/4

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DEVELOPMENT OF COMPONENT CODING OF TELEVISION SIGNALS IN CANADA

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CRC

ABSTRACT

This note gives a description of a new component coding scheme for television signals recently developed at the IBA in the U.K. for the 625 line system and in Canada for the 525 line system. The signals, known as MAC for Multiplexed Analog Components, are well suited for FM modulation over satellite links. It shows that the improvement in the quality of the video signal over the current NTSC signal makes it amenable to large screen display. The paper also describes other important attributes of the MAC signal, namely the audio and data channels and the scrambling scheme.

1. THE DEFECTS OF NTSC

The composite signal of NTSC was designed some 30 years ago. It was optimized for AM transmissions and for compatibility between monochrome and colour receivers. This led to the inclusion of a colour sub-carrier at 3.58 MHz, near the top end of the 4.2 MHz baseband spectrum of the luminance signal. It is the presence of this sub-carrier that creates the most noticeable defects of NTSC: noise, cross-luminance, cross-chrominance, differential gain and phase.

1.1 NOISE

In AM transmission, the power spectrum of the noise is constant throughout the frequency range of the received baseband video signal. The amplitude of the colour sub-carrier was chosen in part to balance the signal-to-noise ratio of the luminance signal and of the colour difference, signal. On the other hand, in FM transmissions, the noise voltage spectrum is triangular, increasing linearly with frequency in the range of baseband frequencies of the received video signal. The colour sub-carrier is therefore subjected to a higher noise level in FM transmissions than in AM transmissions. This high frequency noise is translated into a much more visually noticeable low-frequency chrominance

.../2

noise when the sub-carrier is recovered in the decoder by folding it and centering its spectrum around the zero frequency. This low-frequency chrominance noise manifests itself by the constant movement of a granular structure in areas of saturated colours in pictures.

1.2 CROSS-COLOUR AND CROSS-LUMINANCE

The presence of the chrominance sub-carrier in the spectrum of the luminance signal also creates cross talk between the luminance information and the chrominance information. In the cross-colour effects, high frequency luminance detail is interpreted by the decoder as chrominance and gives rise to spurious coloured patterns. The worst case of this effect occurs at and around the sub-carrier frequency of 3.58 MHz. It creates Moiré fringes of colour in areas of pictures which contain closely spaced black and white stripes. It also manifests itself in areas of sharp luminance transients corresponding to a frequency spectrum extending to the high frequencies of the baseband signal. The effect on the sharp luminance transients makes the edges of the objects appear as if they were coloured and the resulting colour is usually not related to the adjacent environment. The opposite effect of cross-luminance is most noticeable as a moving dot on coloured vertical edges.

These effects can be somewhat diminished by the use of filters. In most receivers, a notch filter removes the luminance information near and around 3.58 MHz, therefore decreasing the spatial resolution of the image. This decrease in resolution is somewhat less noticeable than the effect it tries to eliminate. In the most expensive receivers, a comb filter may be used which effectively separates the luminance and the chrominance information

.../3

above 2.5 MHz. However, the comb filter is only effective to remove the cross-colour on each line (i.e. for any object having vertical edge structure). For objects having inclined line structure which is the general case, any line-spacing approaching a 3.58 MHz frequency component or any sharp luminance or chrominance contrast will still show the cross-chrominance and cross-luminance effects.

These effects can not be eliminated in composite signals, they can only be diminished or traded for less noticeable effects such as limiting the horizontal luminance resolution of composite signals above 2.5 MHz when viewed on a colour receiver. However, the same signal viewed on a quality monochrome receiver would have a resolution equal to the resolution of the transmitted signal i.e. 4.2 MHz but would still show the cross-luminance defects (moving dot).

1.3 DIFFERENTIAL GAIN AND DIFFERENTIAL PHASE

Non-linearities in the transmission channel cause differential gain and differential phase to occur. The colour sub-carrier is very sensitive to this kind of distortion. In NTSC signals, differential gain causes desaturation or oversaturation of the colour information depending on the luminance content of the picture. On the other hand, differential phase causes a change in hue with changing luminance. The later PAL systems conceal this defect by alternating the phase of the two chrominance axis from one line to another. This feature is the main difference between PAL and NTSC.

In satellite systems, the characteristics of the satellite output filter can be well controlled but the characteristics of the filters in the ground receivers may not be as easily controllable particularly for low-cost receivers. The non-linearities caused by poor amplitude and group delay response of the filters would have detrimental effects on NTSC signals.

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1.4 Aliasing

The problem of aliasing is not a problem of transmission but rather a problem inherent to the scanning and to the display. The effect of aliasing is commonly known as the wagon wheel appearing to roll backward in movie projection. It is caused by the undersampling (at 24 frames per second in films) of a fast movement.

In the interlaced scanning and display of television pictures, there are two phenomena which cause aliasing. Firstly, the interlace display causes vertical aliasing which results in a lack of vertical resolution and secondly, the non-continuous nature of the scanning and display (at 30 frames per second) causes temporal aliasing.

In television pictures, vertical aliasing caused by interlaced scanning can only be improved by the sequential display of the lines from consecutive fields. This requires the use of a field store at the receiver. On the other hand, increasing the rate of scanning and display from the current 30 frames per second would simply increase the frequency at which temporal aliasing is observed.

1.5 OTHER DEFECTS

There are other defects such as large area flicker, and lack of resolution which can be noticed in NTSC encoded signals under certain viewing conditions.

Large area flicker is more noticeable in peripheral vision and at low frame rate. At the frame rate of 30 frames per second for NTSC in North America, large area flicker is generally not noticeable at typical viewing distances greater than five times the picture height and under normal brightness conditions.

However, for larger screens and/or shorter viewing distances, when the peripheral vision may become more important, the threshold of perceptibility of large area flicker may be exceeded.

The lack of vertical resolution of the picture is related to the number of lines per frame and to a ratio called the "Kell" factor which takes into consideration the loss of resolution due to interlace. The lack of vertical resolution can only be remedied by removing the interlace and/or by increasing the number of lines per frame which is set at 525 lines for NTSC and 625 lines for the European systems.

Horizontal resolution is a measure of the number of picture elements resolvable on each line. The horizontal resolution is set by the maximum frequency of the baseband luminance signal which is set at 4.2 MHz for NTSC signal. This value was chosen to balance vertical and horizontal resolution of the transmitted picture. However, as previously mentioned, cross-luminance and cross-chrominance may decrease the luminance resolution. The resolution of the colour difference signals is generally less than that of the luminance signal because the human eye is more tolerant to colour differences than to tonal variations.

2 WHAT IS MULTIPLEXED ANALOG COMPONENTS (MAC)

The SECAM, PAL and NTSC signals in use today are all composite signals where a sub-carrier modulated by the colour difference signals is embedded into the luminance baseband for transmission. This situation creates some inherent defects in the received picture as described in the previous section. These three types of signals have different baseband bandwidths, synchronization schemes, colour recovery schemes, sub-carrier frequency and line and field frequencies. However, the colour television signals are all formed from the red, green and blue components of the image from the colour additive process of the tri-colour kinescope phosphors. Each video camera and display device has respectively three pick-up tubes and three electron guns, one for each of the colour components. The three colour components are then rearranged to give a luminance component used in compatible monochrome and colour receivers and colour difference signals only used in colour receivers.

Engineers at the Independant Broadcasting Authority designed a new coding scheme for the transmission of video signals. This scheme is simply the transmission of the luminance and the colour difference components multiplexed in time instead of in frequency. At any given time, only one of the components of the video signal is transmitted instead of the composite of luminance and chrominance signals in NTSC transmission. However, since the luminance component and the chrominance component need be transmitted during a one line scan (63.5 μ sec), both components need be compressed in time for transmission and expanded to their original duration for display. Compression and expansion are accomplished digitally using A/D and D/A converters and digital line storage but the transmitted information is analog and the modulation is FM.

This new coding scheme ignores some of the constraints of NTSC, avoids the presence of the colour sub-carrier and can be better optimized for FM transmission. It has been named Multiplexed Analog Components (MAC) by the IBA. MAC is a generic acronym describing the coding scheme. In fact, the IBA is currently working on the third generation of MAC. Also, there are MAC schemes which derive from the 625 line television systems and others derived from the 525 line systems. It is expected that the MAC family will grow in the future to include such things as EDTV MAC and possibly HDTV MAC.

.../7

However, at this early stage, MAC is not a member of the EDTV family because it does not provide an increased resolution over that theoretically possible with NTSC. It is often perceived as such because MAC removes or reduces the defects inherent to the presence of the chrominance sub-carrier in the NTSC coding. The most prominent defects of NTSC, namely cross-colour, cross-luminance. low-frequency chrominance noise in FM transmissions and the effect of non-linear channels are either eliminated or reduced. The most prominant defect left in the MAC picture is aliasing.

The world center of excellence for MAC is the IBA. One of the original designers of the MAC scheme, Dr. K. Lucas has recently joined Digital Video Systems Inc. (DVS Inc.) near Toronto. The company has recently developed a MAC coding scheme for the 525 line television system oriented towards the North American television market. The remainder of this paper will refer to the DVS Inc. version of MAC unless otherwise indicated.

3 THE CANADIAN MAC BY DVS INC.

The current design of the MAC by Digital Video Systems Inc. delivers more than an improved video picture. The Canadian system is basically made of four equally important components for the secure delivery of high quality video, audio and data.

These are:

- the MAC 525 line video signal,
- the high quality digital audio channels,
- the high capacity data broadcasting capability, and
- a secure scrambling scheme of almost unlimited address capability.

The system is designed for a graceful degradation of performance below FM threshold using majority voting. In other words, during an outage, the system is designed so that the video fails first, followed by the audio and finally

.../8

followed by the data. This is an extension of current practice of the broadcasting industry and ensures that the system timing and the scrambling algorithms are the last ones to fail.

Typical values for the threshold of perceptible impairment under the present MAC system are:

- C/N = 11 to 12 dB for video
- C/N = 8 dB for audio
- C/N ≤ 3 dB for timing and scrambling.

Like the IBA A-MAC system, the Canadian system is optimized for satellite transmission and uses a digital sub-carrier. In the Canadian system, the digital sub-carrier using QPSK modulation is located at 7.16 MHz, outside the video luminance and chrominance signals; it has a 2 Mbit/s. capability for the transmission of audio channels and a data channel. The data channel contains:

- error correction and concealment of the aduio and the video,
- address and error correction,
- encryption key,
- address key,
- personal and other messages,
- system timing at sub-carrier frequency.

The data channel can also be reassigned to user's need.

3.1 THE VISION SIGNAL

In the MAC transmission system, the chrominance signal is separated from the luminance signal and both are transmitted in a time multiplexed rather than a frequency multiplexed manner as illustrated in figure 1. The problem of cross-luminance and cross-chrominance is therefore eliminated. The component signals are transmitted using frequency modulation. The triangular noise characteristic of the FM channel matches reasonably well the human visual system where the perceptibility of noise decreases with increasing frequency. The effects of channel non-linearity on signal quality is minimized.

due to the absence of a colour sub-carrier.

The MAC video signal is composed of one luminance signal, Y, and two colour difference signals R-Y and B-Y. The ratio of bandwidth is 4:2:2 for Y:R-Y:B-Y. During each line scan, the luminance and one colour difference signal are transmitted. A two-line store is used to reconstruct the two colour difference signals from sequential lines in the decoder. Each line of the luminance signal is compressed from 53 μ sec to 40 μ sec and the transmission bandwidth is increased proportionnally from 4.2 MHz to about 6 MHz. Similarly, each colour difference signal is time-compressed to 20 μ sec and transmitted sequentially.

Originally, two clamping periods were thought to be necessary, as illustrated in figure 1. However, this design was found to be conservative and only the leading clamping period is in use today.

The vertical synchronization of the NTSC requires 22% of the transmission time. In the MAC system, synchronization is accomplished digitally and requires only 0.2% of the total transmission time.

The vertical blanking interval of the MAC signal is not modified from that of the NTSC and can still be used for other services such as teletext.

The digital synchronization scheme is very robust even in noisy environments, which may be representative of satellite transmission during heavy rain. Demonstrations have shown the loss of NTSC synchronization at a carrier-to-noise level of about 6 dB. The same demonstration illustrated no loss of synchronization down to 2 dB of C/N ratio for the MAC signal. This better performance of the MAC system is achieved by the highly redundant error correction scheme in the synchronization recovery from the digital sub-carrier. In the MAC system, a synchronization pulse needs to be recovered with a very

.../10

high degree of certainty once per minute and the digital clock which is synchronized on the digital sub-carrier frequency of 7.16 MHz regenerates the missing synchronization pulses.

In satellite transmission of FM television signals, threshold noise becomes apparent when the system is operated below the FM threshold. These conditions may be the result of heavy rain and/or a misaligned receiver. In the NTSC signal, the de-emphasis network transforms this noise into long horizontal white and black streaks which are subjectively annoying and difficult to conceal. Using a MAC signal and its de-emphasis network, the threshold noise does not spread to adjacent picture elements which makes it amenable to concealment. Some preliminary experiments of a concealment scheme were demonstrated showing encouraging results.

In conclusion, there are many advantages of the MAC vision signal over the NTSC signal:

- it is a time multiplexed rather than a frequency multiplexed signal
- the colour noise due to FM is less perceptible than in the NTSC
- the colour bandwidth is well over 2 MHz and consequently, the colour resolution is increased
- RGB signals of studio quality is available in the home for the first time provided that the individuals are capable of displaying it with RGB receivers
- there can be an option for digital processing (e.g. frame stores)
- more rugged synchronization
- the bandwidth can be reduced while retaining colour. Two TV pictures can be transmitted in one channel with quality claimed to be equivalent to 3/4" U-matic recorders. This is not so with NTSC where decreasing

.../11

bandwidth is mostly detrimental to colour.

- total system cost can be reduced because of the simpler RGB receiver.

3.2 THE HIGH QUALITY AUDIO

There are two options for the multi-channel high quality audio:

- two channels of very high quality with a digital sampling rate of 44.056 KHz giving a quality exceeding that of any consumer sound system.
- four channels of high quality with a sampling rate of 31.4 KHz. This gives excellent quality approaching that of most consumer sound systems.

The two options come with a 16 bits dynamic range companded to 10 bits for transmission.

These audio channels can be used for:

- stereo pairs
- multilingual channels

of future television services. It is interesting to note that studies of the EBU have concluded that there is a requirement for DBS in Europe of 8 audio channels accompanying the video. The MAC digital sub-carrier in Europe needs to have a 3 Mbit/s capability to transmit these audio channels with adequate quality. This requirement of 8 audio channels comes from the multi-lingual requirement of the European broadcasting satellites. This increased requirement in Europe is traded against power and bandwidth of the vision signal or against the quality of the audio channels or against the capacity of the data channel.

3.3 SCRAMBLING

One of the most powerful attributes of the Canadian MAC System is its scrambling scheme.

In the television of tomorrow where pay-per-channel, pay-per-view and pay-per-program will become commonplace, the scrambling of these signals is inevitable. The challenge in the development of a scrambling scheme is to provide a simple but secure scrambling method which does not affect the quality of the picture and which is low cost. The following is not intended as a comprehensive review of the scrambling of television signals but rather as an introduction to the DVS Inc. approach to scrambling.

The DVS Inc. scrambling scheme uses soft scrambling for the video and hard scrambling for the data. Majority voting is used throughout where in case of signal outage, the video fails first, followed by the audio and finally by the data.

There are basically two types of video scrambling methods:

- amplitude-based scrambling and
- time-based scrambling.

Techniques used in amplitude-based video scrambling are:

- video inversion,
- line reversal,
- line segmentation and
- line shuffle.

In amplitude-based scrambling, the non-linearities of the transmission channel may lead to the degradation of the picture quality. The magnitude of this degradation may be dependent on the technical characteristics of the scrambling system and of the transmission channel. The perceptibility of the

.../13

degradation may be more apparent in improved quality pictures than in NTSC where in the latter, the picture degradation due to the scrambling may be masked by the inherent defects of NTSC. This type of scrambling method will not be dealt with here.

There are three basic approaches to video scrambling in the time domain with little or no degradation to picture quality due to non-linearities:

- suppression of the synchronization pulse of each line,
- pseudo-random arrangement of line in each field and
- control of the horizontal blanking interval.

In the first approach, the synchronization pulse is suppressed and need be regenerated at the receiver. This is considered to be a very simple approach which is also simple to beat by the non-professional simply by using a digital clock to reconstruct the missing pulses of the "scrambled" picture.

The second approach takes the 262½ lines of each field and mixes them in a pseudo-random manner for transmission. Also transmitted to each addressee is an encryption key giving the pseudo-random sequence of the lines in the field for proper display. This approach can be very secure but unfortunately requires a field store at each receiver. This is an expensive approach considering the current state of technology.

The third approach consists of varying the period of the horizontal blanking interval in a manner which is transmitted to the addressees via the encryption key. If the variation of the period is small, the picture quality does not suffer appreciably. This is the approach which forms the basis for the DVS Inc. video scrambling scheme. This approach can be very secure and low cost; it only requires two lines of storage at each receiver. Since the MAC decoder already has a two-line store for the colour recovery, the scrambling

.../14

can be accomplished by software alone and can be low cost. This type of scrambling is also applicable at low cost to NTSC signals.

In the DVS Inc. video scrambling scheme, the line delay is a maximum of 8 to 10 μ seconds which is the range of acceptable channel linearity equivalent to imperceptible degradation of a high quality picture.

Now that the scrambling method is determined, the pseudo-random sequence of line delays need be broadcasted to millions of homes. This is the encryption code. Also needed is a mechanism to activate the home descrambler of the paying customers and turn off those of the non-paying customers. The latter functions can either be accomplished by mail or by data in the digital channel of MAC. A key and an address for each customer are needed for these functions. For a high capacity scrambling system, the total number of individual keys and addresses must be large. If routing by mail is preferred, the address may not be needed since this function may be accomplished by the postal address of the customer. In this postal mail approach, either a 32 digit number or a magnetic card representing the key for the address is inserted in the decoder. The handling of these keys by mail is claimed to be an expensive and non-secure avenue.

The mechanism preferred by the designers of MAC is to use the data channel to broadcast the encryption code and the key and address of each customer.

The number of possible addresses in the video scrambling system is given by the number of combinations in the 32 bit word address: well over one billion. Each of these combinations need be addressed frequently to enable the scrambling system of the future to respond quickly to impulse viewing. The rate at which addresses are visited in the MAC video scrambling system is one million addresses/minute.

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To guard against the possibility of breaking the code of the video scrambling system, the key and address of each customer are changed simultaneously in a pseudo-random manner at a rate of once per frame.

In addition to the soft video scrambling described above, the data channel is also hard scrambled. For the data channel the word length is 64 bit giving 1 billion X 1 billion possible addresses. These are felt to be needed for the future expansion of the system including the users of the data channel alone. The key and address of each customer can be changed by the broadcaster as frequently as once per minute.

For both the soft video scrambling and the hard data scrambling, error correction techniques are employed.

The above scrambling systems accompanying the MAC vision signal as designed by DVS Inc. is intended for the future. It is designed for very high capacity addressing with a view that a single standard will be a desirable feature for the future. Otherwise, customers may have to have multiple boxes on top of their TV receivers to accommodate the multiple standards. It is also designed for tiering to satisfy the requirement of multiple descramblers in cascade. This is felt to be an important requirement of future scrambling systems for cable systems, hotels, multiple family dwellings, etc. where the signal need be descrambled first at the point of reception and finally at the TV receiver.

In conclusion, the scrambling scheme envisaged has a number of desirable features of an ideal scrambling system:

- transmission algorithm continuity
- hard encryption
- very high capacity

.../16

- potential for single standard
- tiering capability
- secure but simple
- low cost
- no picture degradation

3.4 DATA CHANNEL

The data channel can be used for the transmission of any type of digital information amenable to broadcasting. For example:

- teletext
- telex
- computer software
- video conference
- personal messages
- etc.

These applications of the future can either be accommodated in the narrow band channel of 63 KBits/sec or can be accommodated in a channel of wider bandwidth when the maximum capacity of the scrambling system is not required. In this manner, a capacity of up to 1 Mbits/sec is available.

4. COMPATIBILITY

The problem of the compatibility of MAC with NTSC receivers is very straightforward. The MAC decoder contains two outputs: an RGB output which delivers the full improvement in the vision signal and an NTSC output which delivers an NTSC coded version of the RGB signal. A VHF modulator could also be integrated at low cost for the receivers not equipped with NTSC inputs.

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The RGB output of the MAC decoder can be used by any customer having a television set equipped with RGB input. RGB television sets are starting to appear on European markets. It is now compulsory to include RGB inputs into television sets sold in France and Germany. The North American market is expected to follow similar developments.

For those customers not having RGB sets, the NTSC coded output of the MAC decoder would still deliver an improved picture quality together with high quality audio, scrambling and data channels. The improvement in the quality of the video comes from the reduction of the effects of channel non-linearities on the MAC signal. However, the defects caused by cross-luminance and cross-chrominance would be present in the NTSC coded signal.

In satellite transmission, the problem of compatibility does not really arise. This is because none of the current television receivers is equipped to receive frequency modulated signals at 12 GHz. Television receivers of today are only equipped to receive amplitude modulated signals in the VHF and UHF bands. Therefore, two black boxes are required for the conversion: one outdoor unit and one indoor unit. The outdoor unit contains a low noise converter to amplify and convert the signal from 12 GHz down to the intermediate frequency of around 1 GHz. The indoor unit contains the tuner, the FM demodulator and AM modulator. The output is then compatible with all television receivers.

In the case of a MAC signal, the indoor unit can be equipped with three outputs: one RGB signal, one NTSC baseband and one AM-VSB signal. The only additional components required in the MAC indoor unit is an NTSC coder and an AM-VSB modulator. Of course, the functions of the NTSC decoder in the television receiver are in the case of a MAC signal performed by the MAC decoder in the indoor unit. A schematic of the MAC decoder is given in figure 2.

When scrambling of the television signal is considered, the signal is by definition not compatible and a black box is necessary to descramble the signal for the paying customers. In satellite transmission of NTSC signals, the descrambler can be part of the indoor unit. In satellite transmission of scrambled MAC signals, the descrambler is an integral part of the multifunction MAC decoder.

5. BROADCASTING SATELLITE SERVICE

A Consultative Committee to the British Government recently proposed the adoption of the MAC coding scheme (of the IBA) for the transmission standard to be used in broadcasting satellites in the U.K. One important consideration in the adoption of a MAC coding scheme is its potential use as a European standard for the broadcasting satellite service in Europe and in fact the world for the 625 line systems. The MAC system is now under consideration by the European Broadcasting Union.

It has been demonstrated that the MAC signals are compatible with the technical characteristics of the 1977 Plan for the broadcasting satellite service in Regions 1 and 3. In fact, the satellite power, the necessary bandwidth and the protection ratio of $\geq$ 63 dBW, 27 MHz and 35 dB co-channel single-entry of the 1977 Plan were considered as objectives for the design of the MAC system. In Region 2, the 525 line MAC system designed by Digital Video Systems Inc. is accompanied by audio and data channels and scrambling data included in the QPSK digital channel of 2 Mbits/sec capacity. A 24 MHz transponder bandwidth and a C/N of between 12 and 14 dB were found to be most appropriate for the transmission of the 525 line MAC signals on the basis of adequate high performance of the audio channel above threshold. In the future environment of direct broadcasting satellites, the high performance of a MAC signal may be governed more by interference than by noise. The protection ratio requirement of the 525 line MAC signal will be jointly studied by DOC and DVS Inc. In North America, a number of applicants to the FCC for the delivery of the broadcasting-satellite service in the 12 GHz band are seriously considering the 525 line MAC system for their use. The reasons for this interest are:

- MAC is optimized for frequency modulation
- MAC delivers an increased signal quality
- MAC can grow to an extended definition system
- scrambling of the satellite transmission will be necessary
- reception of 12 GHz signals is not compatible with current receivers in any case and
- MAC decoders can be integrated at low cost for large quantities.

6. PAY-TV

Additionally, MAC is of interest to the fixed satellites for the distribution of television signals. One of these applications of particular interest to Canada is Pay-TV.

Pay-TV in Canada is an expensive product offered to consumers in early '83 and it may be expected that with time, the consumer will want improved quality of both the programming and technical reception. Pay-TV will start operating in Canada with non-scrambled signals. Shortly after its introduction a decision is expected as to the choice of the scrambling scheme to be used by the Pay-TV industry. Many of the advantages of the MAC signals pertinent to the broadcasting satellites are also applicable to the fixed satellites. Of particular interest to the Pay-TV industry are:

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- the scrambling capability of the MAC signal
- the improved visual and audio quality and
- the low cost

Because of the tiering capability of the MAC scrambling system, it is possible to cascade the descrambler at the satellite receiver located at the cable head-end together with the descrambler located at each household. This requires that a MAC signal is transmitted via the cable to the household and the scrambling is governed at the earth station transmitting site. Each household need be equipped with a MAC decoder.

In a different approach, no tiering capability is required. Here, the MAC signal is transmitted to the cable head-ends and descrambled. At this point, the unscrambled NTSC output of the MAC decoder is transmitted via cable to each household. The NTSC signal on cable can be scrambled. In this scenario, the scrambling of the NTSC signal is governed at the cable head-end and each household need be equipped with the NTSC descrambler.

In either of these approaches, the minimum improvement in quality of NTSC signals comes from the absence of the effects of satellite channel non-linearities. These improvements however, may in some cases be masked by the NTSC coding and/or the cable induced degradation.

7. COST

Cost projections have been made by DVS Inc. for the production of 525 line MAC coders and decoders. Cost reduction techniques and integrated circuit technology are applied mostly to the decoders.

Assuming a small production of decoders in 1983 and a large production in 1985, the cost of the decoders is expected to approach the cost of material.

.../21

Prices quoted were $1500 to $2500 in 1983 and $300 in 1985.

The price of the coders is expected to be in the range of $15,000 to $25,000 during the same time frame.

8. EDTV AND HDTV

Current MAC signals are not of the extended definition type; they only extend the quality of the current definition of the 525 line system or of the 625 line system.

Techniques have been proposed for the provision of an extended-definition television service to the public without incurring additional cost for those who do not wish to use the extended definition facility. Vertical and temporal aliasing are the most significant defects left in the 525 and 625 line displays of the MAC picture. Aliasing is not caused by the type of signal but rather by the type of sampling and display. Any dynamic scene is sampled in two dimensions; it is sampled vertically by the line structure and temporally by the field structure. Signal processing at the receivers of those willing to pay for the extended definition would allow for the removal of vertical and possibly temporal aliasing. The use of frame stores at those receivers would give a true 525 line aliasing-free picture in a non-interlaced display. This in turn increases the vertical resolution and temporal resolution and produces pictures of a quality worth displaying on large screen displays. However it should be remembered that the horizontal definition remains unchanged.

The final step to high resolution television implies a change in aspect ratio from the current 4:3 ratio to a ratio closer to 5:3 or 6:3. This represents a fundamental change which may be accomplished in an evolutionary manner with compatibility an essential element or may be accomplished in a discrete manner by the creation of totally new television service not compatible with the current 4:3 aspect ratio.

Regardless of the compatibility aspect, the major developments required for the introduction of HDTV, are: large screen displays, efficent and low cost digital compression algorithms for signal transmission, frame stores, video tape recorders and transmission standards. The current state of these developments would indicate that the introduction of a HDTV service to the general public may be 10 to 15 years away.

The demonstrated capability of the NHK system for HDTV is a major step in the introduction of this new service to the public. The major problems still ahead are:

- standardization
- large screen displays
- transmission bandwidth
- reasonable costs.

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17/12/82

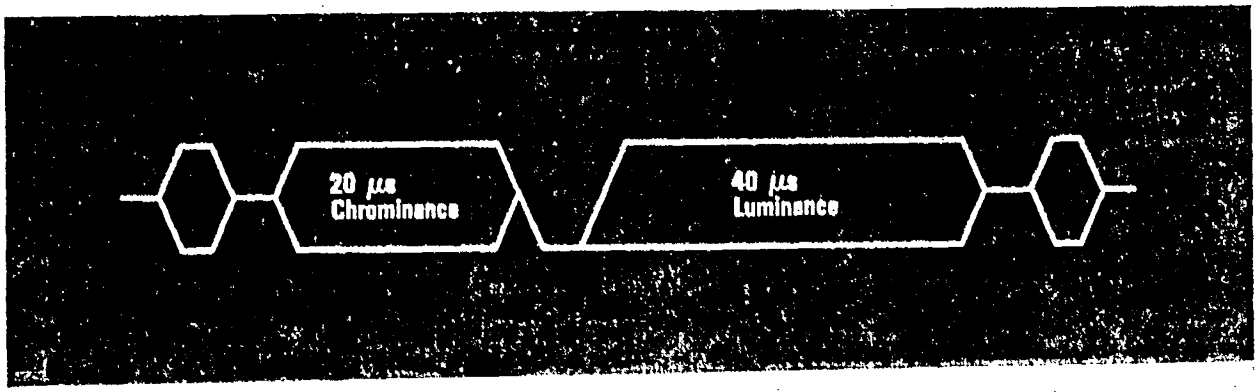

FIG. 1: MAC SIGNAL

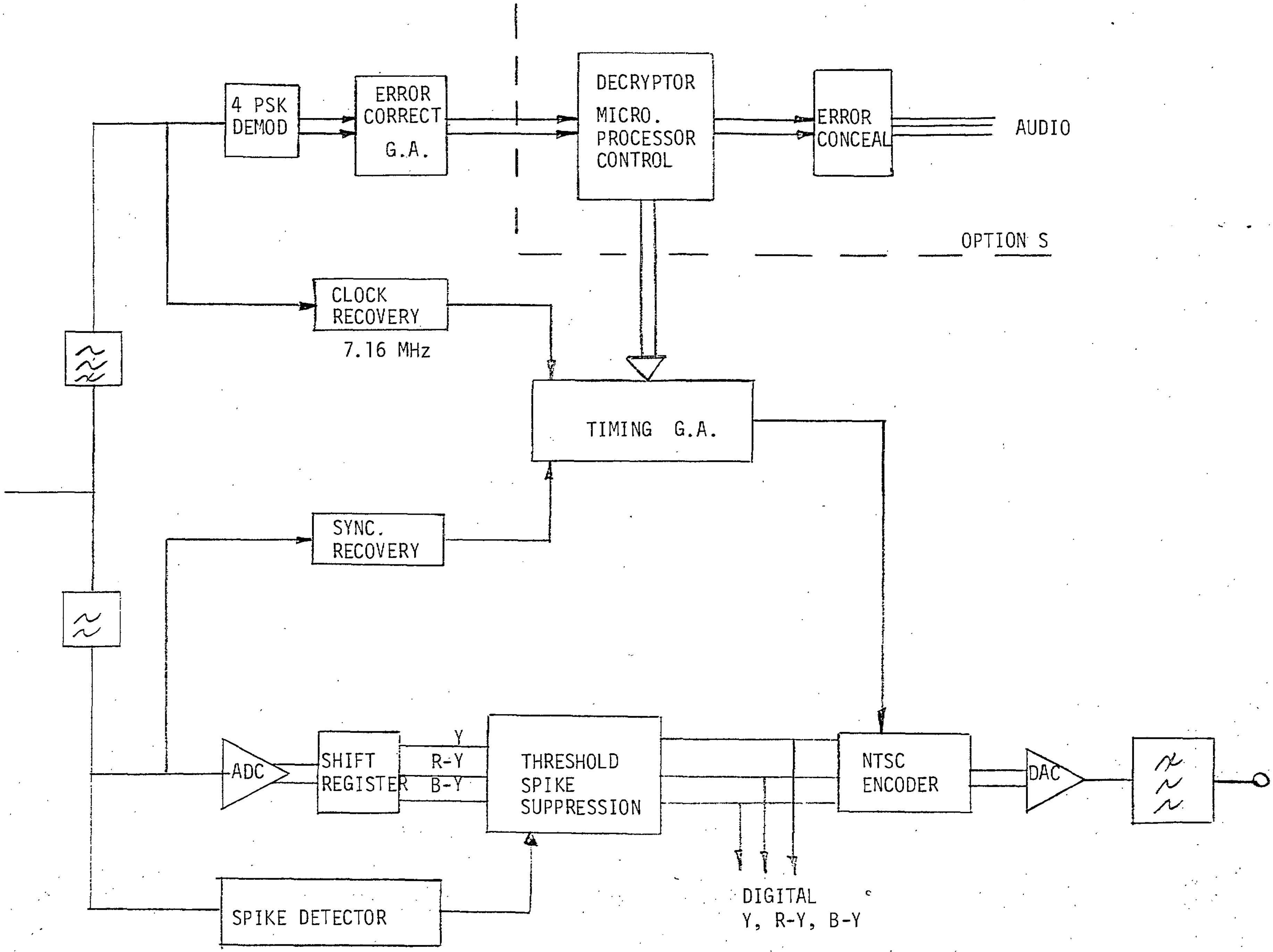

FIG. 2: TYPICAL MAC RECEIVER