A DIGITAL CODING SYSTEM FOR VIDEO SIGNAL TO DISTRIBUE VIDEO MONITORING IMAGES ON COAXIAL NETWORKS

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ABSTRACT

This article describe a digital coding system for video signals called redundancy estimation ADPCM which provide a good quality for transmission of video in 6.5 Mbits or 1.6 Mbits channel.

It uses a differential pulse-code modulation (ADPCM), adaptative prediction and adaptative quantization based on redundancy estimation.

This system could be use for video monitoring on return way of cable networks, so that it could be possible to manage several video monitoring sources in the same numeric channel.

1. INTRODUCTION

Usually analog coding and frequency multiplex system are used in a full duplex coaxial networks to carry return video signals from subscribers taps to the headend.

As video monitoring signal needs 5 MHz bandwith and while return way bandwith is no more than 25 MHz, it is then difficult to transmit multiple number of large bandwith signals on a network. Management of these signals for monitoring or video conference is then complex and not useful in coaxial network.

On the other hand, it is easier to use digital signals, as it is necessary in monitoring, when one needs a large adressing capacity in the system. Nevertheless, digital techniques applied to video need commonly a high rate for transmission, which is incompatible with the small bandwith capacity of return way in coaxial cable.

In fact monitoring signals generally contained a lot of redundancy and it is possible to use highly efficient reduction techniques to decrease the transmission rate needed for those type of signals, in such a way that it could be possible to use simple and low cost receivers. ADPCM techniques seems to be very appropriate for such a purpose and that is the reason why TDF has developped a digital processing system adapted for video monitoring signals transmission.

2. THE PROCEDURE OF COMPRESSION BASED ON DPCM

Generally in the DPCM function, the actual (digital) value of a pixel is compared with a predicted value, and the difference is transmitted. Si :e typical picture has much redundancy, the uncertainty of the difference signal is much less than that of the actual signal. This can result in a low channel capacity requirement for transmitting the video signal information. However, it is difficult to obtain satisfactory picture quality at a lower transmission rate by using a conventional DPCM technique. Therefore, the development of a more efficient bit rate reduction technique is necessary.

To meet this requirement, TDF has recently developped a new coding technique called redundancy estimation ADPCM coding (RE-ADPCM). RE-ADPCM employs both adaptive prediction and adptive quantization based on redundancy estimation. Using RE-ADPCM, a digital TV coding system developed at CERLOR laboratories can transmit a TV program at a rate lower than 6.5 Mbits/sec.

ADAPTATIVE PREDICTION AND ADAPTATIVE QUANTIZATION

Adaptative prediction : In adaptative prediction coding system, several different predictors are operated simultaneously.

However, only one of them will be selected as an actual predictor by a special selection algorithm. The optimum selection method is to choose a predictor which gives the minimum prediction error for each input sample.

<u>Adaptive quantization</u> : Similarly, the adaptive quantization coding system employs several different quantizers simultaneously. Each quantizer has a quantizing level and a quantizing step size which are different from those of the other quantizers. One of them is adaptively selected to fit the prediction error.

It is very important to find an effective selection algorithm which can choose the predictor and quantizer to obtain low bit rate. The redundancy estimation is such an algorithm.

<u>Redundancy estimation</u> : The redundancy estimation algorithm is as follows :
Two successive frame, denoted by frame 1 and frame 2, are stored in memory. Each is grouped into blocks of size 8 x 8 pixels denoted by Bi. The block Bi is divided into two sub-blocks of size 8 x 4 pixels denoted respectively by Bi1 an Bi2 as shown in Fig.2.1. The group of the circled element is Bi1 and the rest of the element is Bi2. Here, i is the ordinal number of the blocks which varies from 0 to 2047.

The redundancy characteristic of block i is described by the correlation coefficient Ci,

$$Ci = f\ (Ci1(11),\ Ci2(11),\ Ci(12))$$

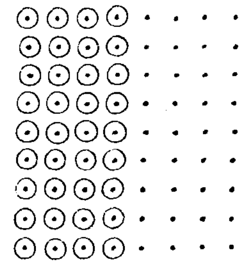
where Ci1(11) and Ci2(11) are separatly referred to as the intraframe correlation coefficient of block Bi1 and Bi2, Ci(12) is referred to as the interframe correlation coefficient of block Bi.

Ci1(11)s are obtained by calculating the dispersion of the value of each pixel of block Bi1 and Bi2. Ci(12)s are computed by comparing the value of each pixel of block Bi in frame 1 with the one of corresponding pixel in frame 2. According to the values of Ci, the predictors and quantizers are selected. The details will be described in 3.2. The correlation coefficient Ci is represented by a 4-bit word.

<u>3. THE CODING SYSTEM AND ITS ENCODING ALGORITHM</u>

<u>3.1. Configuration</u>

This system is designed on the basis of the redundancy estimation ADPCM coding described above.



<u>Fig. 2.1. Pixel arrangement in a block</u>
Bi = Bi1 + Bi2

A block diagram of the system is shown in Fig. 3.1.

<u>3.2. Preprocessing</u>

The preprocessing circuit is shown in Fig.3.4. it is consisted of an analog low-pass video filter, a comb filter, an amplifier clamping circuit, a clock generator, an analog-to-digital (A/D) converter, and a subsampling circuit. The amplifier and clamping circuit provide isolation to the input from any following circuits. The amplifier must have a wide dynamic range without loss of linearity to handle a widely varying unclamped input video signal. The clamp circuit is used to restore the DC level to the video signal.

The amplifier drives a clock generator circuit which produces clock signal synchronized to the incoming video signal. These signals include a line clock at the horizontal line rate, a frame clock, a composite blanking, a composite sync and a sampling pulse. The exact nature of these clocks signals must be tailored to the needs of the specific realization of the circuits they drive.
The 2:1 subsampling pattern shown in fig. 3.2. is used, only the circled samples are transmitted. For decreasing the degradation caused by the subsampling, for example zigzag of oblique edge, we employ two comb filters to increase the bandwith up to theorical Nyquist limit.

So, while the sampling frequency used is close to 10 MHz, it is possible to transmit a bandwith of 4.5 MHz without aliasing distorsion due to subsampling procedure.

The comb filter responses and its position at the transmitter and receiver are illustrated in the Fig. 3.3. The subsampling frequency is chosen to be an odd multiple of one-half the horizontal line frequency so that the baseband spectrum and the replicated spectrum interleave. This is made possible by the well-known property of video spectrum of clustering the energy at multiples of the horizontal line frequency. Consequently, the video baseband spectrum and the replicated spectrum tend to interleave and can be separated by a comb filter.

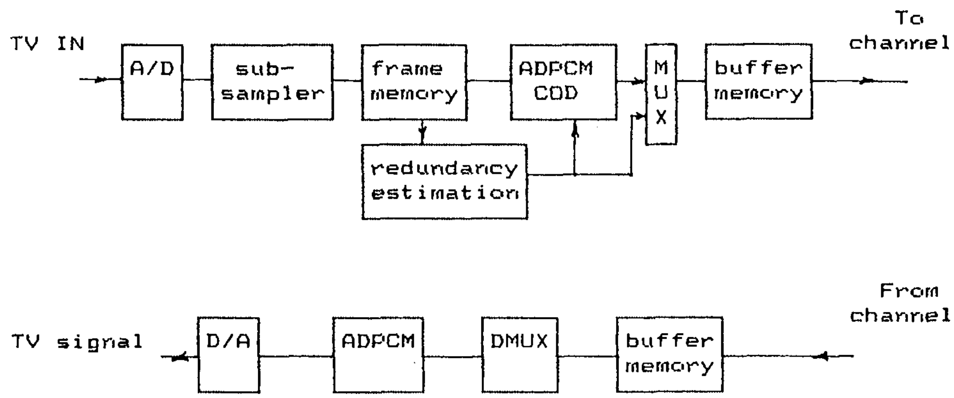


FIG. 3.1.
The configuration of the RE-ADPCM coding system

The comb filter responses and its position at the transmitter and receiver are illustrated in the Fig. 3.3. The subsampling frequency is chosen to be an odd multiple of one-half the horizontal line frequency so that the baseband spectrum and the replicated spectrum interleave. This is made possible by the well-known property of video spectrum of clustering the energy at multiples of the horizontal line frequency. Consequently, the video baseband spectrum and the replicated spectrum tend to interleave and can be separated by a comb filter.

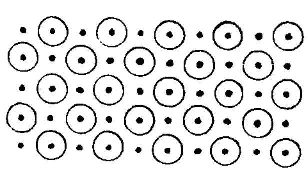


Fig. 3.2.
<u>The subsampling pattern</u>

The full 8-bit output of A/D converter is used. The 8 bit output provides 256 possible levels from o to 255 in decimal.

<u>3.3. Application of the result of</u> redundancy estimation to <u>adaptive</u> prediction and adaptive quantization.

As mentionned before, Ci is the correlation coefficient of block Bi, and Ci = f(Ci1(11), Ci2(11), Ci(12)). Ci1(11) and Ci2(11) are the intraframe correlation coefficient of block Bi1 and Bi2 respectively. Ci(12) is the interframe correlation coefficient of block Bi.

The information rate of block Bi can be estimated as follows :

H= (Si+M1i+M2i+I1ix32+I2ix32)/64

Si is a 4-bit word representing the correlation coefficient Ci.

Ci1(11) Ci2(12)	Quantizer	Bit/pixel	Ci(12)	Quantizer	Bit/pixel
1	0 bit	0.1875	1	0 bit	0.0625
0.5	2 bit	2.1875	0.5	2 bit	2.1875
0	4 bit	4.1875	0	4 bit	4.1875

<u>TABLE 1</u>
Value of Ci and corresponding information rate

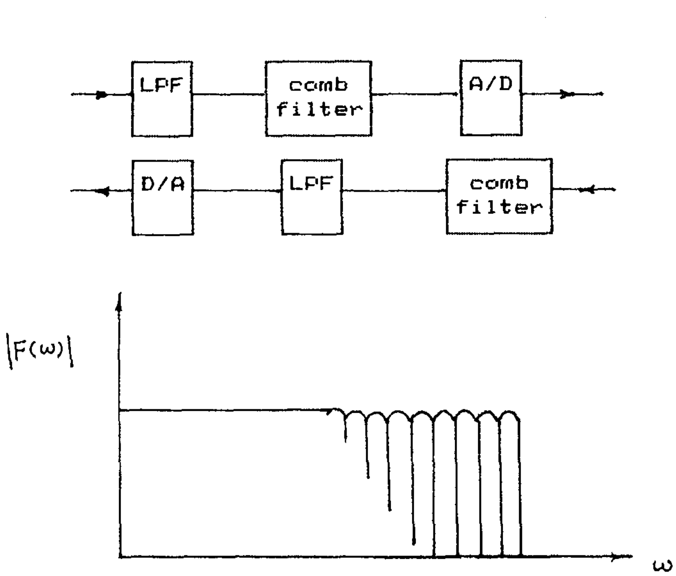


Fig.3.3.
Comb filter's position and its response characteristic

M1i and M2i are the averages of block Bi1 and block Bi2 respectively, coded on a 4 bit word lenght. I1 and I2 are the bit rates of each pixel of block Bi1 and Bi2, which vary from 0 bit to 4 bit. In the following, the selection of the quantizers is described first.

Suppose that Ci1(11), Ci2(11), and Ci(12) take on one of the values 1, 0.5 and 0. The selection of the quantizers and the corresponding bit rate is shown in table 1.

Ci1(11)=1 denotes the case when the difference between the value of each pixel of block Bi1 and the average of this block is quite low. The dispersion of this block is considered to be zero, and only the average of this block is transmitted. At the receiver, the element in the block is reproduced with the average alone. The information rate in this case is 0.1815 bits/pixel.

Ci(12)=1 means that the interframe prediction error of block Bi is so small and therefore it is assumed to be zero. Hence no bit is transmitted for this block. At the receiver, the picture element concerned is reproduced with the interframe prediction values, and the transmission rate is reduced considerably. The information rate in this case is 0.0625 bits/pixel.

The other value of Ci1, are used to quantized the intraframe prediction error on a 2-bits or 4-bits word as shown in table 1.

According to the values of Ci1(11), Ci2(11), and Ci(12), the predictors are selected for blocks Bi1 and Bi2 to obtain the low prediction error. For block Bi1, if Ci(12) > Ci1(11) the intraframe predictor is chosen, else the interframe predictor is chosen instead. For block Bi2, if Ci(12) > Ci2(11) the intraframe predictor is selected, else the interframe predictor is selected. In the case when Ci(12) = Ci1(11) and/or Ci(12) = Ci2(11), the intraframe predictor is selected for block Bi1 and/or block Bi2 to decrease the "dirty window" effect, for a moving image.

3.3. PREDICTORS AND QUANTIZER :

Predictors :

In this study, two predictors that have been proven effective are used. The first simplest predictor is the same pixel in space in the previous frame to the present pixel and is P0. The second predictor is a combination of two pixels from the previous field and present line and is (½ P1 + ½ P2) shown in fig. 3.6. x is the pixel predicted.

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   P1
. . . . . . .
. . x . . . .
. . . . . . .
   P2
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FIG. 3.6

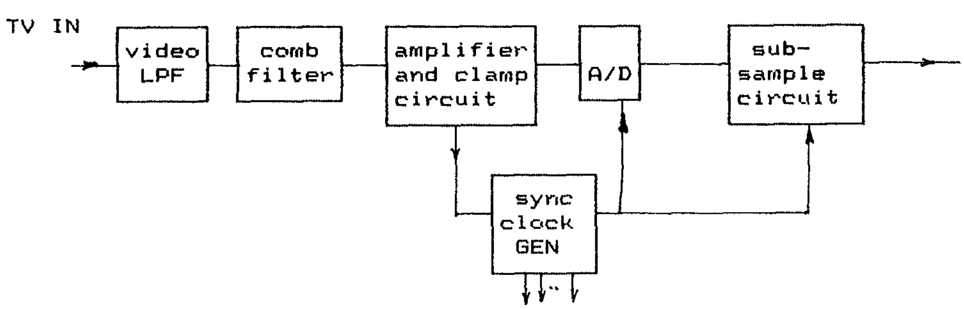

Fig.3.4.

The preprocessing synoptic

These predictors are adaptively selected on the basis of the Ci. Ci is the correlation coefficient of block Bi. The same predictor is used for all element of a block.

Quantization :

The 8 bit/pixel prediction error output data of the ADPCM function is quantized using two tapered non-linear quantizers. The transfer function of the quantizer used in this study is specified in fig. 3.7. The characteristic was chosen according to the subjective experimentation made by CCETT.

The quantizer significantly reduces the number of levels to be coded from 256 to 16 for 4-bit quantizer and from 256 to 4 for 2-bit quantizer. The same quantizer is used for all pixels of a block. The two quantizers are selected by the value of Ci, where Ci is the correlation coefficient of Bi. When the buffer occupancy variable = 0, the 4-bit quantizer is forced to be used.

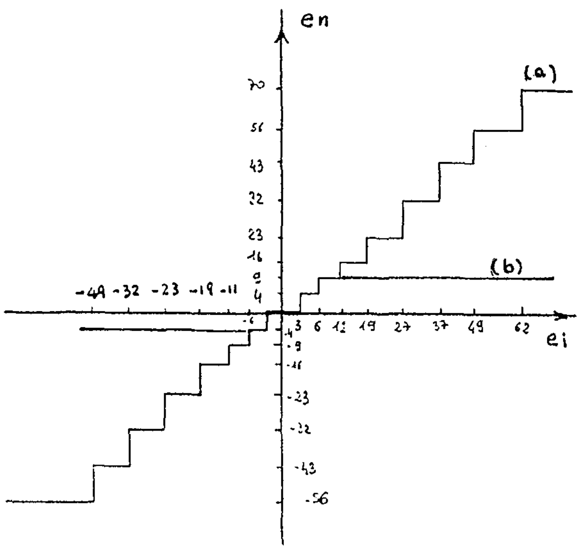

FIG. 3.7

The characteristic of the quantizer

(a) 4-bit quantizer (b) 2-bit quantizer

3.5 BUFFER :

The widely varying output data rate is smoothed in the buffer to a constant bit rate for transmission. Information is read out of the buffer at a constant rate of 1.6 - 6.5 M bits/sec. The size of the buffer is 3 Mbits.

Buffer-occupancy is determined, that is, how many bits are stored or how full the buffer is. The value of the buffer occupancy (VBO) varies linearly with the actual buffer occupancy, with 0 corresponding to an almost empty buffer and 15 corresponding to almost full. When VBO = 15, the input to the buffer stop. This condition prevents buffer overflow. The prediction error data and the value of Ci in this case are not transmitted. The reconstructed pixel values at the receiver are set equal to the predicted values. The interframe predictor is used throughout in this case. When VBO = 0 the 4-bit quantizer is used, and the actual value of each pixel is quantized using 4-bit quantizer.

3.7 TRANSMISSION FORMAT :

The transmission format is shown in fig. 3.8

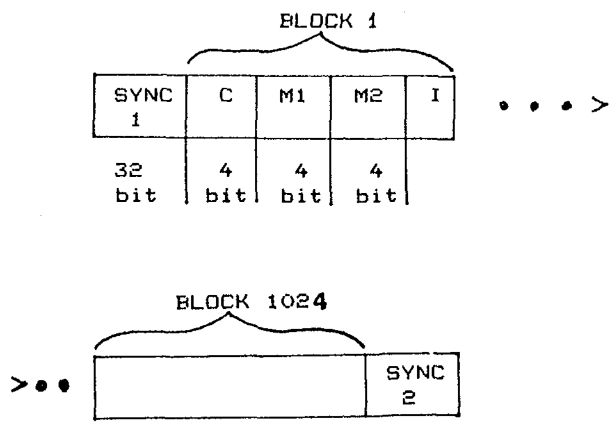

FIG. 3.8 transmission format

The first element consisting of 32 bits in length is the field synchronization signal. This synchronisation signal must be a unique pattern that does not occur in any other part. The receiver continuously looks for this pattern and, upon recognition, signals the start of another field. The sync is followed by 1024 blocks. The arrangement of information in each block is identical.

The first element in a block is the correlation coefficient of the block, which is 4 bits in length. M1 is the average of block Bi1 and the M2 is the average of the block Bi2, which have separately 4 bits word length. It contains the information of each pixel of the block, and its length varies from 0 to 255 bits.

4. THE CODING PERFORMANCE OF THE SYSTEM :

The resolution of picture in this system is 512 lines x 512 pixels.

We have chosen three typical test pictures to evaluate the coding algorithm. These pictures are shown in fig. 4.1 - 4.3. Figures 4.4 - 4.6 show the coded version of the three test pictures. The degradation caused by the encoding will be discussed below.

At 6.5 M bits/sec, i.e 1 bit / pixel

Picture impairment is not severe under this condition . Nevertheless, some slight degradation which can be observed are as follows :

- for the region in which the gray levels changes gradually, the block structure can be perceived, for example the mountain in fig. 4.1. This is due to the usage of the block average. In the flat parts and fine parts of a scene, this deterioration is not observable at all.

- some smear noise is observed when the objects move in the flat blackgroud. This is due to temporal prediction of interframe. But random noise is relatively slight.

At 1.6 M bits/sec i.e (0,25) bit / pixel

For the still picture, the coded picture quality is the same as coded at 6.5 Mbits/sec. If there is a movement associated with the image, two cases must be considered separately. In the first case, all objects in the image move. As a result, the coded image has the same movement but not as fluid. However, if only a certain small object move, for example in a wide scene with several car moving, then the degradation is not observable.

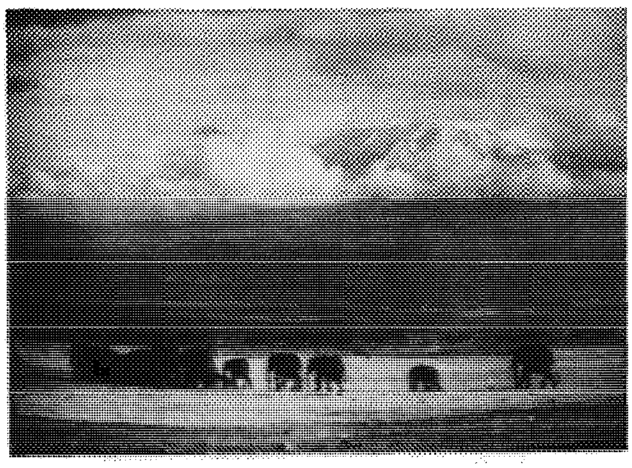

FIG. 4.1

FIG. 4.4

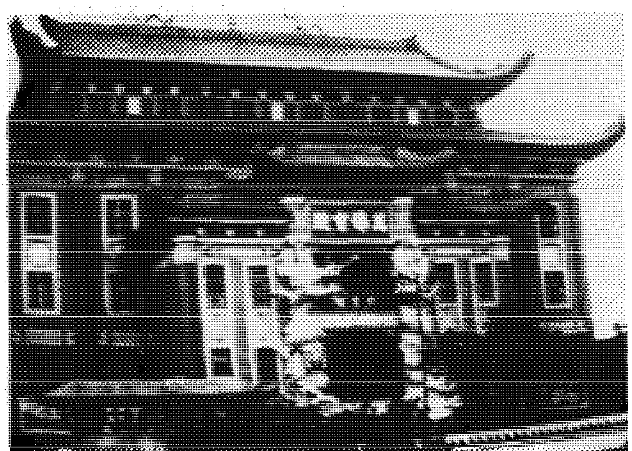

FIG. 4.2

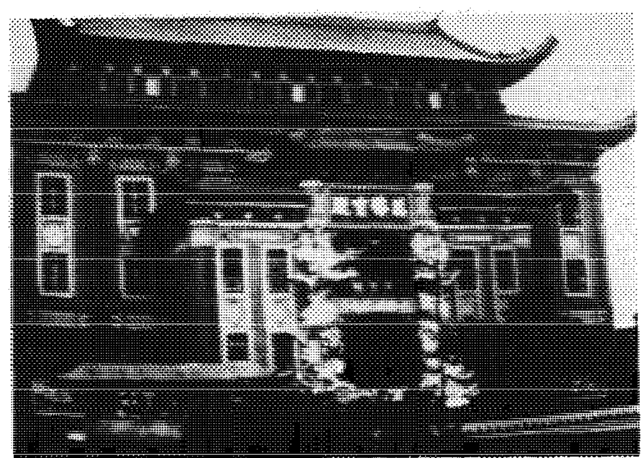

FIG. 4.5

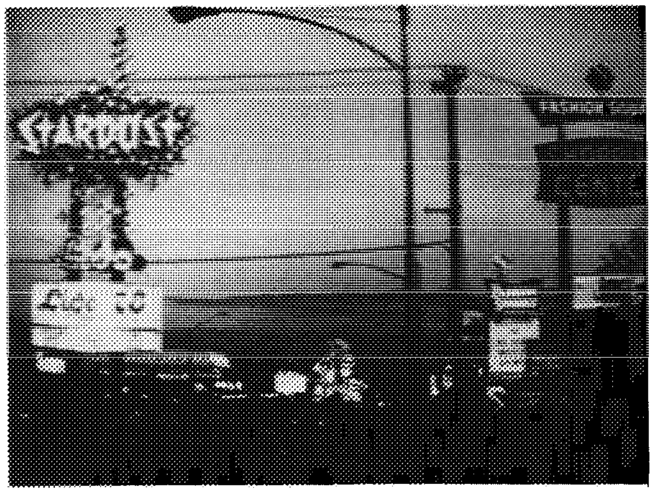

FIG. 4.3

FIG. 4.6

5. USING THE SYSTEM IN COAXIAL NETWORK

The RE.ADPCM has been developped for coaxial network to transmit monitoring video signals with a high resolution and good quality, with the following attempt.

Return way of coaxial network has a small bandwith capacity compared with the services that should be provided. In fact analogic video monitoring signals, either on splitting networks or star coaxial systems, would need the main capacity of the return way so that it could not be possible to experiment other services. In another way video monitoring only concerns a few subscribers. So, such application would not be really economically balanced.

Such discussion exists in France on new private coaxial networks, and most of cable operators think more on interactive system for suscribers in a pay per view or low data rate purpose than for monitoring.

Nevertheless the need for monitoring signals is real and no satisfactory system exists excepted with optical fibers.

It is then reasonnable to consider that the only way monitoring video signals should be implemented in a coaxial system is in the digital domain.

Another reason why analogic video signals should not be transmitted in coaxial network is the bad noise performance of coaxial networks return way. It is common to consider that noise figure of return way in coaxial networks result from an additive operation of the noise figures of each of the amplifiers installed on the network.

That is why taps should be used on the main splitting point of the networks. However the result is that it would be difficult to get a good quality for video signals transmitted in the return way on large coaxial networks. Hence a digital transmission with a high efficiency modulation could offer a better (C/N) ratio.

As it was previously explained, a 1.6 Mbits data rate transmission should be highly sufficient for implantation of digital video monitoring signals.

When a higher rate could be used, it would be then possible using the RE-ADPCM techniques to realize a flexible management system where the instantaneous rate of the channel would be adapted depending whether information has changed or not.

In this case, instantaneous rate for a digital source would be variable form 0.8 Mbits/s for still picture, to 3.2 or 6.5 Mbits/s depending on picture quality required.

On another point we have to consider whether a 4.5 MHz bandwith resolution is really necessary for video monitoring. When a lower bandwith should be sufficient, the same RE-ADPCM techniques would provide a lower rate of transmission only by decreasing the sampling frequency.

Meanwhile we did not experiment a high efficiency multiplex system. 'We think that an 8 Mbits channel would be sufficient to manage more than 15 monitoring video camera. The reason is that in case of video monitoring, only a small part of the picture is moving, so the RE-ADPCM transmission rate needed is very low and shouldn't be more than 1.6 Mbits/s.

6. CONCLUSION

It has been proved that a RE-ADPCM system permit a considerable bit rate reduction, without severe degradation, and that using this technique it would be possible to realize low cost receivers and encoders.

Those system seems so to be well accurate for video monitoring, but also should be employ for other applications like for example tele-teaching.

This could be a good opportunity for cable networks operator in France to put on cable networks large bandwith services as well as other data transmission services.

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