The invention relates to a method for the transmission of a wide bandwidth, temporal and spatial high definition image signal which was obtained at the transmitter end over two transmission channels of narrower bandwidth as well as to an improved receiver for this method.

State of the art

In the conference papers of the HDTV Colloquium 1987, Ottawa, from the 04 -08.10.1987, a transmission system which enables the reception of a high definition television signal, hereinafter referred to as a HDTV signal, as well as that of a standard television signal, hereinafter referred to as a standard TV signal, has been proposed by William E Glenn and Karen G Glenn of the New York Institute of Technology at pages 4.5.1 - 4.5.12 under the title "Improved HDTV with Compatible Transmission". For this, a HDTV signal delivered from a source is split up by means of a digital signal processor utilising a two dimensional spatial filtering to the effect that, as a result, a standard TV signal and a signal which contains the high spatial frequency components of the HDTV signal are produced.
These two signals are transmitted separately over two separate band limited channels wherein the one channel transmits the standard TV signal and the second channel, functioning as an auxiliary channel, the high spatial frequency components of the HDTV signal.
The standard TV signal can then be received at the receiving end by means of a standard TV receiver.
A suitable HDTV receiver is able to reconstruct and reproduce the picture delivered from the source by the evaluation of the signals from both channels.
It is not possible to reconstruct and reproduce a spatial high definition image from the information of the auxiliary channel alone.

Invention

The object of the invention is to provide a method for the transmission of a high definition image signal which, when using two transmission channels of narrow bandwidth, enables the reconstruction of high definition picture information at the receiving end even with reception of only one channel.

This object is achieved by the features given in Claim 1. Advantageous developments of the method are given in the appendant Claims 2 to 4.

A further object of the invention is to provide an improved receiver for this method.

This object is achieved by the features given in Claim 5. Advantageous developments of the improved receiver are given in the appendant Claims 6 to 19.

At the transmitter end, a HDTV signal having high spatial and temporal resolution is split into two signals. The first signal has a low spatial but high temporal resolution and can be converted by corresponding encoding into a standard TV signal e.g. PAL, SECAM, NTSC or D2-MAC or digital with or without data compression and can be transmitted over a first band limited channel.

The second signal has a high spatial but low temporal resolution. This can be achieved for example by leaving out frames, preferably each second frame. By means of a corresponding encoder, it can be converted into e.g. a HD-MAC signal or transmitted directly in digital format with or without data compression over a second band limited channel.

At the receiver end, a complete image signal having low spatial and high temporal resolution is receivable with the help of the first channel.

In contrast to the state of the art, a complete image signal having low temporal and high spatial resolution is receivable via the second channel, from which, by suitable decoding and means for frame regeneration, an adequate spatially high resolution image signal, hereinafter referred to as HD signal, is reconstructable.

The regenerating means serve to reconstruct as far as possible the information, especially in respect of moving sequences, which was lost at the receiving end due to leaving frames out.

In order to regenerate a complete HDTV signal, both channels need to be evaluated at the receiving end. For this, especially for errors due to movement in the reconstruction of the HD image, the high temporal resolution image information of the first channel is utilised.

An information regarding the corresponding first channel is added to the signal of the second channel. Upon reception of the second channel, this information can be evaluated by the receiver to the effect that the latter, by means of a

corresponding evaluation circuit, automatically enables the reception of the first channel.

Advantageously, there thus results from the transmission system in accordance with the invention the introduction of a HDTV transmission system compatible with the conventional transmission systems wherein the first channel provides an image signal having a resolution corresponding to the present television standard and the second channel delivers a complete image signal having high spatial resolution.

Drawings

Embodiments will be explained in detail with the aid of the drawings, which depict in:

Fig. 1 a 2-channel HDTV transmission system;
Fig. 2 a transcoder in the transmitter (encoder);
Fig. 3 a transcoder in the receiver (decoder);
Fig. 4 a HD encoder (in the transmitter);
Fig. 5 a HD decoder (in the receiver);
Fig. 6 a frame regenerator;
Fig. 7 an example of the way in which a frame regenerator functions;
Fig. 8 a space-time filter.

Embodiments

Fig. 1 shows a 2-channel HDTV transmission system. A HDTV signal produced from a source is supplied to a first transmission path comprising a transcoder 1, a TV encoder 2, a TV decoder 3 and a transcoder 4 and to a second transmission path comprising a frame suppression circuit 5, a HD encoder 6, a HD decoder 7 and a frame regeneration circuit 8.

The transcoder 1 of the first transmission path reduces the horizontal resolution of the image by 2:1 and the vertical resolution by 3:2 by means of corresponding filtering. In addition, the existing non-interlaced HDTV signal is converted into an interlaced signal whereby the temporal resolution is maintained. The output signal of the transcoder 1 is supplied to the TV encoder 2 which generates a standard TV signal e.g. PAL, Secam, NTSC or D2 MAC and whose output is connected to a first transmission channel. If however, the output signal of the transcoder is stored e.g. in a digital recorder, it is passed either directly or via a data compression device to the first transmission i.e. recording, channel.

The incoming standard TV signal is decoded in a decoder 3 in the receiver of the first transmission channel. The standard TV signal is then reproducible at the output of the TV decoder 3.

The HDTV signal which is to be supplied to the second transmission path undergoes a frame suppression in order to be matched to a band limited second transmission channel. For example, with the aid of the frame suppression circuit 5, only each second frame is transmitted. It is conceivable that for signals relating to static pictures there may be a suppression of more than each second frame whereby the thus freed channel capacity is available for the coding and transmission of the remaining frames. The output signal of the frame suppression circuit 5 passes via the HD encoder 6 to a second transmission channel. The HD encoder generates either an analogue signal e.g. HD-MAC, or a digital signal which is transmitted over the channel directly or after data compression.

In the receiver of the second transmission channel, the incoming signal is supplied to the HD decoder 7. The output of the HD decoder 7 is connected to the frame regeneration circuit 8 which effects a reconstruction of the frames that were suppressed at the receiving end by utilisation of an estimate of the movement by means of a block comparison. A HD signal having high spatial resolution and a frame frequency of e.g. 50 Hz is thus reproducable at the output of the frame regeneration circuit 8 although with possible defects in the region of moving contents of an image.

In order to minimise these defects in the region of moving parts of an image and thus to achieve the high temporal resolution of the input HDTV signal, an inversion of the sampling rate conversion of the transcoder 1 is effected on the standard TV signal by means of the transcoder 4. Both signals, that of the transcoder 4 and that of the frame regeneration circuit 8 are supplied to a combination filter 9 which, by suitable weighting, delivers a HDTV signal having high spatial and temporal resolution.

Fig. 2 depicts the transcoder 1 in the transmitter. The ingoing HDTV signal is supplied to a horizontal transcoder filter 9 which lowers the horizontal sampling rate by 2:1 by suitable filtering. A basic process for doing this is described in Pirsch, P,; Bierling, M.: "Changing the sampling Rate of Video Signals by Rational Factors", Proc. EUSIPCO '83, Signal Processing II: Theories and Applications, EURASIP 1983, pp 171 - 174. Thereafter, the signal passes through a vertical transcoder filter 10 which lowers the vertical sampling rate by 3:2. The

output signal then passes through a vertical low pass followed by an interlacer 11 which carries out a frame dependent vertical sub sampling of 2:1 for the generation of an interlaced video signal.

If the HDTV signal at the input of the transcoder 1 has e.g. 1440*864 active picture elements per frame with a frame repetition frequency of 50 Hz and progressive sampling of 1:1, then the frame format will be reduced in the following steps:

1. 720*864, 50 Hz, 1:1
2. 720*576, 50 Hz, 1:1
3. 720*576, 50 Hz, 2:1

Fig. 3 depicts the transcoder 4 in the receiver. The incoming standard TV signal which is in the form of digital sampling values is supplied to a de-interlacer 12 which generates a video signal in the format 720*576, 50 Hz, 1:1 from a video signal in the format 720*576, 50 Hz, 2:1 by extraction of frame dependent lines and interpolation of the intermediate lines. This signal is supplied to a vertical transcoder filter 13 which regenerates a signal in the format 720*864, 50 Hz, 1:1 by a vertical sampling rate conversion of 2:3. By means of a subsequent horizontal transcoder filter 14 having a horizontal sampling rate conversion of 1:2, there results a signal whose format of 1440*864, 50Hz, 1:1 is comparable to the HDTV input signal.

Fig. 4 depicts the HD encoder 6. The HDTV input signal passing through the frame suppression circuit 5 is supplied to a mode selection circuit 23 as well as to a block-detection circuit 31. Either an inter- or intra- frame mode is selected for the coding of the input signal in the mode selection circuit 23, by comparison of the input signal with the output signal of the block-detection circuit 31. The coding occurs e.g. uniformly for a block containing 8*8 picture elements. If for example, the deviations of the current image from the preceding image are large, then an intra- frame coding takes place. In the other case, for the purposes of data compression, an inter- frame coding is used. In the inter- frame mode, the image signal is predicted along determined motion vectors and the difference signal between the original and the predicted signal is passed-on. In the intra- frame mode, the input signal itself is passed-on. The block-detection circuit 31 determines a motion vector for each current block. The motion vector can be determined for example from the minimum sum of the absolute values of the differences, the minimum sum of the change of energy or minimum variance. Following the mode selection circuit 23, the signal is supplied to a discrete cosine transformer 24. Its output signal

is sorted in a sorter (scanner) 25 and thereafter supplied to a weighting circuit 26 and a quantiser 27. The output signal of the quantiser 27 is supplied to a coder 28 and also, for the reconstruction of the image signal, via a circuit for the inverse weighting 36, an inverse sampler 35 and an inverse discrete cosine transformer 34, to a block reconstruction circuit 33 whose output is connected to a frame store 32.
The coder 28 receives as input signal, quantised weighted transformation co-efficients in the order determined by the sampling. For the data compression, it carries out a coding having variable word lengths and provides coded coefficients and addresses as output signal. This is supplied to a video multiplexer and buffer store 29. The data stored in the frame store 32 is data relating to the previous frame. It is needed in order to determine a movement information for a current block. To do this, the position of a block of the current frame incorporating for example 8*8 picture elements is varied in a search area of the preceding block incorporating e.g. 16*16 picture elements with the aid of the so-called block matching, until a location of the current block is found in the preceding block at which the least deviations are identified. From this thus resulting position, a vector is determined which is supplied to the mode selection circuit 23 and to a coder 30. Similarly, this coder 30 also carries out a coding of variable word length and passes-on the coded motion vector together with the corresponding signal data to the video multiplexer and buffer store 29 for the intermediate storage. For the control of the quantisation, the buffer store 29 is connected to the quantiser 27.
The result of the mode selection is supplied to the video multiplexer and buffer store 29 and, for the correct reconstruction of the blocks, to the block reconstruction circuit 33.
The output signal of the buffer store 29 is supplied at a constant data rate to the second transmission channel.

Fig. 5 depicts the HD decoder 7 and a buffer store and video multiplexer 15. Each output of the buffer store 15 leads to a respective decoder 16 and 21. One output of the decoder 16 leads via an inverse weighter 17, an inverse sampler 18 and an inverse discrete cosine transformer 19 to a block reconstruction circuit 20. The output of the block reconstruction circuit 20 leads to the frame regeneration circuit 8 as well as to a frame or block store 22. Likewise, the output of the decoder 21 containing the decoded motion vectors leads to a further input of the frame or block store 22.

The addresses and co-efficients are decoded into their original form in the decoder 16. The decoder 21 does the same thing for the motion vectors.
An information lead 54 extends, from the buffer store 15 to the block reconstruction circuit 20, the information as to whether the block was coded in inter- or intra- frame mode. A further lead 15 leads from the buffer store 15 to the decoder 16 for transmitting the state of the buffer and information regarding the quantisation status.

Fig. 6 reproduces the frame regeneration circuit 8. The output signal of the HD decoder 7 is supplied to a frame store 38. One output of the frame store 38 leads to a frame interpolation circuit 37, a further output to a frame store 39 and a multiplexer 40.
Further inputs of the frame interpolation circuit 37 carry further data from the HD decoder 7, e.g. the motion vectors 53 and the coder mode information 54 i.e. information about inter- or intra- frame coding. An output of the frame interpolation circuit 37 leads to the multiplexer 40. A HD signal having 1440*864 picture elements, 50 Hz, 1:1, hereinafter referred to as a HDTV TV signal, is available at the output of the multiplexer 40.

The manner in which the frame regenerator 8, Fig. 6 functions is illustrated in Fig. 7 with the aid of a uni-dimensional example. Each $2n+1^{th}$ frame from the HD decoder is stored in the frame store 38, the previously transmitted $2n-1^{th}$ frame being held in the frame store 39. The intermediate frame 2n was suppressed at the transmitting end by the frame suppression circuit 5.

Fig. 7 depicts the signals on the frame interpolation circuit 37. One input carries the output signal 46 of the frame store 39 having the frame information 49 and 50. The second input carries the output signal 48 of the frame store 38. The output signal 47 containing the image information 51 is supplied to the multiplexer 40.
If block 52 of the just processed frame was transmitted over the channel in intra- frame mode, then block 51 of the intermediate frame 2n is determined directly, on a block basis, from the frame 2n-1 and the frame 2n+1, by a point by point like averaging of the image contents. This is not illustrated in Fig. 7.
If on the other hand, inter- frame coding is present, then the motion vector 53 of the block 52 is known from the HD decoder. For block 51 of the frame which is to be interpolated, the block 50 of the frame 2n-1 (46) displaced by half of the motion vector 54 is utilised.

Moreover, the frame 2n can be generated by interpolation of the picture elements from the frames 2n-1 and 2n+1 each oppositely displaced by half the motion vector.

Fig. 8 illustrates the space-time filter 9. The temporally high resolution, spatially interpolated TV image, which was generated by the transcoder 4 and which thus has a format corresponding to the HDTV image, is supplied to an adder 41. Likewise, the output signal of the frame regeneration circuit 8 is supplied to the adder 41. The adder 41 determines the sum of the absolute grey value differences of the two differently regenerated image signals in a point-by-point manner using an n*n window. The sum forms a value Z per window size n*n.
Factors for weighting the TV and HD image signals are developed from the value Z in the circuit 43. Thus, the TV signal is multiplied by a in a multiplier 42, the HD signal by 1-a in a multiplier 44. In dependence on the value Z, the weighting factor a can have a value between 0 and 1.
If the value Z is large, i.e. if defective interpolation results have occurred in the frame regenerator 8, Fig. 6, due to large movements, then the factor is a=1 and thus the image information from the TV signal is used. If on the other hand, the value Z is very small, i.e. if the picture content is static for example, then the data from the HD signal is used as this represents the original spatially high resolution from the source to the sink.
The results of the multiplication by the multipliers are supplied to an adder 45 whose output signal corresponds to the original HDTV signal.
The HD images transmitted in the second transmission channel are emitted directly from the output of the combination filter 9, corresponding to a=0 for the entire image.

The method of regenerating the picture is carried out at the receiving end by evaluating both channels. For this, the images generated by the previously described frame regeneration processes are combined as follows. The differences, between the temporally high resolution, spatially interpolated HDTV TV signal that was generated by transcoding and which corresponds in format to the HDTV image, and the HDTV HD image generated by frame interpolation, are calculated point for point. The sum of the absolute grey value differences of the two differently regenerated image signals are determined and weighted in a point-by-point manner using an n*n window. A factor a in the region between 0 and 1 is determined by the weighting. The HDTV TV and HDTV HD image signals are coupled with the weighting factor a as follows: the HDTV TV signal is multiplied by the factor a, the HDTV HD signal by the factor 1-a

If, in the regeneration of the HDTV TV signal defective interpolation results have occurred due to large movements, then the factor a=1, and thus the image information from the HDTV TV signal is used. If on the other hand, the value is very small, i.e. if the picture content is static for example, then the data from the HDTV HD signal is used as this represents the original spatially high resolution from the source to the sink.

In accordance with the invention, the weighting factor a is set at 1 if the weighted sums of the absolute grey values exceed a threshold value which is lower than 1. Up to this threshold value, the value of the weighting factor increases proportionally from 0 to 1.

In addition, the weighted addition of the two channels may be improved further by evaluated HD decoder information i.e. information regarding the transmission mode, the quantisation status or the movement of the block.

Claims

1. Method for the transmission of a wide bandwidth, temporally and spatially high resolution image signal obtained at the transmitter end over two transmision channels of narrower bandwidth, wherein a first transmission channel transmits a first complete image signal of a known norm of low spatial and high temporal resolution, characterised in that, a second transmission channel transmits a second complete spatially high resolution and temporally low resolution coded image signal which, alone or combined with the first image signal, can be decoded and reproduced by an improved receiver, wherein the generated image signal corresponds to the temporally and spatially high resolution image signal which is to be transmitted and reproduced and wherein the first image signal can be decoded and reproduced by a standard receiver.

2. Method according to Claim 1, characterised in that, the second transmission channel transmits at most each nth frame of the second image signal where n = 2, 3, 4, ..., .

3. Method according to Claim 2, characterised in that, the second image signal is transmitted digitally coded for the purpose of data compression, wherein, in particular, motion vectors are determined and are transmitted together with an information regarding the type of coding.

4. Method according to any one or more of Claims 1 to 3, characterised in that, an additional information which contains information regarding the first transmission channel is transmitted in the second transmission channel.

5. Improved receiver for a method according to any one or more of Claims 1 to 4, characterised in that, the receiver incorporates a HD decoder (7) and a following frame regeneration circuit (8, 37), which decode the second image signal alone, and, in conjunction with a subsequent combination with the decoded first image signal decode into a temporally and spatially high resolution image signal and in so doing carry out a picture element block reconstruction in accordance with the type of coding of the second image signal, wherein transmitted motion vectors are also supplied to the frame regeneration circuit (8, 37).

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6. Receiver according to Claim 5, characterised in that, the frame regeneration circuit (8, 37) generates an image signal having increased frame frequency from the received decoded second signal by means of decoded mode information (54) and/or data of the motion vectors (53).

7. Receiver according to Claim 6, characterised in that, for the generation of a frame 2n, the frame 2n-1 or 2n+1 displaced blockwise by half the motion vector is utilised, wherein n = 1, 2, 3, 4, ..., .

8. Receiver according to Claim 6, characterised in that, for the generation of a frame 2n, the frames 2n-1 and 2n+1 oppositely displaced by half the motion vector are interpolated on a picture element basis, wherein n = 1, 2, 3, 4, ..., .

9. Receiver according to Claim 6, characterised in that, with an intra- frame coding, for the generation of picture elements of a frame 2n, corresponding picture elements from corresponding decoded picture element blocks of the frames 2n-1 and 2n+1 are averaged, wherein n = 1, 2, 3, 4, ..., .

10. Receiver according to any one or more of Claims 5 to 10, characterised in that, the receiver incorporates a transcoder (4) with a de-interlacer (12) which generates non-interlaced frames from the first image signal by extraction of frame dependent lines and interpolation.

11. Receiver according to Claim 10, characterised in that, the transcoder (4) incorporates, connected one after the other, a vertical transcoder filter (13) and a horizontal transcoder filter (14) for the sampling rate conversion.

12. Receiver according to any one or more of Claims 5 to 11, characterised in that, a space - time filter (9) incorporates an adder (41) whose inputs are connected to the outputs of the frame regeneration circuit (8) and the transcoder (4), that the output signal (Z) of the adder (41) is supplied to a weighting circuit (43), that a first multiplier (42) is connected to the output signals of the transcoder (4) and the weighting circuit (43) and a second multiplier (44) to the output signals of the frame regeneration circuit (8) and the weighting circuit (43) and the outputs of the multipliers (42, 44) are connected via an adder (45).

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13. Receiver according to Claim 12, characterised in that, for the avoidance of movement defects as well as for the adoption of the spatial resolution of the decoded second image signal, within picture element blocks on a picture element basis, the absolute grey differences between the picture elements of the current picture element block of the frame 2n and the picture elements of the current picture element block of the frame 2n -1 reconstructed from the first image signal are added without interlacing via a window and therefrom a weighting factor a is determined for each picture element of the frame 2n, wherein n = 1, 2, 3, 4, ..., .

14. Receiver according to Claim 13, characterised in that, the non-interlaced frame generated from the first image signal is multiplied on a picture element basis by the weighting factor a lying between 0 and 1 and the frame 2n by 1-a.

15. Receiver according to Claim 14, characterised in that, the weighting factor a has the value 1 when the weighted sum of the absolute grey differences lies above a threshold.

16. Receiver according to Claim 15, characterised in that, below this threshold, the weighting factor a rises proportionally to the weighted sum of the absolute grey differences.

17. Receiver according to Claim 13, characterised in that, for the determination of the weighting factor a, additional data from the HD decoder (7) is drawn upon, in particular regarding the transmission mode, the quantisation status and/or movement information.

18. Receiver according to any one or more of Claims 5 to 17, characterised in that, an evaluating circuit for the additional information is provided which upon reception of the second transmission channel automatically switches in the first transmission channel.

19. Receiver according to Claim 18, characterised in that, the receiver incorporates two receiving devices.