

"Fernseh- und Kinotechnik", 34th year, Issue No. 2/1980, Pages 41 - 48 describes a process for a compatible enhancement of the detail resolution for colour TV transmission systems. The process is known as offset sampling and uses planar pre- and post-filtering. Similar sampling processes, known as Sub-Nyquist Sampling Processes, are described in "A Single Channel HDTV Broadcast System - the MUSE - ", NHK Laboratories Note, Serial No. 304, September 1984.

In the process referred to above the signal is transmitted via a band-limited channel, whereby an element of the signal within a frequency division range, which produces the enhanced resolution, is not transmitted in the original spectral position but is shifted by offset sampling or offset modulation into a carrier frequency position, a so-called offset position. For example a signal element, which may not be transmitted by a normal TV channel with a 5 MHz bandwidth, is transposed by offset modulation into a frequency position within the channel, which may be transmitted together with the actual baseband video signal of 0-5 MHz via the normal TV channel. In the known process the sampling modulation frequency, i.e. the frequency of a signal, which brings about the offset modulation, is outside the bandwidth of the transmission channel. At the receiving end the signal transposed into the offset position must be converted by offset demodulation back to its original frequency position, in order that it can bring about the enhanced resolution. To return this signal element to its original spectral position a synchronous post-sampling/demodulation is required at the receiving end. In this process the spectral elements transmitted in a base position plus the spectral elements returned from the carrier frequency position to their original position by offset demodulation, are joined together by a Nyquist filter. In the case of a compatible design the additional signal information carried in the channel is a problem for standard receivers. The result, depending upon the way the additional information is distributed over two or more fields of the standard interlacing system, is flicker interference of varying frequency. If the information for luminance and colour is not transmitted free from crosstalk (PAL, NTSC, SECAM), the additional signal information causes additional crosstalk problems. To improve compatibility EP-A-0 146 694 discloses a modulation process equivalent to the offset sampling (offset modulation) with a lowering of the amplitude of the additional signal information on the transmission side.

A synchronisation process, which ensures synchronous post-sampling or offset demodulation at the receiving end is described in EP-A-0 158 770. This synchronisation process works with a phase reference signal, which, in the case of the half sampling/modulation frequency, lies in the 6 dB point of the Nyquist filter.

With the switch to a modulation process, as described in EP-A-0 146 694, it is no longer essential for telecommunication reasons to design the entire system with a Nyquist channel. This means that different criteria may be used to divide the spectrum

of total information within the bandwidth of the transmission channel.

To achieve a further improvement in compatibility, when using the offset modulation process with a PAL system, DE-A 34 35 264 proposes a low-pass filtering of the additional signal information. In this way the overlap range between transmitted chrominance information and additional luminance information (resolution enhancement) is reduced and the compatible reception is no longer visibly impaired by cross-colour distortions produced by the offset modulation.

If a low-pass filter is used, the spectrum of total information is not divided symmetrically as it is with a Nyquist filter. The frequency band division is asymmetrical. This means that the phase-sensitive point of the spectral summation may no longer be represented by a reference signal of the half modulation frequency.

The aim of the invention is to design a process of the type already described, which facilitates an offset demodulation at the receiving end, which is synchronous with the offset modulation on the transmission side whilst retaining compatibility with existing television standards such as NTSC, SECAM, PAL, MAC and taking account of an asymmetrical frequency band division between the spectral elements transmitted in a base position and the spectral elements of an enhanced resolution.

This aim is solved by the invention described in claim 1. Advantageous embodiments of the invention are described in the dependent claims.

With the solution as provided by the invention two oscillations, each of a different frequency, transmit the information for the phase via the spectral summation at the receiving end of the base video signal (0-5 MHz) and the video signal obtained by the offset demodulation on the one hand and the information for the offset modulation phase. The advantage of this is that the summation of the video signal transmitted in the baseband and the video signal obtained by the offset demodulation, which will bring about the enhanced resolution, may ensue from a random edge characteristic of a low-pass for the first-mentioned signal and a high-pass for the second-mentioned signal. In this case it is assumed that the summation is effected by a corresponding complementary high-pass/low-pass split, whereby the frequency fb of the first oscillation lies in the edge intersection. This provides a greater degree of freedom for the frequency position of the overlap range between the two aforementioned video signals i.e. the intersection of the characteristics of the low-pass for the first video signal and of the high-pass for the second video signal. This means that the distance between this critical frequency range and other signals also being transmitted, e.g. a PAL colour carrier, may be designed to advantageous effect i.e. at a distance which is sufficient to avoid interference.

The invention is explained below by means of the drawings. They show

- Fig. 1 a block diagram for the realization of the process as per the invention,
- Fig. 2 the position of the additional signal information i.e. of the additional spectrum, low-pass filtered and amplitude-reduced and
- Fig. 2a with a compatible transmission and
- Fig. 2b after offset demodulation and increase in amplitude,
- Fig. 3 the spectral position of the two oscillations representing the reference signal,
- Fig. 4 a block diagram for the phase control at the receiving end and
- Fig. 5 a block diagram of an embodiment of the invention with two transmission channels.

The following symbols are used in the description below:

- fb = frequency of the oscillation S1 of the reference signal transmitted first
- fo = maximum frequency of the broadband video signal Y available on the transmission side and at the receiving end following offset demodulation
- fo-fb = frequency of the oscillation of the reference signal transmitted second.

In Fig. 1 the luminance signal Y is connected to the input terminal 1. This signal contains the spectral elements for an enhanced resolution and for example has an increased bandwidth of 7 - 8 MHz. By means of an overlay circuit 2, which is described in greater detail in EP-A-0 158 770, the oscillations S1 of a reference signal with a frequency fb are inserted into a vacant line in the vertical blanking gap in each field, e.g. lines no. 15 and 328, for the duration of these lines. By means of an offset modulator 3, which is described in greater detail in EP-A-0 146 694, the oscillations S1 with the frequency fb are converted by the offset modulation frequency fo into oscillations S2 with the frequency fo-fb. In the summation stage 4 the oscillations S1, S2 with the frequencies fb and fo-fb are put together and are available for transmission at the output terminal 6 on the transmission side. Transmission is via the transmission channel 7, so that the oscillations S1, S2 with the frequencies fb and fo-fb are available for processing at the input terminal 8 at the receiving end. The sum total resulting from oscillations S1, S2 with the frequencies fb and fo-fb is conveyed to the offset demodulator 9, which is analogous in design to the offset modulator on the transmission side. The offset demodulator 9 works in the unregulated state with an

oscillation S3 with the frequency f_o' , which is produced with the help of synchronous signals such as line synchronization pulses in a PLL circuit in the frequency recovery circuit 11. Initially the oscillation S3 with the frequency f_o' has a random phase angle. After completion of the offset demodulation of the oscillations S1, S2 with the frequencies f_b and $f_o - f_b$ the phase angles of the resultant oscillations present at the output of the offset demodulator 9 are compared in the phase control circuit 10 with the oscillations with the frequencies f_b and $f_o - f_b$ available at terminal 8. The resultant control is such that the initially random phase angle of S3 is regulated to an oscillation S4 with the reference phase angle of f_o . This means that there is phase synchronization between the offset modulation on the transmission side and the offset demodulation at the receiving end.

The base video signal of about 0 - 5 MHz transmitted via the channel 7 and the video signals of about 5 - 8 MHz produced by offset demodulation are conveyed to the circuit 12 for asymmetrical frequency band division. Such a circuit is described in greater detail in DE-A-34 35 264. The luminance signal Y with the increased bandwidth of about 8 MHz is then available at the output terminal 13 at the receiving end for image reproduction with an enhanced resolution.

Fig. 2a shows the position within the transmission channel 7 of the low pass filtered and amplitude-reduced additional signal information, i.e. the additional spectrum Z produced by the offset modulation for the purpose of enhancing the detail resolution.

Fig. 2b shows the entire spectrum of the luminance signal Y as available at the receiving end at the terminal 13 after offset demodulation with an increase in amplitude during stage 9 and a frequency band division during stage 12. It may be seen that this spectrum, with about 8 MHz, has a greater bandwidth than the transmission channel 7, with about 5 MHz. The summation of the spectral elements transmitted in the baseband and the spectral elements of the additional spectrum offset with f_o by the offset demodulation is effected via the edge characteristic f , whereby the most sensitive phase point is represented by the oscillation S1 with the frequency f_b .

Fig. 3 shows the spectral positions of the oscillations S1, S2 of the reference signal, as produced on the transmission side by the layout shown in Fig. 1, relative to the transmission channel 7. In the PAL television standard (PAL (G)) the specified frequencies f_o , f_b may have the following values:

f_o	=	7.8 MHz
f_b	=	4.7 MHz
$f_o - f_b$	=	3.1 MHz

In this case f_o corresponds approximately to the highest frequency of the spectrum produced at the receiving end as per Fig. 2b.

Fig. 4 shows a block diagram of the phase control circuit 10 at the receiving end as per Fig. 1.

The oscillation S1 of the frequency fb and the oscillation S2 of the frequency (fo - fb) influenced by the modulation phase ϕ_s are conveyed via the transmission channel. As a result the following signals are available at the receiving end for control purposes:

$$\cos [2 \pi f_b.t] + \cos [2 \pi (f_o - f_b).t + \phi_s] \quad (1)$$

The offset demodulator 9 at the receiving end operates initially in an unregulated state with a frequency fo', which is marked with a random phase ϕ_e . The frequency fo' is obtained from the line synchronization pulses by means of a frequency recovery circuit (PLL) 11, whereby the phase relation is

$$f_o'.t = f_o.t + \phi_e. \quad (2)$$

The modulation of the oscillations as per equation (1) with fo' as per equation (2) is described by

$$\{\cos [2 \pi f_b.t] + \cos [2 \pi (f_o - f_b).t + \phi_s]\} \cdot 2 \cos [2 \pi f_o.t + \phi_e] \quad (3)$$

After offset demodulation point a in Fig. 4 is as follows:

$$\begin{aligned} & \cos [2 \pi (f_b + f_o).t + \phi_e] + \cos [2 \pi (f_o - f_b).t + \phi_e] \\ & + \cos [2 \pi (2f_o - f_b).t + \phi_s + \phi_e] + \cos [2 \pi f_b.t + \phi_e - \phi_s] \end{aligned} \quad (4)$$

As the stable operating point of the control lies at the phase difference $\phi = 0$, the input signals as per equation 1 are conveyed to a 90° phase modifier 14. The phase detector (PD) 15, designed as a multiplier, receives the signals as per equation 4 and at point b the input signals phase displaced by 90°.

Point b:

$$\begin{aligned} & \cos [2 \pi f_b.t + \pi/2] + \cos [2 \pi (f_o - f_b).t + \phi_s + \pi/2] \\ & = -\{\sin [2 \pi f_b.t] + \sin [2 \pi (f_o - f_b).t + \phi_s]\} \end{aligned} \quad (5)$$

After being filtered by the low pass TPR 16 of the closed loop a multiplication of the terms as per equation 4 and equation 5 delivers a control direct voltage for the phase modifier 17. For the control voltage U_0 the calculation results in

$$U_0 = \sin (\phi_e - \phi_s).$$

The control now operates in such a way that the argument of the sinusoidal function is now zero i.e.

$$\phi_e = \phi_s.$$

The phase modifier 17 has an operating range of $\pm 180^\circ$.

In Fig. 5 the signals described in Fig. 1 from the output of the overlay circuit 2 and the offset modulator 3 are not summated but are transmitted via separate transmission channels 7a and 7b. This may be appropriate if one transmission channel is insufficient for reasons of bandwidth, if there are cable runs with limited bandwidth or if the two signals are registered on separate tracks of a magnetic tape. When transmission takes place in this way via two separate transmission channels different propagation times may arise with the result that the signals at the receiving end no longer have an identical time

relation. To compensate for this time difference the signals from the two transmission channels 7a, 7b pass through two controllable delay elements 19, 20 in the receiver circuit 18 and in addition are conveyed to the inputs of a propagation time comparison stage 21. In the comparison stage 21 the time relation between the signals from the two channels 7a, 7b is determined. Preferably the line synchronization pulses of the signals from the two channels control a start/stop oscillator, which produces a pulse string of a constant frequency between two line synchronization pulses, which themselves should be isochronous. The number of pulses is counted with a meter. The meter reading is a measurement of the time difference between the line synchronization pulses of the signals from the two channels 7a, 7b. The meter reading is converted into an analog or digital control voltage, which, depending upon the direction of the time difference, controls the delay element 19 or 20 and thus the effective delay time in the signal path in such a way that the signals at the inputs of the summation stage 22 have an identical time relation. In the propagation time comparison stage 21 both the vertical synchronization pulses and the line synchronization pulses of the signals from the two channels 7a and 7b are compared in the way described. The delay elements 19, 20 are controlled in such a way that at the inputs of the summation stage 22 the signals from both channels 7a, 7b have an identical time relation i.e. vertical synchronization pulses and lines of an identical ordinal number in each case of an image in the two transmission channels 7a, 7b are coincident in time. This control is so accurate that the maximum residual difference does not exceed $\pm$ half the duration of the frequency f_0 . This degree of accuracy is required by the receiver circuit as per Fig. 4 which is connected at the terminal 8. The delay elements 19, 20 have a basic propagation time so that the effective delay in the signal path may in each case be either increased or reduced by the control voltage emanating from the phase comparison stage 21. Such circuits, called timing error equalization circuits, are known in the field of magnetic recording technology and described in the "Video Handbook" by van Wetzels.

The circuits described so far are for analog signal processing using offset modulation/demodulation. It is possible in principle to design all devices so that they are suitable for digital processing. In this case the use of modulators/demodulators would be replaced by the use of digital samplers/post-samplers.

The process as per the invention is suitable both for the transmission of television signals and for the synchronization, at the receiving end, of television signals recorded say by means of video recorders.

Patent claims

1. Process to achieve a compatible enhancement of the resolution of a colour TV system, whereby on the transmission side one signal element is transposed by an offset modulation (3) in the frequency and at the receiving end is re-transposed by an offset demodulation (9), whereby a reference signal for the offset demodulation (9) is transmitted during a vacant line of the vertical return time, characterised by the following features:
 - the reference signal consists of a first oscillation (S1) with a first phase and with the frequency f_b , which represents the edge intersections of the edges to be combined at the receiving end - and belonging to the partial spectra formed by the offset modulation - and of a second oscillation (S2) with a second phase and with the frequency $f_o - f_b$, which is formed from the difference between the offset modulation frequency f_o to be used and the frequency f_b ;
 - the frequency f_b of the first oscillation (S1) is higher than half the offset modulation frequency f_o ;
 - with the aid of the two oscillations (S1, S2) the offset demodulation (9) at the receiving end and the summation of the partial spectra are carried out in correct phase relation by using the two oscillations (S1, S2) as reference signals for a phase control (10) at the receiving end;
 - the phase control circuit (10) at the receiving end sets an offset modulation frequency f_o' (S3) as generated by a frequency recovery circuit (11), which has an initially random generated phase angle identical in its phase to the offset modulation frequency f_o on the transmission side.
2. Process as claimed in claim 1 characterised in that the output voltage (S4) of a phase control circuit (10) is connected at the receiving end to the offset demodulator circuit (9) and to the inputs of this phase control circuit are connected the input and the output of the offset demodulation circuit and the output (S3) of a frequency recovery circuit (11) controlled by the line synchronization pulses.
3. Process as claimed in claim 2 characterized in that the frequency of the output voltage (S3) of the frequency recovery circuit (11) is equal to an integer multiple of the line frequency of the video signal.
4. Process as claimed in claim 1, characterised in that



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the initial oscillation (S1) and the second oscillation (S2) are transmitted by separate transmission channels (7a, 7b).

5. Process as claimed in claim 4, characterised in that at the receiving end the signals of the two transmission channels (7a, 7b) are conveyed to a propagation time comparison stage (21), the output voltage of which representing the difference in propagation time of the two transmission channels (7a, 7b) exerts an influence on delay elements (19, 20) in the first and/or second transmission channel (7a, 7b) in such a way that the transmitted signals at the outputs of the delay elements (19, 20) have an identical time relation.
6. Process as claimed in claim 5 characterised in that the delays of the delay elements (19, 20) are controlled in such a way that the signals at the outputs of the delay elements (19, 20) have a time difference of no more than half the duration $\pm 1/(2 \cdot f_0)$ of the maximum frequency (f_0) of the video signal representing the enhanced resolution.
7. Process as claimed in claim 5 or 6, characterised in that in the propagation time comparison stage (21) a comparison is made of the time relation of the vertical synchronization pulses and of the line synchronization pulses of the signals of the two transmission channels (7a, 7b), in such a way that lines of an identical ordinal number of the two transmission channels are coincident in time at the outputs of the two delay elements (19, 20).

