3/4 L_1) to one-fourth of the next following line's amplitude (e.g., 1/4 L_2) produces successive picture elements, which are identified by triangular elements in FIGURE 2. These triangular elements are located one-fourth of the way from the earlier line to the next following line. These triangular elements are displayed on the TV screen when the electron beam scans the earlier or top field - indicated as the odd field OF in the DRAWING.

The addition of one-fourth of the earlier line's amplitude (e.g., 1/4 L_1) to the three-fourths of the next following line's amplitude (e.g., 3/4 L_2) generates successive picture elements, which are identified by inverted triangular elements in FIGURE 2. These inverted triangular elements are located three-fourths of the way from the earlier line or one-fourth of the way from the next following line. These triangular elements are

displayed on the TV screen during the later or lower field - indicated as the even field EF in the DRAWING.

To produce a frozen picture, the incoming video signal CS is written into the field memory 104 for one full field period, the memory writing procedure is inhibited, and then the information from the field memory is read out repetitively so long as the TV receiver is in the freeze picture mode. The memory reading operation is synchronized with the horizontal and vertical deflection signals, as is well known in the art.

As can be seen from the odd field OF in FIGURE 2, the start of each new vertical trace coincides with the start of a horizontal line (i.e., OF/L_1). Therefore, the reading of the stored field from the field memory 104 can commence immediately for the odd fields. For the even fields, however, the start of each new vertical trace occurs in the middle of a horizontal line (i.e., EF/L_0). The reading of the stored field must be delayed for the even fields until the beginning of the first full horizontal line in the even field (i.e., EF/L_1).

Thus, the even field EF is spatially located below the odd field in the TV raster produced by the aforesaid freeze field action. The operation of the memory in this manner produces 262.5 horizontal lines (i.e., OF/L_1 ... OF/L_{263}) for the odd field, and produces 262 horizontal lines (i.e., EF/L_1 ... EF/L_{262}) for the even field.

As mentioned earlier, the spatial interpolation for the odd field produces a horizontal line which is located one-fourth of the way from the earlier line (e.g., OF/L_1) to the next horizontal line (e.g., OF/L_2). This interpolated line will be displayed when the electron beam is scanning the earlier line (e.g., OF/L_1). Thus, a spatial offset of one-fourth of the spacing between successive horizontal lines (i.e., L/4 as shown in FIGURE 2) is produced for the odd field.

The interpolated lines for the even field are located three-fourths of the way from the earlier lines (e.g., OF/L_1), but are displayed when the electron beam is

scanning the even lines (e.g., EF/L_1) that fall half-way between the two lines (e.g., OF/L_1 and OF/L_2). Thus, a spatial offset of one-fourth horizontal line (L/4) is again produced for the even field. Since the spatial offsets produced by this arrangement are equal for both the odd and even fields (i.e., L/4), correct relative spatial positioning of the respective picture elements occurs.

Another advantage of this algorithm is that it produces additional Y/C separation in the output signals F1 and F2, and that the amount of the additional Y/C separation for both odd and even fields is the same. This will be seen from the following illustrative calculations for the luma channel:

$$\circ\ F_1 = 3/4\ L_1 + 1/4\ L_2$$
$$= 3/4\ (Y+C) + 1/4\ (Y-C)$$
$$= Y + 1/2\ C \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\circ\ F_2 = 1/4\ L_1 + 3/4\ L_2$$
$$= 1/4\ (Y+C) + 3/4\ (Y-C)$$
$$= Y - 1/2\ C \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Thus the chroma contamination in the luma channel is reduced by one-half the amplitude of the chroma signal. This means that a further Y/C separation of 6 dB occurs in the interpolated output signals F_1 and F_2 for both of the interlaced fields. The effects of the residual contamination are not as great because the polarities of the residual chroma signals alternate 180° from line to line.

In the same vein, the luma contamination in the chroma channel is reduced by 6 dB for both the odd and even fields. Again, the visual impact of the contamination is reduced because of alternating polarities on a line-to-line basis.

It is desirable to have complete Y/C separation in the output signals F_1 and F_2 in the upper portion of the frequency spectrum, where the luma highs and the chroma signal share the spectrum. In this region of the frequency spectrum, it is more important to have total Y/C separation than to have equal spatial offsets in both fields. To this

end, a frequency responsive interpolating apparatus 200, shown in FIGURE 3, is provided.

In the FIGURE 3 apparatus 200, the component signal CS is applied to the field store 204 and the 1-H delay line 206, in the same manner as in FIGURE 1. The line-delayed and non-delayed signals L_1 and L_2 are respectively coupled to the first and second input terminals 216 and 218 of a first multiplexor 214. The line-delayed and non-delayed signals L_1 and L_2 are also respectively applied to the second and first input terminals 238 and 236 of a second multiplexor 234. The multiplexors 214 and 234, responsive to the control signal C, couple their respective first and second input terminals 216, 236 and 218, 238 to the output terminals 220, 240 thereof during the first and second field periods respectively.

The outputs of the multiplexors 214 and 234 are applied to an adder 250 to generate a $(L_1 + L_2)$ signal. The output of the adder 250 is coupled to a multiply-by-two circuit 260 (hereinafter multiplier 260), which generates a $2(L_1 + L_2)$ signal. The output of the multiplier 260 is applied to another adder 270.

The outputs of the multiplexors 214 and 234 are further applied to the minuend and the subtrahend terminals of a subtracter 280. It will be seen that the subtracter 280 produces a first difference signal $L_1 - L_2$ during the odd fields and a second difference signal $L_2 - L_1$ during the even fields. The difference signals from the subtracter 280 are lowpass filtered in a filter 282 to eliminate, from its output, frequencies occupying the high frequency luma and chroma signal region (i.e., 2.5 to 4.3 MHz). The lowpass filtered difference signals are added to the $2(L_1 + L_2)$ signal in the adder 270.

The output of the adder 270 is applied to a divide-by-four circuit 290 (hereinafter, divider 290). The signals F_1' and F_2' at the output terminal 292 of the divider 290 are tabulated in the OUTPUT TABLE below:

OUTPUT TABLE

Interlaced Field	Output Low Freq.	High Freq.
Field 1	$F_1' = 3/4\ L_1 + 1/4\ L_2$	$F_1' = 2/4\ L_1 + 2/4\ L_2 = 1/2\ L_1 + 1/2\ L_2$
Field 2	$F_2' = 1/4\ L_1 + 3/4\ L_2$	$F_2' = 2/4\ L_1 + 2/4\ L_2 = 1/2\ L_1 + 1/2\ L_2$

The output signals F_1' and F_2' of the FIGURE 3 apparatus 200 are the same as the output signals F_1 and F_2 of the FIGURE 1 apparatus in the low frequency range of the frequency spectrum (e.g., below 2.5 MHz). In the high frequency region (e.g., 2.5 to 4.3 MHz - where the high frequency luma and chroma signals share the frequency spectrum), the output signals F_1' and F_2' are identical, and are the same as the signals produced by a typical line comb filter (i.e., $1/2\ L_1 + 1/2\ L_2$).

Thus, the frequency responsive apparatus 200 of FIGURE 3 produces equal spatial offsets for both odd and even fields (e.g., L/4) for lower frequencies (where Y/C separation is not required). For higher frequencies (where equal spatial offset is not as critical), it comb filters the output signals (i.e., produces total Y/C separation when there is no vertical detail in the picture).

A limitation of the FIGURE 3 apparatus 200 is that, for higher frequencies, the spatial offset for the odd fields is equal to one-half the line spacing (i.e., L/2), while there is zero offset for the even fields. The practical effects of this limitation are minimized because the high frequencies are interpolated one-fourth of a line below the low frequencies for the odd fields and the high frequencies are interpolated one-fourth of a line above the low frequencies for the even fields. Therefore, the effects due to unequal offsets for the high frequencies tend to cancel.

The operation of the FIGURE 3 interpolating apparatus 200 is similar to that of the FIGURE 1 apparatus 100. Basically, in the freeze mode, one field of video signal is stored in the field store 204. The writing process is inhibited when a full field is stored, and then the stored field is repetitively read out to generate output signals F_1' and F_2' during the odd and even fields respectively. The output signals are used to generate a pair of interlaced fields on the screen of a display device - such as a television receiver.

CLAIMS:

1. A television apparatus for processing an incoming television signal to develop a pair of non-identical interlaced field signals comprising:

an input source for applying said incoming television signal;

delay means coupled to said input source for generating a line-delayed television signal L_1 displaced in time by one horizontal line period relative to non-delayed, incoming television signal, L_2, applied to its input terminal; and

output means coupled for receiving said line-delayed and said non-delayed television signals L_1 and L_2 for producing a pair of output signals F_1 and F_2, each representative of a respective one of said first and second interlaced fields, where F_1 is proportional to the sum of $3L_1$ and L_2, and F_2 is proportional to the sum of L_1 and $3L_2$, over only a low frequency portion of the frequency spectrum of said incoming television signal, and where both F_1 and F_2 are substantially identically proportional to the sum of L_1 and L_2 over a high frequency portion of said frequency spectrum.

2. The apparatus defined in Claim 1 wherein F_1 substantially equals $3/4\ L_1 + 1/4\ L_2$ and F_2 substantially equals $1/4\ L_1 + 3/4\ L_2$ over said low frequency spectrum portion.

3. The apparatus defined in Claim 1 further including:

a field store interposed between said input source an said delay means for storing a field of said incoming television signal; and

control means coupled to said field store for inhibiting the passage of said incoming television signal into said field store after the completion of a full field

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period following the initiation of a freeze field operation, and thereafter repetitively reading said stored field signal to alternately generate one and the other of said pair of interlaced output signals F_1 and F_2 during the respective one of said interlaced field periods.

4. The apparatus defined in Claim 3 wherein said output means comprises:

subtracting means coupled for receiving said line-delayed and non-delayed television signals L_1 and L_2 for developing a first difference signal (L_1-L_2) during said first interlaced field period and a second difference signal (L_2-L_1) during said second interlaced field period;

a low pass filter coupled for receiving the output of said subtracting means;

summing means coupled for receiving said line-delayed and non-delayed television signals L_1 and L_2 for developing a sum signal proportional to the sum of $L_1 + L_2$ during both of said first and second interlaced field periods; and

adding means coupled to said low pass filter and said summing means for combining the output of said lowpass filter with said sum signal to generate said first and second output signals F_1 and F_2 during the respective ones of said interlaced fields;

wherein each of said output signals is proportional to said sum over said high frequency portion of said spectrum outside the passband of said low pass filter.

5. The apparatus defined in any preceding claim further including means, coupled to said output means, for repetitively displaying said first and second output signals F_1 and F_2 during the respective one of said interlaced field periods to generate a still picture.

6. Television signal processing apparatus substantially as hereinbefore described with reference to FIGURE 3 of the accompanying drawings.

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