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An HDTV encoder for PALplus transmissions, supplemented with a digital residual signal

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An HDTV Encoder Design for the Transmission of PALplus signals, supplement with a Digital Residual Component

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Abstract— This paper discusses the design of a video encoder which will enable PALplus compatible HDTV transmissions, by embedding a digital residual component within the standard analogue PALplus television signal. The design strategy includes a 2-D diagonal prefilter, together with a QMF band-splitting filter pair, from which the residual is initially derived. The performance of these filters is reviewed, especially in respect of the errors introduced by aliasing and crosstalk distortion. A number of different digital modulation techniques are then examined for the transmission of the residual signal and a qualitative appraisal of their effectiveness presented.

I. INTRODUCTION

CURRENTLY there are a number of activities which are directed towards the launch of digital television services [1], [2]. During 1995, the PALplus standard was officially introduced in Europe as a straightforward, compatible extension to the standard PAL system, overcoming the inherent limitations and introducing a wider 16:9 picture format. PALplus is completely analogue and so is therefore less flexible for further extensions. This paper proposes an encoding scheme, which enables standard PALplus receivers to process HDTV signals without losing compatibility and more importantly with no additional bandwidth requirement.

Fig. 1 provides an insight to the proposed encoder. The incoming HDTV signal is initially di-
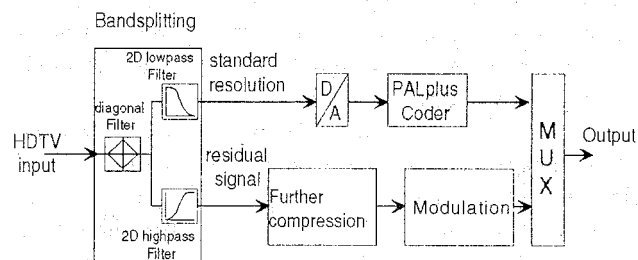
Fig. 1. Block diagram of the proposed encoder

agonally filtered, before being subsequent band-split for compatibility, into a low and high resolution component, further referred as the residual. The low resolution signal is then PALplus coded, whereas the residual undergoes further digital compression and suitable modulation techniques before being integrating together with the PALplus signal.

II. PRE-PROCESSING

As mentioned, the input signal is first decomposed into the standard resolution component, which is subsequently PALplus coded and a residual signal necessary for generating the original resolution at the decoder. The novel approach of a Dual Channel Subband structure is proposed for this pre-processing [3]. It is based closely upon the principles of a standard two dimensional subband coding implementation, with the crucial difference that a 2-D diagonal prefilter is additionally employed to suppress all oblique frequencies in the spatial plane. Subjectively, the loss of such information is acceptable, since the probability of diagonal components occurring is generally much less than for either horizontal or vertical frequen-
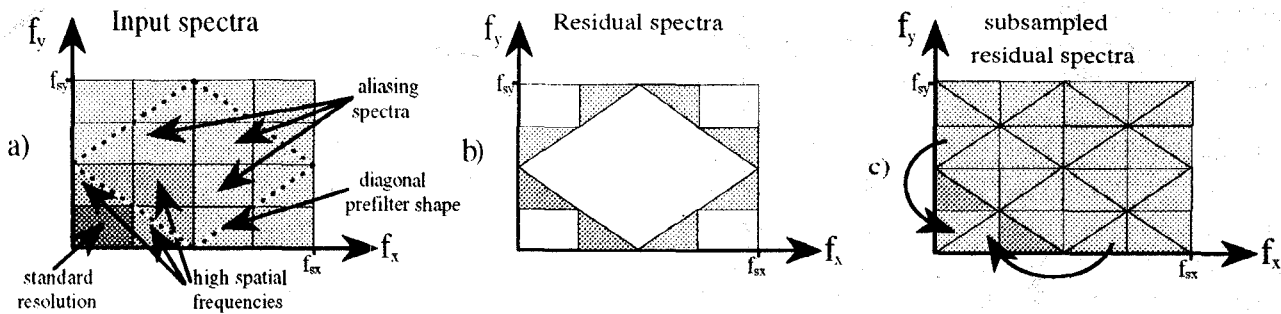
Fig. 2. a) input spectrum with respect to the four subbands; b) highpass bands with diagonal pre-filter; c) decimated highpass signal

cies. The spectral effect of diagonal filtering is illustrated in Fig. 2 where it clear that the input signal bandwidth is halved without compromising either horizontal or vertical resolution. By employing a 2-D QMF analysis bank to obtain the lowpass band, the residual now consists of the two highpass wedged-shaped frequency components shown in Fig. 2b. Following subsampling by a factor of two, these spectral components fold back into the same frequency range as the lowpass band, so the requisite bandwidth of the highpass subbands becomes equivalent to that of the lowpass signal (see Fig. 2c) and the total number of subbands required for transmission is reduced to only two.

The general case of a separable two-dimensional QMF analysis section has been modified and due to the combination of the two highpass wedge-shaped frequency components (Fig. 2), crosstalk effects occur upon both aliased and normal signal components.

The major source of crosstalk error is due to the non-ideal response of the diagonal filter. When the high resolution horizontal and vertical wedges are folded back after subsampling (see Fig. 2c), an overlapping occurs along the diagonal frequency components. The effect of this error upon the residual spectrum is indicated by the dark oblique criss-cross pattern in Fig. 3, and leads to a horizontal / vertical frequency distortion, which causes high horizontal frequency components to become crossed-over and appear as vertical frequencies and vice versa [4]. A comprehensive explanation, together with a special filter arangement for compensating some of the cross-talk com-
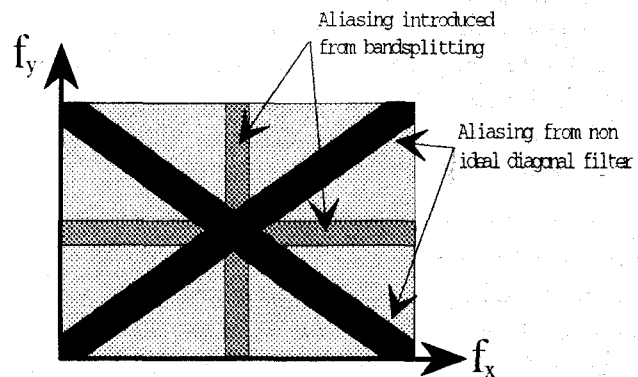

Fig. 3. Frequency overlap following the subsampling of the residual signal

ponents is given in [3].

The finite transition bandwidth of the two band-splitting filters, followed by the subsampling process, also raise alias components, denoted by the horizontal and vertical criss-cross pattern in Fig. 3 and these will encroach upon the normal resolution signal, as well as the residual spectrum. Such aliasing is clearly visible in standard resolution pictures, so the design of the band-splitting filters has to balance the subjective picture quality with filter complexity. Using a filter arrangement which conforms to the QMF design rules [5] this distortion can be removed from the reconstituted signal at the receiver.

III. DIGITAL MODULATION TO FACILITATE EMBEDDED DIGITAL TRANSMISSION

Previous research activities in exploring sub-channels in television signal have primarily been focused upon HDTV or EDTV compatibility ap-

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proaches [6], where the additional resolution is analogue modulated to be transmitted within these channels. Current activities focus upon employing additional digital transmissions together with television signals mainly for multimedia services, which is known as Datacasting. Several suggestions have been made for the NTSC-System [7], but both PAL and PALplus provide equally good potential for additional digital sub-channels. The PALplus signal consists of two different components which are suitable for further digital modulation, the standard video signal, which is PAL-coded using the Colorplus technique and secondly the vertical helper, which is used to carry the additional information to reconstitute the widescreen picture format.

A. Additional colour carrier modulation

In contrast to the NTSC-system, where the colour-difference signals I and Q are quadrature modulated, PAL alternates the phase of the colour carrier phase V-component between 90 and 270 degrees from line to line. This switching results in different spectral locations for the two colour components in the three dimensional frequency plot of the television, with the V-carrier modulated on its 90-degree phase and the U-carrier on its 0-degree. Hence, both frequencies can be additionally modulated by using the orthogonal component and provide two sub-channels of 0.5 MHz bandwidth each. The various effects appertaining to the standard PAL signal and a full explanation of the complete system is given in [8].

B. Additional helper modulation

The PALplus helper is modulated with the zero degree phase component of the colour sub-carrier, but the idea of using the quadrature component for integrating the additional information though attractive, is impractical because single sideband modulation is used for the helper signal.

A specific subcarrier arrangement with a slightly different carrier frequency to that of the PALplus helper, which is a 25Hz frequency offset realised by alternating the helper carrier phase between 0 and 180 degrees from field to field, results in different locations within the vertical / tempo-
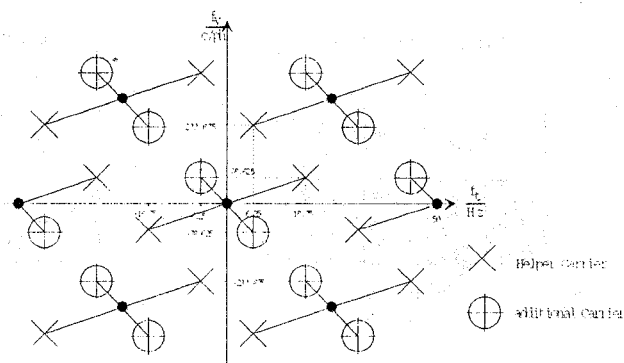

Fig. 4. Positions of the PALplus helper and additional carrier in the vertical /temporal plane

ral spectral plane as illustrated in (Fig. 4).

This affords the possibility of using a temporal filter for separating the two components, because after a 312 line delay the additional carrier is in-phase, while the helper carrier is anti-phase.

For the standard PALplus helper, demodulation of this additional data will appear as extraneous noise at high vertical frequencies. This degrades the overall visual quality of the signal because of the imbalance in the signal-to-noise ratio for the helper and standard signal part. Further attenuation of the additional component however overcomes this problem.

The digital modulation of this additional carrier is proposed to be a modified Quadrature Amplitude Modulation (QAM) technique, where the in-phase component is bandlimited to approximately 0.5 MHz, rather than 3.5 MHz for the qudarature part. Depending on the order of the QAM, a bit-rate in the range 2 Mbit/s to 8 Mbit/s is possible.

IV. FURTHER DATA COMPRESSION

The bandwidth of the residual component is equivalent to that of the standard resolution signal, so when integrating this within a PALplus signal, supplementary compression techniques are required, in order to ensure that the data rate fits with the embedded digital channel.

The raw residual data rate is approximatly 80 Mbit/s, so a compression ratio between 10 and 40 must be achieved. An adaptive quantizing scheme, as proposed by Amor [9] was under investigation, but using only this technique the req-

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uisite compression ratio will not achieved. Using the ubiquitous Discrete Cosine Transformation (DCT), which is defined in the Joint Picture Expert Group (JPEG) still-image compression standard [10], raises the problem that the decorrelation property of the DCT has little or no effect on a differential signal input such as the residual. However, the coefficient quantizing provides good potential to fit the spectral components to the perception of the human eye.

Of much greater promise are those data compression techniques or hybrid systems, that are based upon temporal methods and temporal subsampling [4].

Considerably care has to be exercised in general, when using lossy intrafield compression techniques, because both the residual component and the standard resolution signal, consist of spectral elements which are intended for alias compensation at the TV receiver. Distortions introduced by the lossy nature of a compression algorithm can very easily compromise picture quality by introducing additional aliasing artefacts. It is not always the case that such distortion is visually perceived by the viewer, however the subjective impression of the picture quality must be taken into account in the course of realising any such algorithm.

V. CONCLUSIONS

This paper has presented the details of an encoder design which enables PALplus compatible HDTV transmissions by supplementing the analogue TV signal with a digital residual. Various design issues have been examined and a digital modulation strategy proposed based upon a modified PSK solution of a subcarrier arrangement which has a slightly different carrier frequency to that of the PALplus helper signal. Appropriate data compression methods for the residual signal were also discussed.

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