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(54) Scrambling multiplexed component video signals

(57) A multiplexed analog component signal Fig. 3A comprises a sequence of time compressed components (Y, R—Y, B—Y). In order to scramble the signal for security, the individual components are separately time-rotated with respect to rotation points K1, K2 and K3, Fig. 3B. The position of clamping levels between the components is unchanged. Thereby any clue as to the degree of rotation is removed.

Fig. 3A

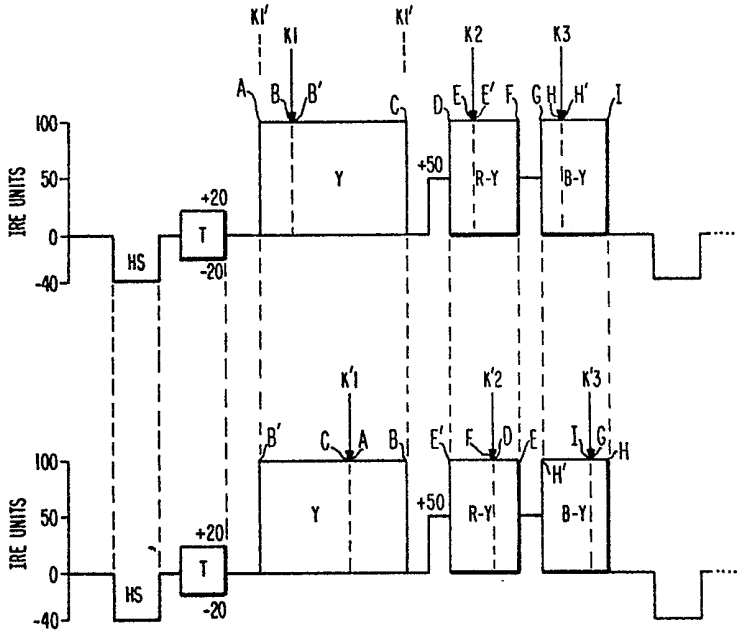

Fig. 3B

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Fig. 1A

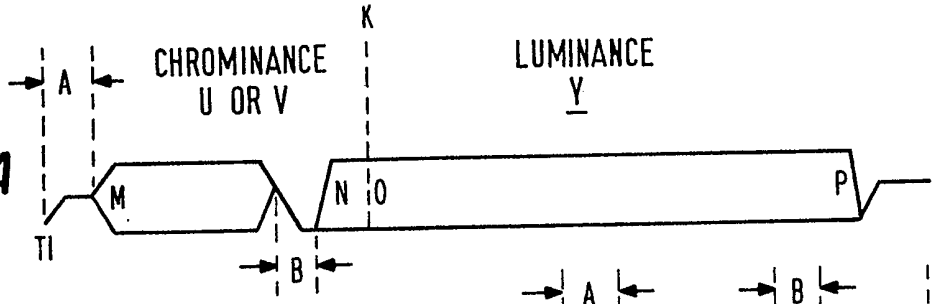

Fig. 1B

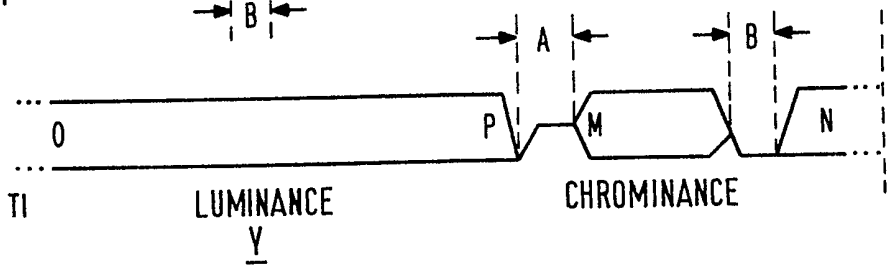

Fig. 2A

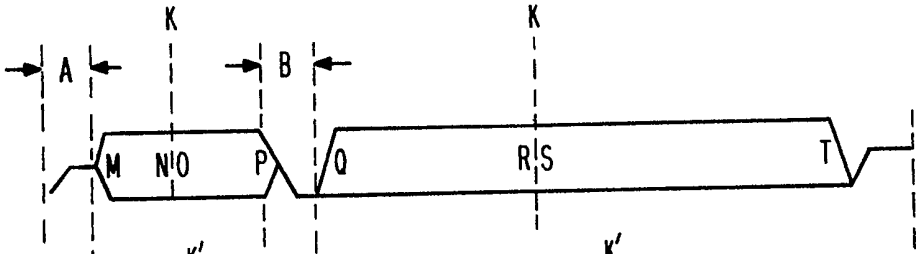

Fig. 2B

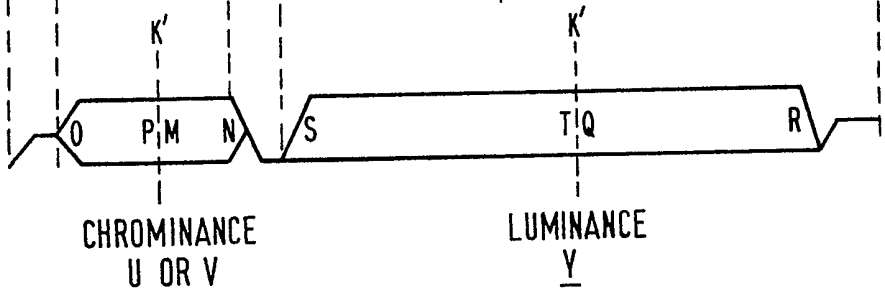

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Fig. 3A

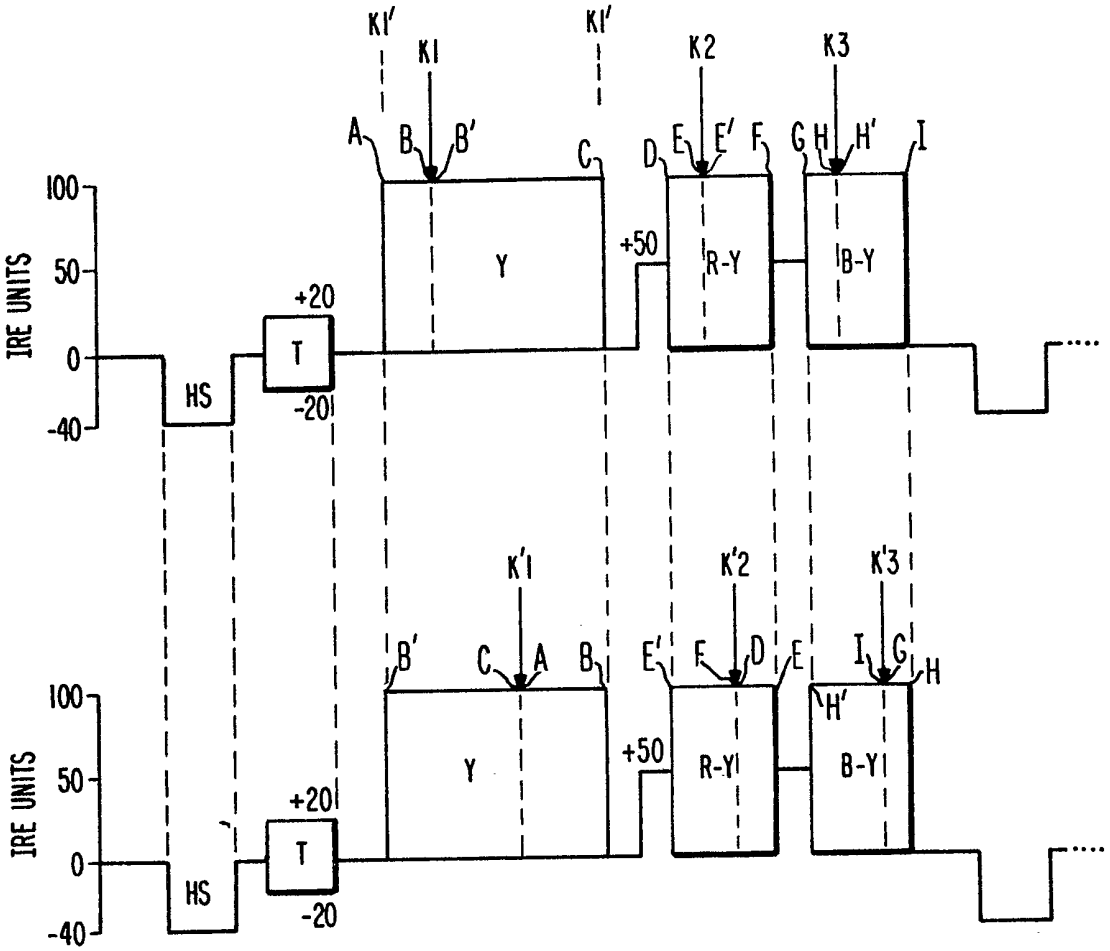

Fig. 3B

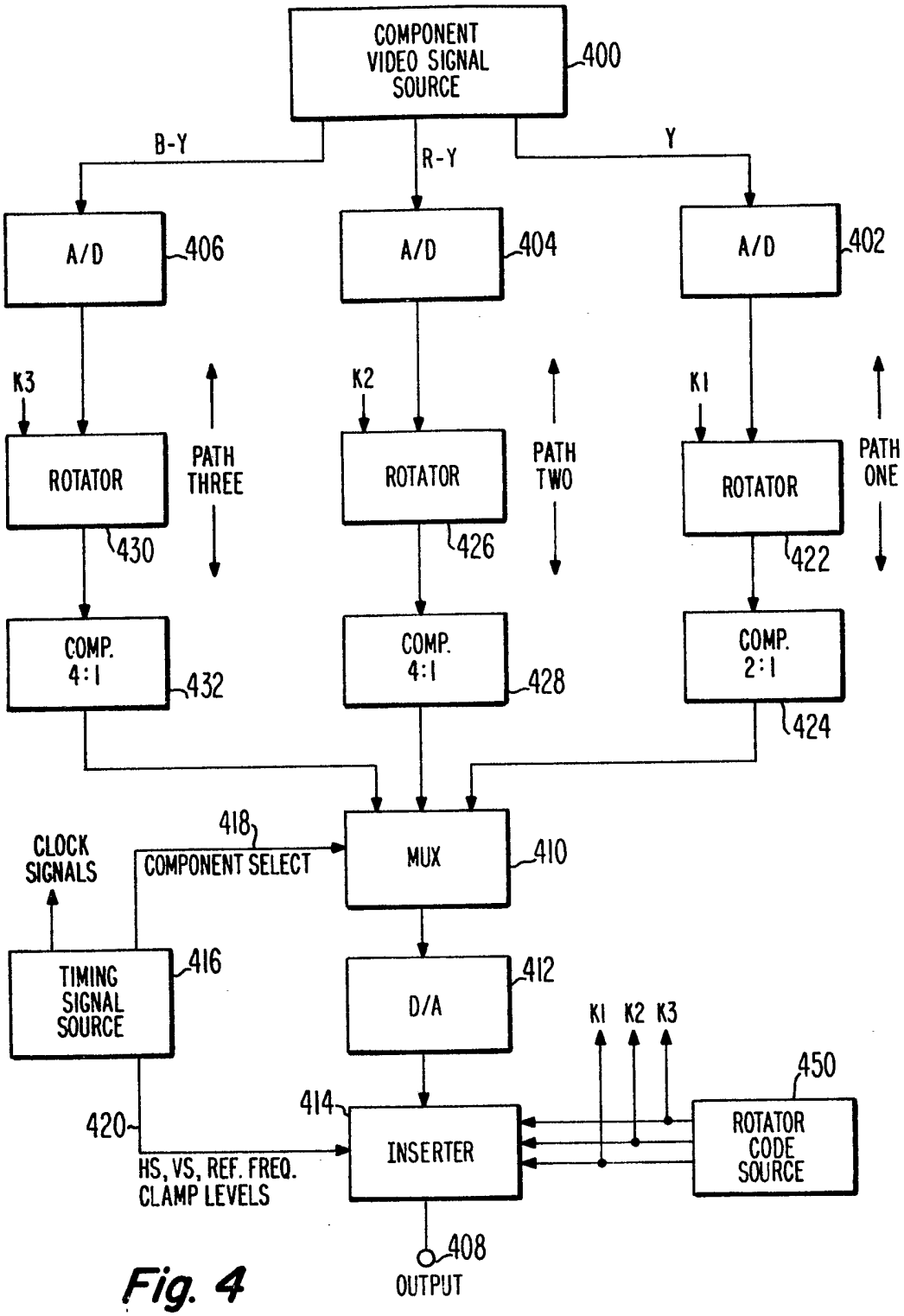
COMPONENT VIDEO SIGNAL SOURCE
400
B-Y
R-Y
Y
A/D
406
A/D
404
A/D
402
K3
K2
K1
ROTATOR
430
ROTATOR
426
ROTATOR
422
PATH THREE
PATH TWO
PATH ONE
COMP. 4:1
432
COMP. 4:1
428
COMP. 2:1
424
418
CLOCK SIGNALS
COMPONENT SELECT
MUX
410
TIMING SIGNAL SOURCE
416
D/A
412
K1 K2 K3
450
414
420
INSERTER
ROTATOR CODE SOURCE
HS, VS, REF. FREQ. CLAMP LEVELS
408
OUTPUT

Fig. 4

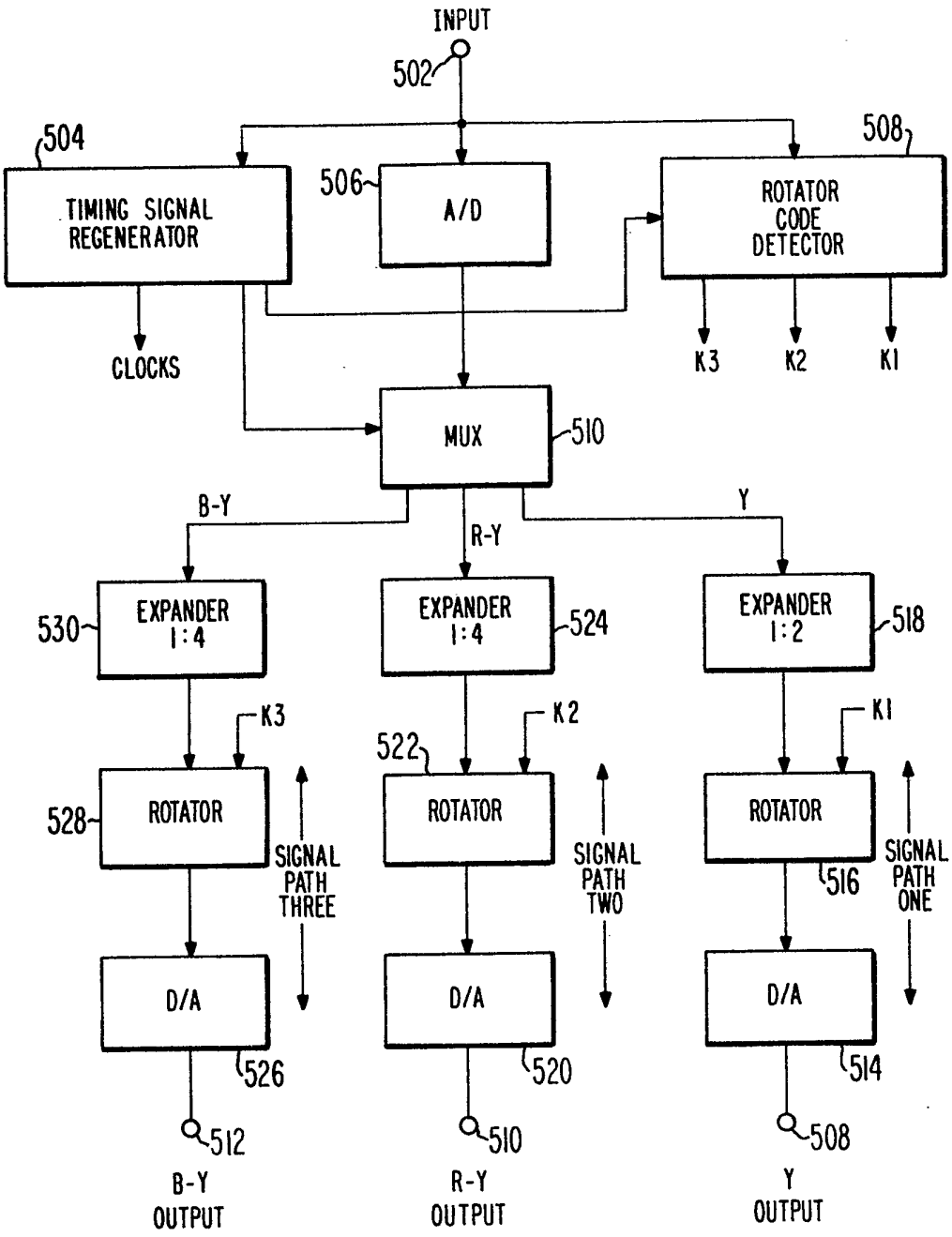
INPUT
502
504
TIMING SIGNAL REGENERATOR
506
A/D
508
ROTATOR CODE DETECTOR
CLOCKS
K3
K2
K1
MUX
510
B-Y
R-Y
Y
530
EXPANDER 1:4
EXPANDER 1:4
524
EXPANDER 1:2
518
K3
K2
K1
522
528
ROTATOR
ROTATOR
ROTATOR
516
SIGNAL PATH THREE
SIGNAL PATH TWO
SIGNAL PATH ONE
D/A
D/A
D/A
526
520
514
512
510
508
B-Y OUTPUT
R-Y OUTPUT
Y OUTPUT

Fig. 5

SPECIFICATION

Transmission and Reception of Multiplexed Component Video Signals

Field of the Invention

This invention relates to the transmission and reception of component video signals. It concerns scrambling and unscrambling multiplexed analog component (MAC) video signals.

Background of the Invention

It is desirable to encode television signals to provide secure transmission in applications such as cable TV, satellite transmission and subscription broadcast television. Known coding arrangements may be considered, generally speaking, to be of either the amplitude alteration type or of the time sequence alteration type. Amplitude encoders include, illustratively, those which alter the vertical or horizontal synchronizing pulse amplitude or which modulate the video signal with an encoding waveform (e.g., a sinewave) and have an advantage in that the decoder may be relatively simple and inexpensive. A disadvantage of amplitude encoding is that, generally speaking, the codes are rather easily recognized and deciphered, thus creating a potential "black market" for unauthorized decoders. From a technical standpoint, the amplitude distortion imparted to the video signal may not be completely removed by the decoder and critical decoder adjustments may be required to reduce the residual distortion of the decoded signal to acceptable levels. Other problem areas associated with scramblers of the amplitude alteration type include signal-to-noise ratio degradation and loss of dynamic range.

Encoders of the time sequence alteration type reorder the video signal sequence so as to create a non-standard signal sequence which may be changed at random so as to provide a very high level of security. Examples of such encoders include those which reverse the sequence of picture elements (pixels) within a horizontal line, those which transpose or interchange lines within a field and those which transpose or rearrange segments of each line of the video signal as described in U.S. Patent No. 4,070,693 which issued January 24, 1978 to H. B. Shutterly, the relevant disclosure of which is herein incorporated by reference.

The Shutterly system, which scrambles one line of video at a time (an intra-line scrambler), has an advantage of requiring less encoder and decoder memory requirements over encoders of the type which alter line sequences within blocks of lines (an inter-line scrambler). Briefly, in the Shutterly system, each active line of composite video signal is "rotated" about a predetermined point which is randomly changed from time to time. Information as to the point of rotation is conveyed during a selected line of the vertical interval. The rotation code does not itself directly indicate the rotation point but rather is used to synchronize a random number generator in the decoder with a similar random number generator in the encoder thereby providing security as to the rotation point.

Summary of the Invention

The present invention resides in part in the recognition that the method of intra-line pixel rotation encoding as applied to conventional composite video signals results in a code which may be rather easily deciphered as applied to video signals of the so-called "MAC" (multiplexed analog component) video transmission format.

In MAC video transmission systems a color video signal is transmitted through a channel, (e.g., a satellite transponder, a cable or broadcast system, a VTR, etc.) using serially transmitted time compressed analog components. Serial transmission is preferred so that only one channel is needed. The use of time compressed components to represent the color signal (e.g., Y, R—Y, B—Y or Y, U, V or Y, I, Q or R, G, B, etc.) provides a desirable reduction in cross-talk between the luminance and chrominance components. See generally, U.S. Patent No. 4,376,957 entitled "Transmission System With Sequential Time Compressed Baseband Color" which issued March 15, 1983 to Dischert et al. and U.S. Patent Application Serial No. 509,786 entitled "A Worldwide Compatible Synchronizing Signal For Accurate Time Base Correction In An Analog Component Interface Standard" which was filed June 30, 1983, by T. M. Gurley, each incorporated herein by reference.

It is an object of the invention to obtain the benefits of intra-line pixel rotation encoding in a video transmission system of the multiplexed analog component type without loss of coding security as will be subsequently explained.

A method of encoding a television signal for transmission and embodying the invention comprises providing a source of television signal to be encoded, each line of said television signal including a luminance component and at least one chrominance component. First and second signal paths are provided for selectively coupling the luminance component and the chrominance component, respectively, to an output terminal during selected non-overlapping time intervals. The luminance component in the first path is time compressed by a given amount and the chrominance component in said second path is time compressed by a greater amount. The luminance component signal sequence in the first path is rotated independently of rotation of the chrominance component signal sequence in the second path so as to encode said luminance and chrominance components without alteration of the time position of said components in the encoded line of said television signal produced at said output terminal.

Brief Description of the Drawing

In the drawing:

Figures 1A and 1B are simplified waveforms illustrating intra-line rotation encoding of MAC formatted video signals;

Figures 2A and 2B are simplified waveforms illustrating of intra-line rotation encoding of MAC formatted video signals in accordance with the invention;

Figures 3A and 3B are detailed waveforms illustrating the principles of the invention as applied to a video transmission system wherein three components are included in each line;

Figure 4 is a block diagram of an illustrative encoder embodying the invention; and

Figure 5 is a block diagram of an illustrative decoder embodying the invention.

Detailed Description

Figure 1A is a simplified representation of one line of a "two component" MAC waveform (sync and receiver timing signals are not shown). Region A is a clamping level of the video signal which precedes the chrominance component. In the two component system, the U and V color components are transmitted on alternate lines, as opposed to a "three-component" system, in which luminance and both chrominance components are transmitted in the duration of one horizontal line, equivalent to about 63 μs. Region B corresponds to the clamping level interval between the chroma component (U or V) and the luminance component Y.

Figure 1B illustrates the effect of "rotating": the signal components of Figure 1A about the point K. It is instructive to note that regions A and B have shifted with respect to the start of the line (T1, an aribitrary reference point) and this shift is directly indicative of the rotation of the picture elements (pixels) of the line. In more detail, the rotation point K in Figure 1A is bounded by points N and O in the Y signal. Upon rotation (Figure 1B) the new line begins at point O of the Y signal, and progresses through points P, M and N, as shown, so as to form a new "rotated" signal sequence for the transmitted line.

The problem illustrated by Figures 1A and 1B is that one may easily determine the degree of rotation of the signal elements of the rotated line by simply measuring the time from the last horizontal sync pulse (not shown) to either of the readily recognizable clamping level intervals A or B. As a result, the scrambling code may be easily broken thereby encouraging a "black market", so to speak, in "pirate" decoders. This illustrates the heretofore unrecognized problem that intra-line pixel rotation, which is very effective in the composite video transmission systems of the type described by Shutterly, is not effective in MAC formatted video transmissions.

Figures 2A and 2B are similar to Figures 1A and 1B but illustrate the intra-line rotation encoding technique of the present invention. As is readily apparent, the clamping level intervals A and B in the unencoded line (Figure 2A) and in the encoded (rotated) line (Figure 2B) convey absolutely no information as to the degree of rotation. In other words, the clamping level regions A and B do not shift and are not altered in any way by the rotation process. This desirable result, which provides a high level of security for the encoded signal, is achieved in accordance with the invention by rotating each component individually with respect to its own rotation point (K and K'). Carrying this principle forward to a three component system, each component is individually rotated with respect to its own rotation point (K, K' and K'') for each respective component (e.g., Y, I and Q or Y, U and V, or Y, R—Y and B—Y, etc.).

Figures 3A and 3B provide a detailed example of the principles of the invention as applied to a three component MAC formatted video transmission system of the type described, for example, in the aforementioned U.S. Patent Application of T. M. Gurley. Notice that, as in the examples of Figures 2A and 2B, that the "signal flags" (clamping levels) hold their same positions in the scrambled signal (Figure 3B) as in the unscrambled signal (Figure 3A) and no fixed, identifiable patterns exist by which the signal can be unscrambled.

In this system, the "unscrambled" waveform (3A) begins with a horizontal sync pulse at —40 IRE units followed by a timing signal burst (T). Burst T has peak to peak values of —20 and +20 IRE units and is utilized in the receiver/decoder for synchronizing a phase lock loop (PLL) which provides decoder timing signals and is not the conventional color burst signal used in composite TV transmissions.

The luminance component Y, R—Y color difference component and the B—Y color difference component follow the timing component, T, in order recited. The component order, however, is not of importance to the present invention. What is important is that each individual component is rotated about its own separate rotation point which are: K1 for Y, K2 for R—Y and K3 for B—Y and that all the clamping levels in the encoded signal (3B) are aligned with the corresponding levels in the unencoded signal (3A).

In more detail, the unencoded component Y begins at point A with rotation point K1 at location B, B' and ends at point C. When the component Y is rotated, the rotated component begins at point B'. This is followed by the segment B' to C, the point K' and then the segment A to B. Component Y thus begins, in this example, with the B'—C region, followed by point A (the unencoded beginning point) and point B. This rotation, in order words, places the latter signal elements of component Y at the beginning of component Y in the encoded signal but the order of the pixels within each rotated segment remains unchanged. Each of the components Y, R—Y and B—Y have their own respective rotation points. It will be observed that all of the clamping levels (e.g., 0 IRE, and +50 IRE) between the components retain their exact positions in the encoded component signal as in the unencoded component signal.

The principles of the present invention are of general utility in MAC format video transmission

systems. Figure 4 is illustrative of the individual component rotation encoding technique of the present invention as applied to a MAC transmission encoder of the type described in the aforementioned U.S. Patent Application of T. M. Gurley. The Gurley system is a single channel system in which the components Y, R—Y and B—Y are transmitted during each line interval.

The encoder comprises a component video signal source 400 which supplies a luminance component Y to an analog to digital (A/D) converter 402, a first color difference component R—Y to an A/D converter 404 and a second color difference component B—Y to an A/D converter 406. Source 400 may comprise, illustratively, a matrix circuit for converting the R, G and B outputs of a color camera or any other suitable source of Y, R—Y and B—Y components. A/D converters 402, 404 and 406 may comprise conventional eight bit flash converters. Such converters, suitable for operation at video rates are well known and commercially available.

The digitalized outputs of converters 402, 404 and 406 are coupled via three respective paths (path one, path two and path three, respectively) to a multiplexer 410 which selectively couples the paths to an output terminal 408. The multiplexer switch unit, 410 receives the three Y, R—Y, B—Y, signals from the paths at its inputs and supplies selected ones of those signals to the terminal 408 via a D/A converter 412 coupled in series with a timing and code inserter unit 414.

A timing signal source 416 provides clock signals to the A/D converters (and also to rotators and time compressors in the paths, as will be described). Source 416 also supplies selection signals via bus 418 to MUX switch 410 and supplies horizontal and vertical synchronizing signals (HS, VS), a reference frequency burst signal and clamp level enabling signals to inserter 414 via bus 420. Each of the three signal paths includes a series connection of a rotator and a time compressor (422, 424 respectively in path one; 426, 428, respectively in path two; and 430, 432, respectively in path three). Digital and analog time-compressors as well as signal sequence rotators are quite well known. Examples are given in the previously mentioned patents and patent application. Inserter 414 also is coupled to receive the rotation code signals K1, K2 and K3 from a rotator code source 450 which signals are also supplied respectively to rotators 422, 426 and 430. Briefly stated, the encoder time compressors 424, 428 and 432 time compress the video components Y, R—Y and B—Y by factors of 2:1, 4:1 and 4:1, respectively. Source 416 operates MUX 410 to sequentially select the outputs of paths one, two and three for application to D/A converter 412. Inserter 414 adds HS, VS, the reference frequency signal and provides clamping under the control of source 416.

In accordance with the present invention, rotator code source 450 supplies the rotation codes K1, K2 and K3 to signal element rotators 422, 426 and 430 which, independently of each other, rotate the signal elements of the Y component in path one, the R—Y component in path number two and the B—Y component in path number three. As a result, there is no change in the relative positions of the components or clamping levels of the component signals when rotated as previously described in connection with Figure 3 and thus there is no clue in the component signal position contained in the coded signals appearing at terminal 408.

Rotator code source 450 also supplies the rotation codes K1, K2 and K3 to signal inserter 414 for transmission during the vertical interval of the video output signal at terminal 408. Security of the rotation codes may be enhanced by the previously described technique of Shutterly or the rotation codes may be conveyed by other means (e.g., a separate transmission channel, a permanently programmed read only memory or some other secure transmission system). What is of importance to the present invention, as previously stated, is that each component transmitted be rotated or otherwise encoded in a manner that does not alter the time position of the transmitted components.

The MAC format video security encoding system of Figure 4 may be coupled to decoder via a satellite communications link, via a direct cable transmission system or any other suitable communications channel. Figure 5 is exemplary of a suitable decoder for the encoder of Figure 4.

In Figure 5 the encoded signal is applied to input terminal 502 which is coupled to a timing signal regenerator 504, an analog-to-digital converter (A/D) 506 and to a rotator code detector 508. Timing signal regenerator 504 includes a phase locked loop (PLL) and counters and is responsive to the reference frequency component of the encoded input signal for generating clock signals for the expanders, rotators and digital converters in the decoder. Regenerator 504 also keys rotator code detector 508 during the appropriate line of the vertical interval to decode the rotation codes K1, K2 and K3.

The output of A/D converter 506 is applied to a demultiplexer or switch unit, 510 controlled by regenerator 504 to selectively couple the output of the converter 506 to signal paths one, two and three, respectively, in synchronism with the transmission of the component signals Y, R—Y and B—Y, respectively. Path one includes a first D/A converter 514 having an output coupled to a Y component output terminal 508 and an input coupled via a series connection of a signal element rotator 516 and a 1:2 time expander 518 to the Y component output of switch unit 510. In paths two and three the D/A converters 520 and 526, the rotators 522 and 528 and the time expanders 524 and 530 are similarly connected. The time expanders for the color difference signals R—Y, B—Y, however provide 1:4 expansion as compared with the 1:2 expansion factor for the Y component expander in path one.

Operation of the component decoder of Figure 5 is essentially as described in the Gurley patent application except for the presence of the rotator code detector 508 and the individual component signal element rotators 516, 522 and 528. The three rotation codes conveyed during the vertical interval of the input signal applied to terminal 502 are detected by rotation code detector 508 and routed to the three component rotators 516, 522 and 528 in paths one, two and three, respectively, which rotate the respective signal elements of the Y, R—Y and B—Y signals in a sense opposite to the original rotation thereby decoding the individual components Y, R—Y and B—Y.

It will be appreciated that the application of the principles of the invention to the three component Y, R—Y, B—Y Gurley system is but one example of the invention. Rotation of the chrominance and luminance components individually in multiplexed analog video (MAV) transmission systems provides the simplicity of intra-line scrambling characteristic of component transmission systems but avoids the problem, previously mentioned, of time shifting components in proportion to intra-line rotation thereby giving a clue as to the time shift or rotation required for decoding. The present invention, in other words, brings to sequential component transmission systems the level of security characteristic of conventional line-rotation composite video transmission systems. The principles of the invention are of general utility and may be applied to two or three component systems (as previously mentioned) and may be applied to components including Y, I and Q or Y, U and V as well as to the example given of Y, R—Y and B—Y.

CLAIMS

1. A method for encoding a color television signal for transmission comprising the steps of:

(a) providing a source of color television signals to be encoded, each line of said television signal including a luminance component and at least one chrominance component;

(b) providing a first signal path and at least one further signal path for selectively coupling said luminance component and the or each chrominance component, respectively, to an output during selected non-overlapping time intervals;

(c) time compressing said luminance component in said first path by a predetermined amount and time compressing the or each chrominance component in the or each further path by a greater predetermined amount; and

(d) independently time-rotating said luminance component signal sequence in said first path and time-rotating the or each chrominance signal component in the or each further signal path so as to encode said luminance and chrominance components without alteration of the time position of said components in the encoded line of said television signal produced at said output.

2. A method for decoding a color television signal having a luminance component and at least one chrominance component transmitted in time sequential component form wherein each component is separately encoded by rotation of signal elements within the component comprising the steps of:

(a) providing a first path for coupling the luminance component of said television signal to an output (508) during a first time period;

(b) providing at least one further path for coupling the or each chrominance component of said television signal to an output during a second time period, said second time period being spaced from said first time period by a predetermined period during which the television signal is clamped to a given clamping level; and

(c) rotating signals elements of said luminance component within said first time period so as to restore said luminance signal to its original time sequence and separately rotating signal elements of the or each chrominance component within said second time period in a sense to restore the or each chrominance component to its original time sequence.

3. Apparatus for encoding a color television signal for transmission comprising:

(a) a source of color television signals to be encoded, each line of said television signal including a luminance component and at least one chrominance component;

(b) a first signal path and at least one further signal path for selectively coupling said luminance component and the or each chrominance component respectively, to an output during selected non-overlapping time intervals;

(c) means for time compressing said luminance component in said first path by a predetermined amount and time compressing the or each chrominance component in the or each further path by a greater predetermined amount; and

(d) means for independently time-rotating said luminance component signal sequence in said first path and time-rotating the or each chrominance signal component in the or each further signal path so as to encode said luminance and chrominance components without alteration of the time position of said components in the encoded line of said television signal produced at said output.

4. Apparatus for decoding a color television signal having a luminance component and at least one chrominance component transmitted in time sequential component form wherein each component is separately encoded by rotation of signal elements within the component the apparatus comprising:

(a) a first path for coupling the luminance component of said television signal to an output during a first time period;

(b) at least one further path for coupling the or each chrominance component of said television signal to an output during a second time period, said second time period being spaced from said first time period by a predetermined period during which the television signal is clamped to a given clamping level; and

(c) means for rotating signals elements of said luminance component within said first time period so as to restore said luminance signal to its original time sequences and separately rotating signal elements of the or each chrominance component within said second time period in a sense to restore the or each chrominance component to its original time sequence.

5. A television system characterised by encoding apparatus according to Claim 3 and decoding apparatus according to Claim 4.

6. A color television transmission system, comprising:

(a) a source of a color television signal in component form;

(b) means for time compressing the components of said television signal by respective amounts to enable serial transmission of the components of each line within each line interval;

(c) means for separately time-rotating the signal sequence of each component of each line;

(d) transmission means for serially conveying the time compressed and individually time-rotated components to a receiving means, said receiving means including

(e) means for separating the serially conveyed and individually time-rotated components; and

(f) means for time-rotating and time expanding each of said separated components in complementary fashion to the said first-mentioned time-rotation and time compression.

7. A method of encoding a television signal substantially as hereinbefore described with reference to Figures 2A and 2B or to Figures 3 and 3B or to Figure 4.

8. A method of decoding a television signal encoded according to the method of Claim 7 and substantially as hereinbefore described, or as hereinbefore described with reference to Figure 5.

9. Apparatus for encoding a television signal substantially as hereinbefore described with reference to Figure 4.

10. Apparatus for decoding a television signal substantially as hereinbefore described with reference to Figure 5.

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