DEVELOPMENT OF BASEBAND DECODER COMPATIBLE WITH EIA INTERFACE STANDARD FOR CABLE RECEIVERS AND DECODERS

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ABSTRACT

The EIA Television Receiver Committee has been developing an interface standard for improving the compatibility of TV receivers and decoders operating on cable TV systems. This paper reviews pertinent specifications of the standard and efforts involved in developing a compatible decoder. Specific problems encountered, such as the generation of AGC control signals (derived from received scrambled signals) with the required response time, are described. Overall characteristics of the decoder and its performance during field tests are reviewed.

INTRODUCTION

Separate developments in the cable television and television receiver industries have resulted in equipment with several incompatibilities and duplicate functions, frustrating to the subscriber and cause for non-essential in-home equipment costs. This situation is apparent even with the introduction of "cable ready" television receivers. Subscribers have been finding that after paying additional money to obtain a "cable ready" receiver they still cannot receive channels which have been scrambled.

A committee formed under the EIA (Electronics Industries Association), called the Television Receiver Committee (R-4) Interface Working Group, has been working with cable operators and equipment suppliers to alleviate some of these incompatibilities. The result has been the development of the NTSC Television Receiver Baseband (Audio/Video) Interface Standard IS-15 (reference 1).

This paper illustrates some of the duplicate functions which are eliminated by the use of equipment compatible with the Interface Standard. It also describes some of the steps involved and the problems encountered in developing a cable decoder compatible with the IS-15 Standard.

TECHNICAL DISCUSSION

Cable Versus Broadcast TV Channel Assignments

The utilization and assignment of carrier frequencies different than those assigned for standard broadcast television transmission occurred early in the development of cable television. This provided several advantages, among them the use of frequency bands not available for transmission over the air. This in turn permitted transmission of up to 54 channels without having to use carrier frequencies above 408 megahertz, a definite advantage when considering the increased attenuation of coaxial cables at higher frequencies.

However, until just the last few years, television receivers were unable to tune most of the cable channels available, and required a separate cable converter in order to receive the cable channels. Even today, most television receivers on cable systems are tuned to one channel (3 or 4) and selection of the cable channels is performed with a set-top converter or converter/-decoder.

Television receivers advertised as "cable ready" are now available which can tune the cable channels. But the use of scrambling techniques on some channels means that those channels remain unavailable to these receivers. Furthermore, the use of a converter/decoder to view the programs on the scrambled channels relegates these receivers to fixed tuning on one channel and as a result most of this tuning capability ends up wasted (along with the TV remote control function).

Cable Decoder and TV Receiver Functions

Figure 1 is a block diagram illustrating typical functions performed by a cable decoder and television receiver when interconnected for reception from a cable TV system. In the case of the decoder, the functions illustrated are for an OAK Sigma unit, as this was the unit later modified for compatibility with the EIA standard. The Sigma system's implementation of digital audio transmissions has been described in a previous NCTA paper (reference 2).

The functions of the decoder can be summarized as follows:

a) A remote control unit (or local keyboard) is used to select the channel to be received from the cable by the tuner on the decoder.

b) The output of the tuner passes through the IF amplifier section where filters are used to separate the audio (in unscrambled mode) and video carriers.

c) An audio demodulator recovers the baseband audio signal from the audio carrier (in the unscrambled mode).

d) The video demodulator recovers the base-band video signal from the video carrier. In the scrambled mode, digital signals carrying the audio information are also recovered by this demodulator.

e) If the baseband video signal is scrambled a video unscrambler section provides unscrambling. This section is transparent to nonscrambled signals.

f) In the scrambled mode the baseband audio signals are recovered by the digital audio decrypter and D/A (digital to analog) converter from the encrypted digital signals carrying the audio.

g) An RF modulator section generates modulated carriers on one channel for transmission of the recovered video and audio signals to an external receiver.

The functions of the television receiver are summarized as follows:

a) The remote control unit or front panel controls are used to select the channel to be received from the cable decoder. Note: In most installations, once this selection is performed, the receiver remains on that channel indefinitely.

b) The output of the tuner passes through the IF amplifier section where filters are used to separate the audio and video carriers.

c) An audio demodulator recovers the baseband audio signals from the audio carrier. These signals are then amplified by a power amplifier and used to drive a loudspeaker.

d) A video demodulator recovers the baseband video signal from the video carrier.

e) Sync processing circuits separate the horizontal and vertical sync from the composite video signals. The sync signals are used to drive a high voltage power supply and deflection system which ultimately cause the display of an illuminated raster on the picture tube.

f) Luminance and chrominance processing circuits provide three video signals (one for each primary color) for driving the picture tube thereby displaying a composite color (or black and white) picture.

Figure 1 and the description of receiver and decoder functions above, clearly illustrate that the remote control unit, associated infra-red receiver, tuner, IF amplifier, audio and video demodulator functions are repeated in each unit. These functions impose penalities in complexity, cost and functionality.

In addition the desirability of avoiding repetition of RF and baseband processing, especially demodulation and remodulation, is well established. These processes can introduce distortions into the original signals so that the quality of the displayed picture and audio signals may degrade from repeated processing. It should be noted that decoder manufacturers, being aware of this problem, use considerable care and optimize equipment design to assure that the degradation will be minimum and usually imperceptible compared to direct viewing and listening with a just a receiver.

TV Monitor Approach for Reducing Redundancy

Figure 2 illustrates one approach towards reducing the redundant functions previously described for the decoder and receiver. The approach utilizes a decoder wherein the RF modulator has been replaced by baseband audio and video driver amplifiers. These amplifiers deliver baseband signals directly to a television monitor instead of a receiver.

There are several technical reasons favoring this approach. The interface between the decoder and monitor is very straightforward. Furthermore, a television monitor can display a better picture than an equivalent quality receiver, again because of reduced signal processing. This improved display capability is often exploited in monitors used for computer graphic displays. A monitor can also improve the playback from a video tape recorder or other video source which features baseband video output.

However, this approach was not seriously considered by the EIA committee since most cable television subscribers already own receivers, not television monitors.

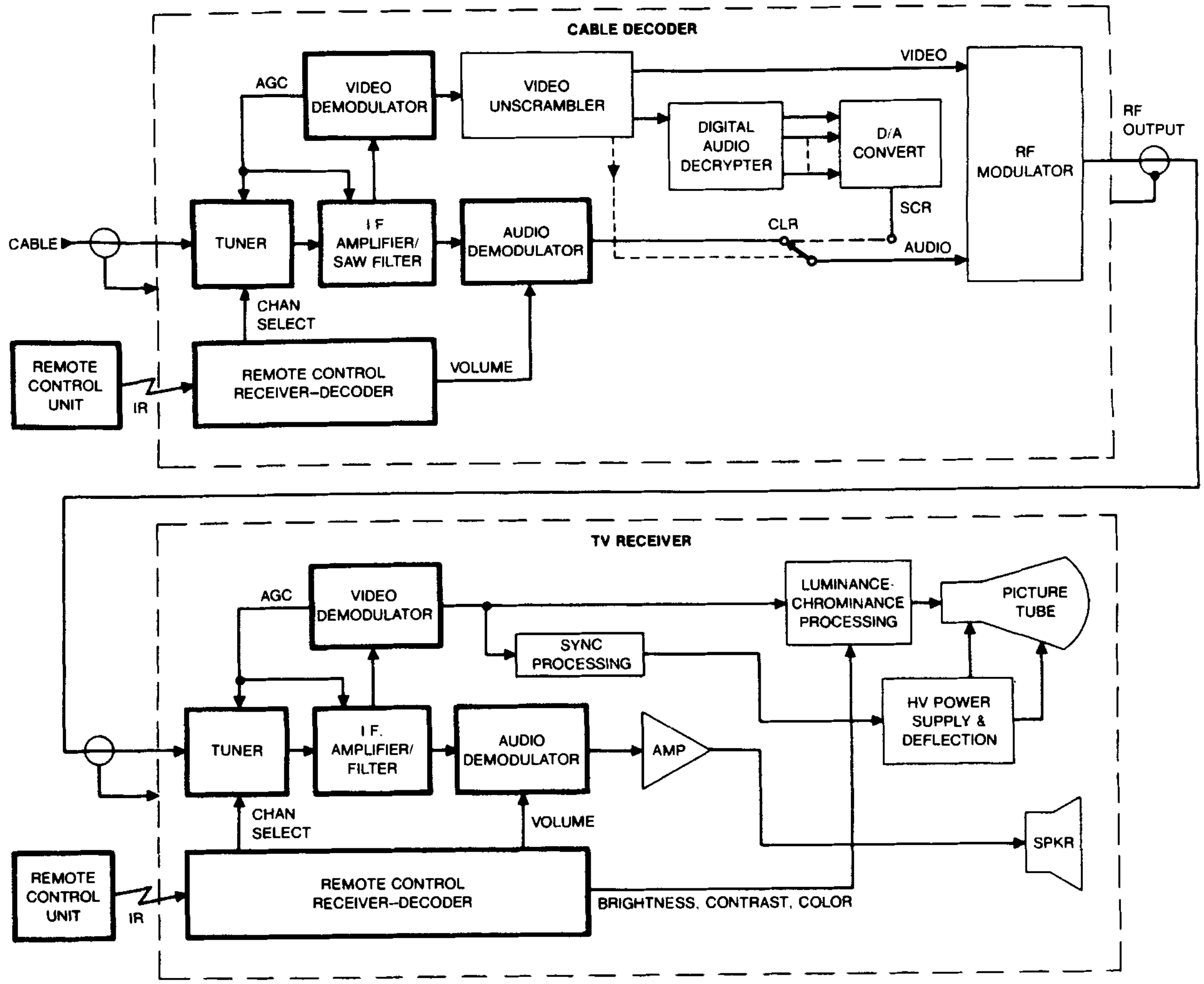


FIGURE I
CABLE DECODER
AND TV RECEIVER FUNCTIONS
(REDUNDANT FUNCTIONS SHOWN WITH BOLD OUTLINE)

Baseband Decoder Approach

Figure 3 illustrates the basics of the approach adopted by the EIA committee in order to achieve improved compatibility between the decoder and receiver. As shown, this approach maintains most of the receiver functions while reducing the decoder functions. However, it requires modification of both the decoder and receiver to include internal interface circuits. These circuits normalize the baseband audio and video signals as well as generate control signals which are exchanged between the receiver and decoder.

In operation, channel selection is performed by the tuner in the receiver. Baseband video signals from the video demodulator pass through the receiver interface circuits and are sent to the decoder. These signals may be scrambled or unscrambled.

The decoder receives the video signals through its interface circuits and sends them to the video unscrambler. The video output from the video unscrambler is then sent back to the receiver through a similar path. Nonscrambled video signals pass through the decoder without modification (transparently). Thus video signals transmitted to the receiver are in standard NTSC format for both clear or scrambled signals (from authorized channels).

The decoder generates control signals which the receiver uses for determining selections to be made for scrambled or unscrambled modes of operation. In the nonscrambled mode, internal receiver AGC control is selected along with audio from the receiver's internal demodulator. In the scrambled mode, receiver gain is controlled by the output of a video level measuring circuit in the decoder and, for OAK Sigma descrambling, audio is selected from the D/A converter in the decoder.

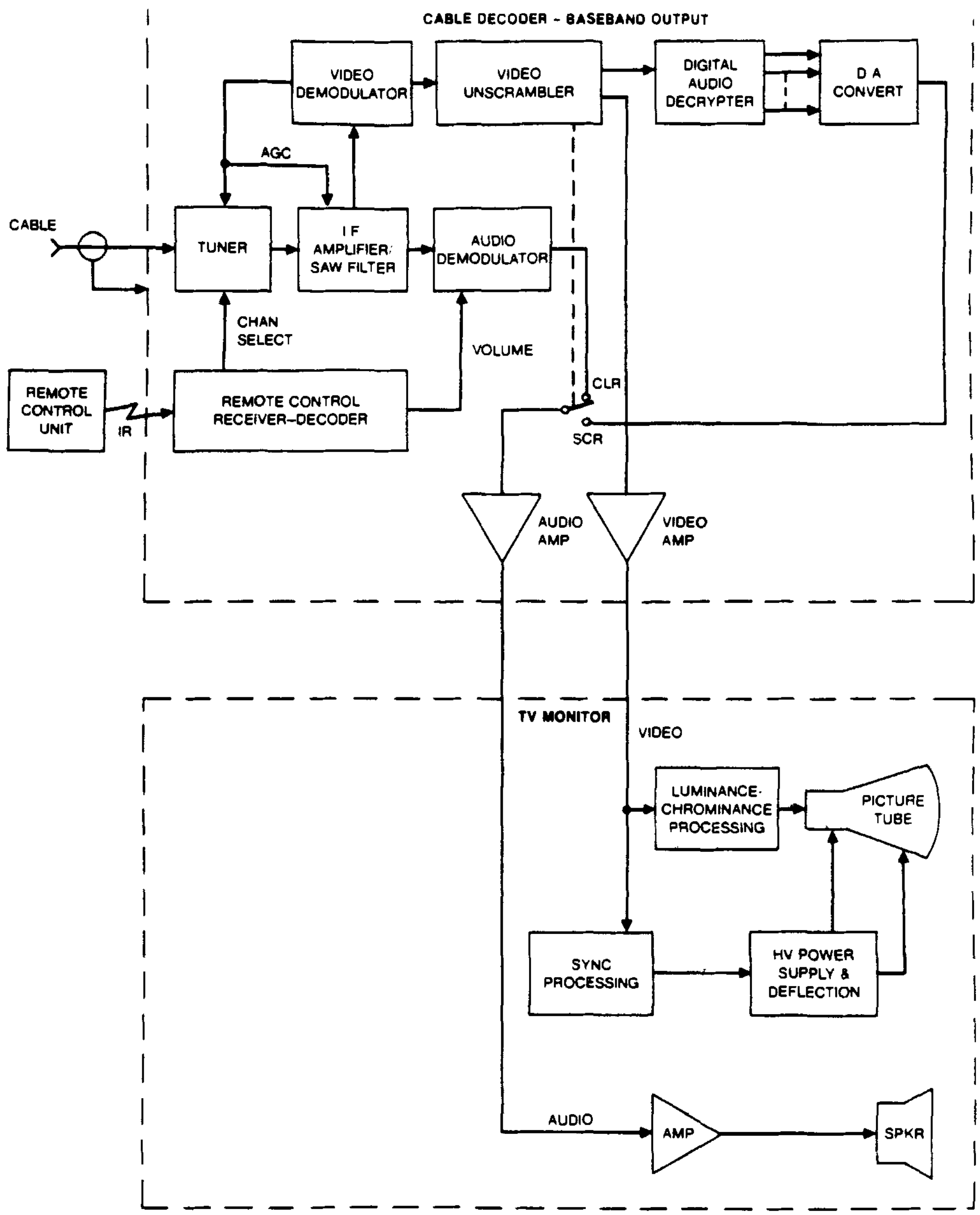


FIGURE 2

CABLE DECODER
AND TV MONITOR FUNCTIONS

Summary of EIA Standard

The following list summarizes some of the items which have been specified by the NTSC Television Receiver Baseband (Audio/Video) Interface Standard (IS-15) developed by the EIA Television Receiver Committee (R-4).

a) Specifies a 20 pin (plus shield) connector of a type used widely in Europe for interconnections with RGB operation, called a Cenelec connector. The connector is to be installed on the rear of receivers and decoders (optional) designed for this standard.

b) Defines the functions of 18 of the pins and associated conductors of an interconnecting cable expected to be less than 2 meters in length.

c) Standard allows for 4 possible interfaces to the receiver from a decoder or other audio/video device. Four interfaces are: monaural, stereo, monaural + RGB, and stereo + RGB.

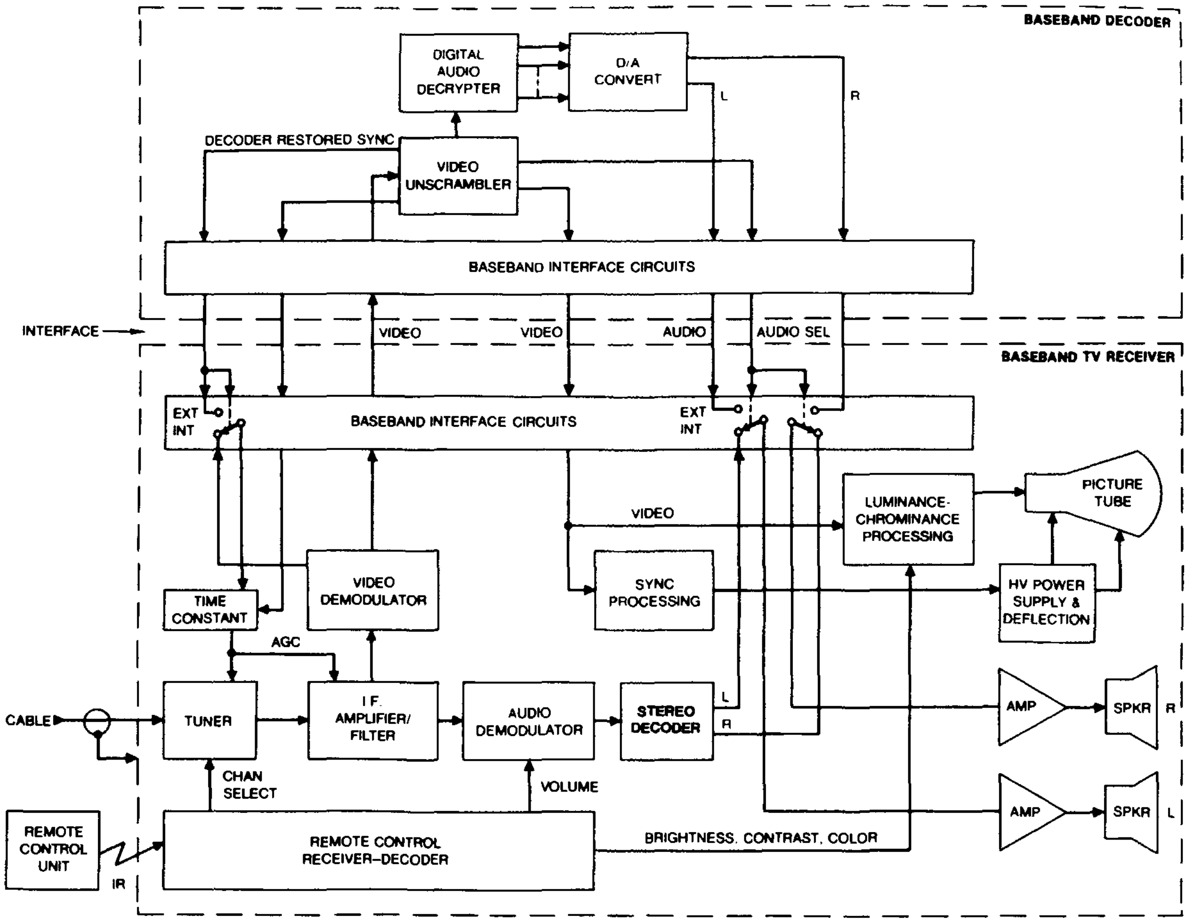


FIGURE 3
BASIC BASEBAND CABLE DECODER AND
TV RECEIVER FUNCTIONS

d) The main baseband video connections between a decoder and receiver are:

Pin 19, video signals from receiver to decoder.
Pin 20, video signals from decoder to receiver. These signals are nonscrambled when pin 19 receives scrambled signals from selected (authorized) channels.
Pin 18, video or control signals from decoder to receiver; same signal as pin 19 during acquisition mode, a DRS (Decoder Restored Sync) for AGC control when operating with a scrambled channel and a high level when receiving a clear signal on pin 19.

e) Audio connections between a decoder and receiver include:

Pin 2, left channel audio signals from decoder to receiver.
Pin 6, right channel audio signals from decoder to receiver.
Note: In monaural reception both pins carry same signal.

f) Control signals between a decoder and receiver (other than pin 18) include:

Pin 1, signal from decoder to receiver to select receiver internal (receiver) or external (decoder) audio source.
Pin 3, signal from decoder to receiver used with signal on pin 18 for selecting slow, fast or normal receiver time constant.
Pin 14, signal from receiver to decoder indicating a channel change or power interruption.

<u>Variations in AGC Control</u>

Television receiver manufacturers vary in their philosophy and methods of achieving AGC. Some use very short time constants in attempting to overcome effects of rapid carrier level changes such as airplane flutter. Others use various longer time constants. For level detectors, peak, gated and other types are employed. Expertise in the design of AGC circuits is apparently scarce;

it has been stated (reference 3) that it is limited to "probably less than twenty experts in the entire world."

AGC Problems Anticipated and Realized

Knowing some of the above variations, the EIA committee anticipated that one of the most severe problems faced in developing the interface standard would be defining the AGC functions with the receiver interconnected to a decoder, especially in the scrambled mode. The overall AGC functions must be shared between the decoder and receiver. Furthermore, the receiver has to provide some degree of AGC control during the acquisition phase in order to deliver usable video signals to the decoder. Achieving this degree of AGC control when dealing with scrambled signals with suppressed or non-existent sync was a major concern of receiver manufacturers.

The committee's apprehension over AGC performance was justified during the first field tests, conducted in January of 1985. At those field tests almost every decoder and receiver interconnected for the first time, exhibited various types of AGC instability. A common symptom was a mode where acquisition by the decoder was followed by a change in receiver gain, which in turn affected the video to the decoder sufficiently to cause loss of acquisition, followed by re-acquistion, etc. The visual result was a televised display flashing wildly between a blank screen and a picture.

Basic AGC Control Functions

Figure 4 illustrates the main functional elements of a typical television receiver AGC control loop. The main function of the overall circuit is the maintenance of a constant video output level while receiving RF carrier levels varying from one channel to the next and possibly varying with respect to time, especially during over-the-air reception.

Video processing involves obtaining a measure of a fixed, repetitive portion of the video level, often the sync pulse, through peak detection, gated sampling or other technique. The processor output is filtered by passage through a low-pass filter, then compared with some fixed reference in order to generate an error control signal. This error signal is then used to control the gain of the IF amplifier and sometimes the tuner of the receiver.

Combined Receiver-Decoder AGC Control Functions

Figure 5 is a simplified block diagram showing the combined receiver and decoder functions involved in control of AGC, with equipment modified for the baseband interface standard.

As shown on the diagram, baseband video signals from the receiver's detector are sent to the decoder through buffer stages in the respective interface circuits. The unscrambler circuits in the decoder provide an unscrambled video output which is then sent back to the receiver.

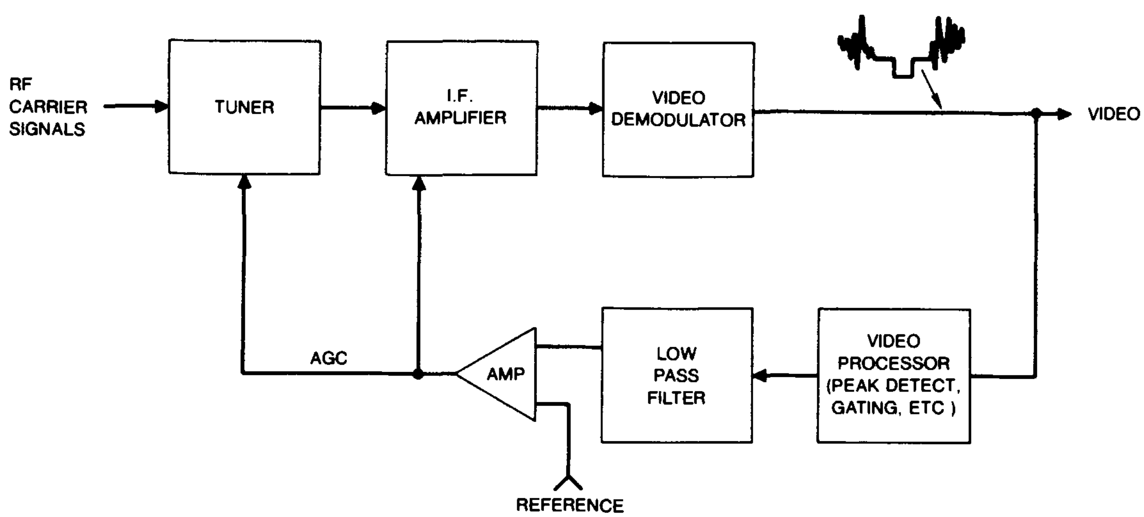


FIGURE 4

TYPICAL AGC CONTROL LOOP

The unscrambling circuits also generate a gating pulse which drives a sample and hold stage. Sampling takes place at the time a recurring reference is received with the scrambled video signals, so that the voltage generated is representative of the video amplitude. This voltage is scaled, compared with an internal reference and the resulting output is gated on and out to the receiver as a DRS (decoder restored sync) signal.

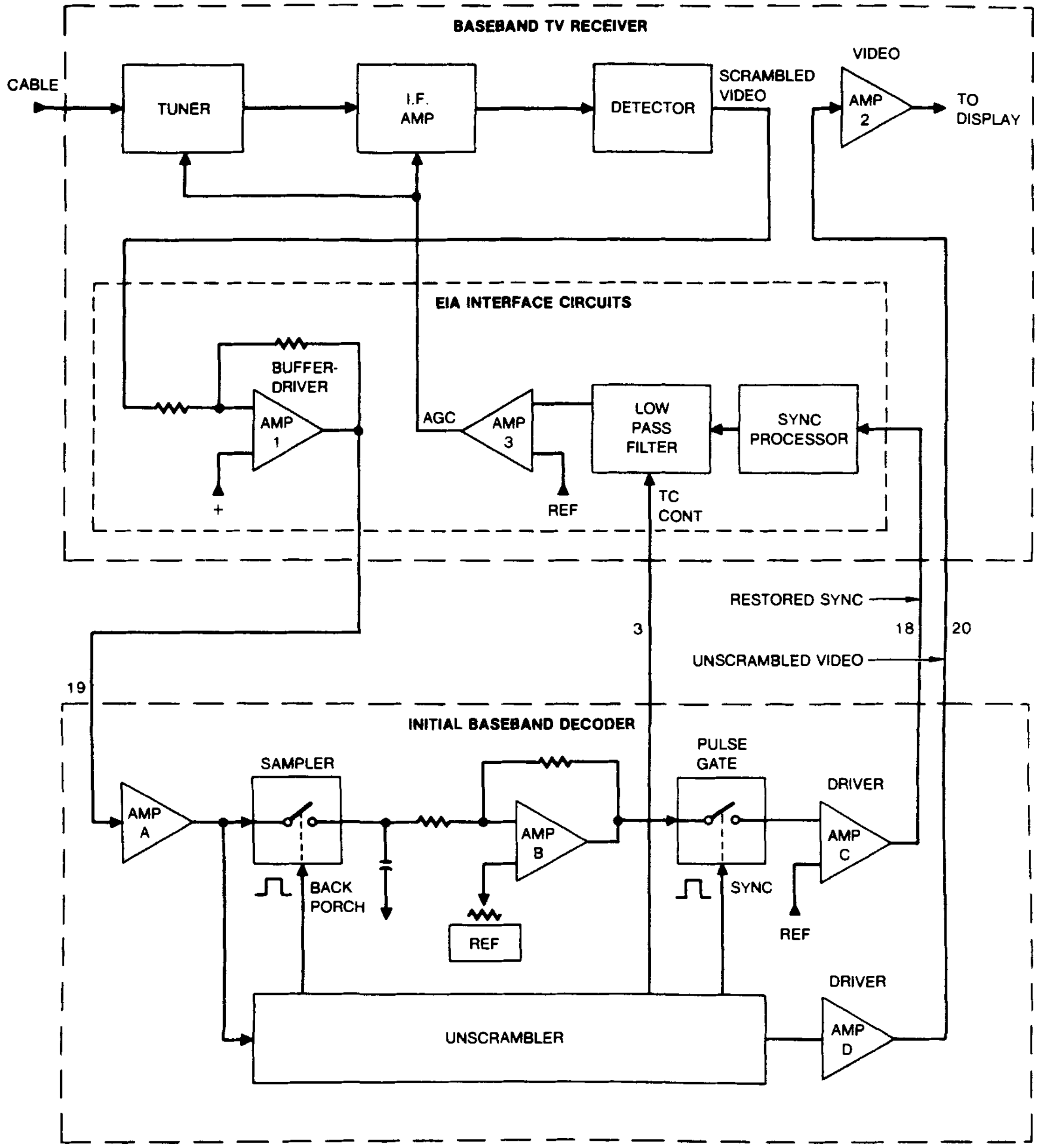


FIGURE 5

TYPICAL AGC FUNCTIONS
INITIAL BASEBAND DECODER AND RECEIVER

At the receiver the DRS signal is typically processed by the interface circuits, passed through a low-pass filter and the result, a slow varying dc voltage, is then used to control the gain of the receiver.

After acquisition the loop settles at a level where the output of the decoder's sample and hold circuit equals the reference on the following comparison stage. With everything operating correctly, this should correspond to an optimum video level to the encoder and DRS level to the receiver.

<u>Achieving AGC Stability for Interfaced Receiver & Decoder</u>

To achieve stability for the combined receiver and decoder the cumulative effects on the phase margin of the AGC system from the combined transfer functions of both must be carefully controlled. The specification provides for selectable receiver time constants. Through judicious selection, minimum interaction can thus be obtained between the time constants of the receiver and decoder. For scrambled signals this selection of time constants is determined by decoder generated control signals.

Note: Time constants were defined in part as the time required to reach 90% of steady state following a step change in the input signal level.

Before the field tests described above, the specifications provided selection between a slow time constant of 20 milliseconds or greater and a "normal" time constant for the receiver. The slow mode was to be selected by the decoder only while decoding (during the acquisition mode).

For the decoder a time constant of 5 milliseconds maximum, was specified initially. With a sampling circuit of the type shown on figure 5, a time constant of about 0.2 milliseconds was obtained.

A problem encountered which contributed to some of the instabilities during the January field tests was that the "normal" time constant differed for each receiver and was in some instants interactive with the time constant of the decoders.

To overcome this problem the committee later agreed to specify both a SLOW and FAST time constants for the receiver, still selectable by a control line from the decoder. These were:

SLOW: 20 milliseconds or greater

FAST: 1 millisecond or less for an carrier increase of 6 dB
2 milliseconds or less for a carrier decrease of 6 dB

Field tests conducted in June demonstrated a marked improvement in the AGC operation for interfaced receivers and decoders indicating a benefit from specifying the time constants as shown.

The latest specifications have incorporated the above SLOW and FAST time constants. In addition a "normal" time constant has been made available for selection at the receiver if the decoder indicates (through signal lines) that a nonscrambled channel has been selected at the receiver.

For the decoder, the time constant specification now calls for a response time of 1.0 millisecond or less, which the decoder can readily achieve.

Video Level Variations

Variations encountered in the absolute level of the video signals delivered to the decoder by different receivers was a severe problem for the original OAK decoders. These variations were verified during the June tests. Using 5 step linearity test video signals, the dc level delivered for each step was different from each receiver. However, the receivers were well within the specifications as written at that time.

In the committee meetings during the development of the specifications, reference was often made to an ideal receiver with a video output as shown in figure 6 (a). Specifically, the ideal voltage output for 0 carrier level was 2.143 volts, for 100 IRE (corresponding to 12.5% modulation) it was 2.000 volts and for sync tip (100% modulation) the output was 1.000 volt. However, the specifications as published in May 1985, allowed video amplitude of 1.0 +/- 0.25 peak to peak and the dc level for sync tip of 1.0 +/- 0.25 volts.

A brief analysis of the operation of the original decoder as illustrated in figure 5 identifies the reason for its sensitivity to absolute levels. The sampler circuit was designed with the expectation of a specific dc level during the arrival of the recurring reference signal present in the scrambled mode. In standard Sigma decoders, this is assured by a factory adjustment in a circuit following the video demodulator, which normalizes the output of the internal receiver in every decoder.

With the receivers used at the field tests any variation in the received reference level was translated into an error in the DRS signal. This in turn caused an incorrect receiver gain setting. The net effect was obervable as a variation in the contrast of the receiver displays, especially when changing between clear and scrambled channels.

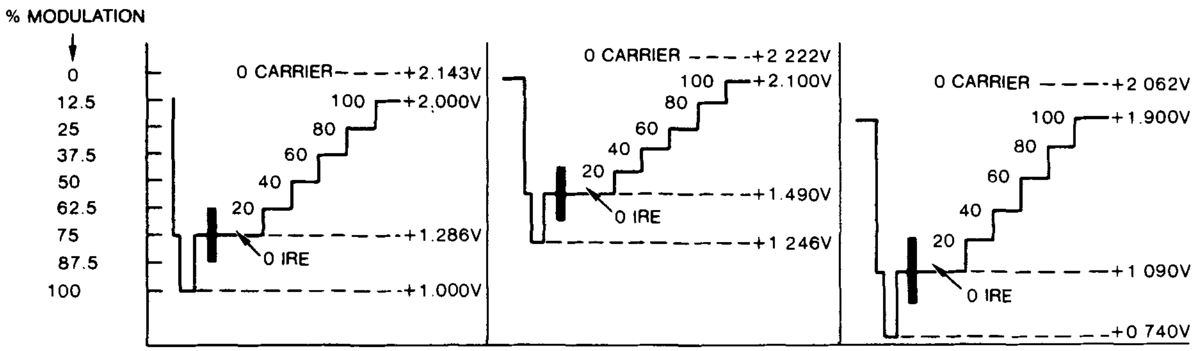
In discussions of recommendations, after the field tests of June 1985, the receiver manufacturers generally agreed that the installation and setting of a video normalizing adjustment (as used in Sigma decoders) was too severe a requirement for mass produced receivers. However, the committee agreed to improve the specifications on receiver video output. As published in the latest specifications they are as follows:

Blanking to Peak White	0.71 +/- 0.1 Volt P-P
Sync to Blanking	0.29 +/-0.06 Volt P-P
DC Level at 100 IRE	2.00 +/- 0.1 Volts

These changes now limit the variations to those shown on figures 6 (b) and (c). But, noting the variations of dc levels which are possible for the 80 IRE steps (near the reference level used in a Sigma scrambled signal) a variation of +/- 15 IRE units relative to the optimum level can still occur.

Modification for Two Reference Levels

On the basis of the above specifications, previous experience with the OAK Orion satellite scrambling system and also recommendations made by committee members, a decision was made to incorporate two reference levels into the overall scrambling system, for the EIA baseband equipment.



(A) OPTIMUM SIGNAL	(B) LOW LIMIT SIGNAL	(C) HIGH LIMIT SIGNAL
VIDEO = 0.71V P-P	VIDEO = 0.61V P-P	VIDEO = 0 81V P-P
SYNC = 0.23V P-P	SYNC = 0.23V P-P	SYNC = 0 35V P-P
100 IRE = 2.00V	100 IRE = +2.10V	100 IRE = +1 90V

FIGURE 6

VIDEO TOLERANCE RANGE
LATEST SPECIFICATIONS

With two reference levels a measurement of the difference between the two levels provides a good measure of the amplitude of received video signals. And more importantly, with a properly designed differential circuit, the measurement can be obtained while largely ignoring the absolute dc levels common to both of the received references.

The encoders used with the system were modified to provide a second reference level (0 IRE) for a few lines during each vertical blanking interval of the scrambled video signal. The normal reference level, presently 75 IRE, which is transmitted once every line, was left unchanged.

Decoder Modification for Two Levels

Initial laboratory tests with a decoder modified to receive and process two reference levels demonstrated very good performance, with one exception. The response to step changes in the video input was slowed down due to the fact that sampling of the video signal for the new reference was restricted to only one sample per field (i.e. 16.6 milliseconds). Initial considerations towards sending both references once per line had to be rejected since this would have required a major system re-design.

Consultation with one of our colleagues (reference acknowledgement) resulted in the design of a unique circuit capable of achieving the fast decoder response required in spite of the slow sampling of one of the references. The basic circuit configuration is shown on figure 7 along with a diagram of a portion of the scrambled signal applied to its input. A summary of its operation is as follows:

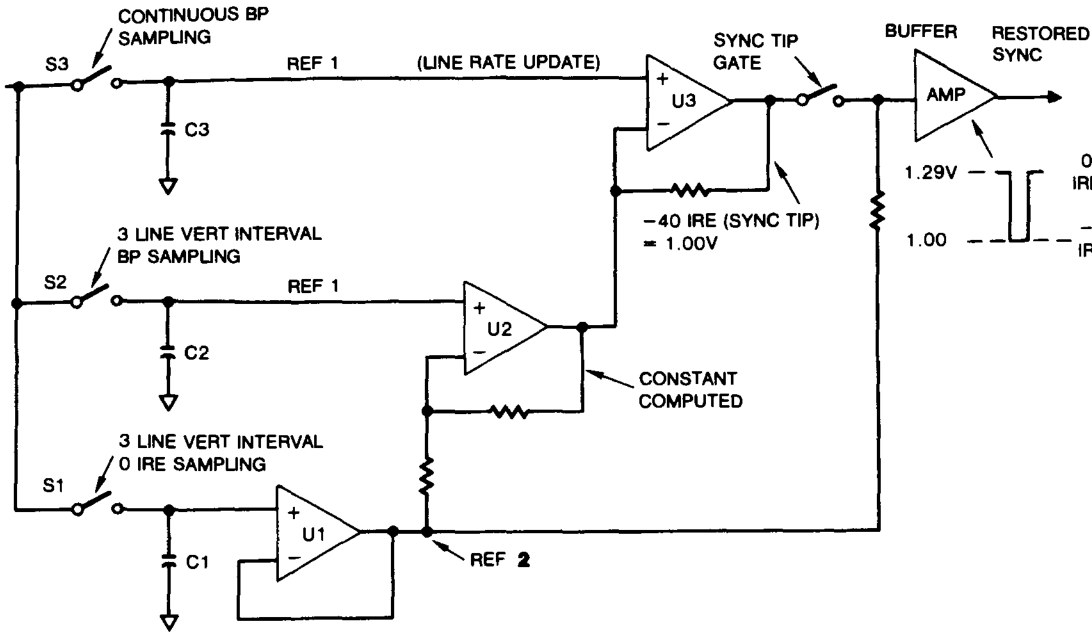
One reference signal is transmitted during the back porch interval also used for sending the color burst. This occurs on every line thus allowing a fast response time. The second reference is only transmitted as a video signal for a few lines during the vertical blanking interval.

Switch S1 closes during the arrival of the second reference signal and this level is stored in C1. Switch S2 closes for the same lines but during the arrival of the first reference signal, which occurs on the back porch of every line and this level is stored in C2. Switch S3 also closes during the arrival of the first reference but on every line and this level is stored in C3.

Operational amplifiers U1 and U2 are used to compute a constant based on the difference between the levels stored in C1 and C2. The output of U2 is thus a constant which may change from one receiver to the next but will not change even with video level changes or after selection of different channels.

Amplifier U3 is used to compute the sync tip level, based on the nearly static input level from U2 and the fast changing input from C3. The result is a sync tip level signal which also responds rapidly, well within the 1.0 millisecond maximum specified for the decoder.

As shown in figure 7, the actual restored sync output is generated by sending out the sync tip level through a switch (actuated during sync time) and an output buffer stage. The rest of the time when the switch is open, 0 IRE level is sent out. This composite output



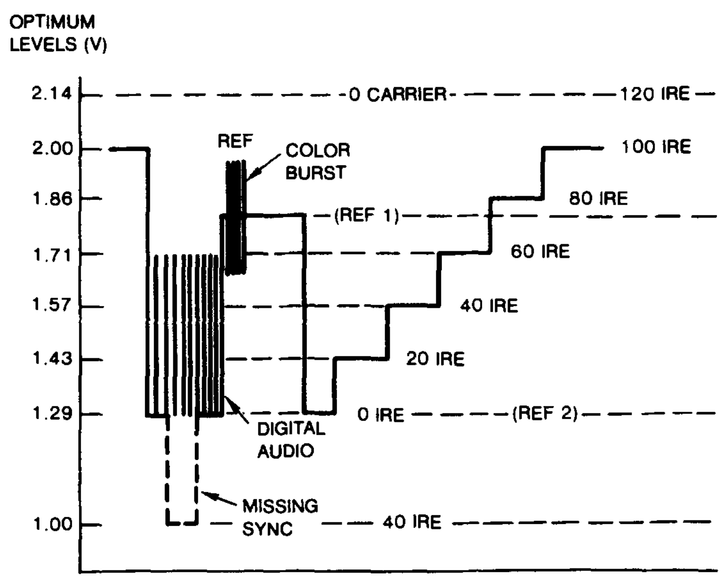


FIGURE 7

SCRAMBLED SIGNAL - TWO LEVEL PROCESSING

is the DRS (decoder restored sync) used by the receiver for AGC control, as described earlier.

Final Baseband Decoder Interface

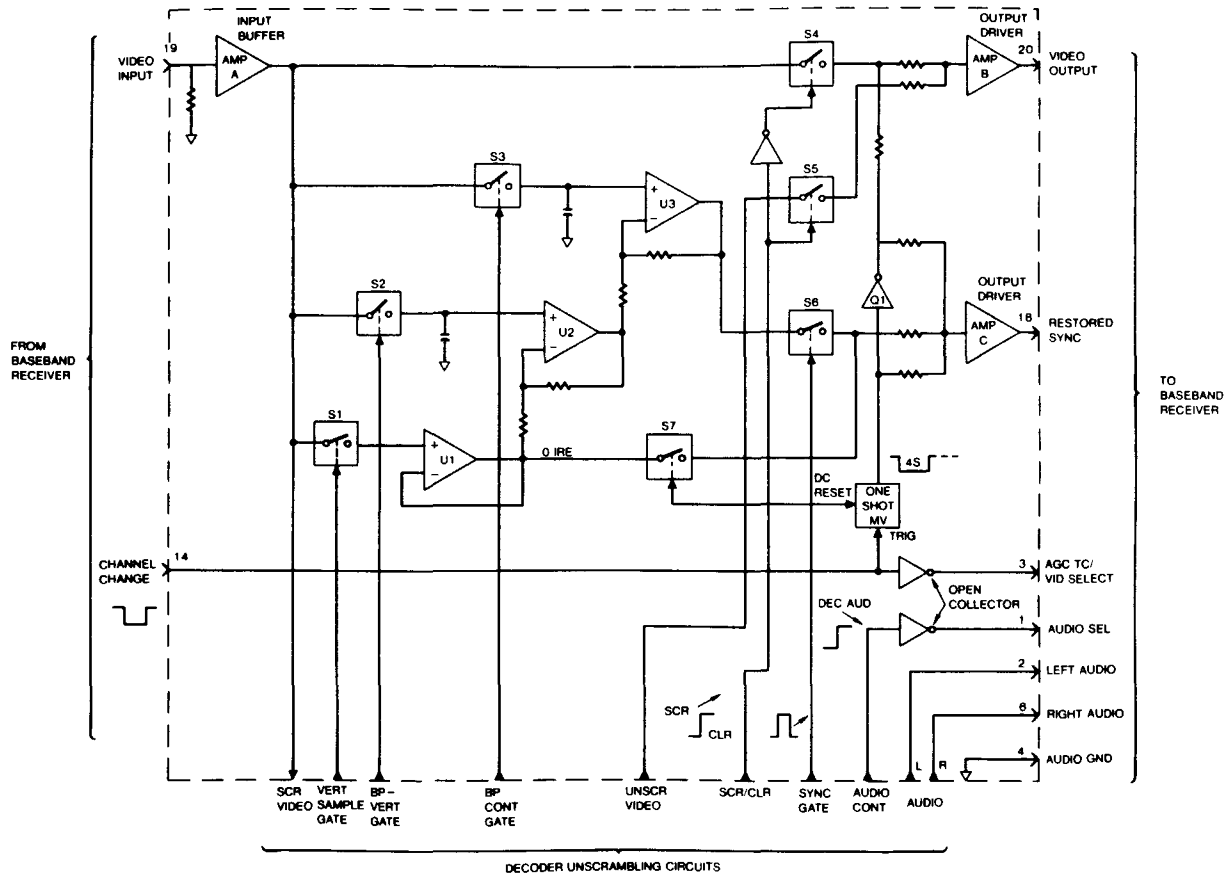
Figure 8 is a block diagram illustrating the overall functions provided within the decoder in order to achieve the baseband interface requirements. A brief description of these functions is as follows:

Video input signals from the receiver are received through input buffer amplifier A. For unscrambled signals these pass through switch S4 and the output driver B and back to the receiver in a transparent mode.

After receiving a channel change signal from the receiver a one-shot multivibrator is actuated for a few seconds. During this time transistor Q1

FIGURE 8

BLOCK DIAGRAM
FINAL BASEBAND DECODER INTERFACE



is turned off which allows the sending of video signals from S4 through output driver C, providing transparency for the input video out of the restored sync port (18). If the received video is unscrambled the one-shot will time out, driving Q1 to interrupt the video, while sending a high level out through output driver C indicating a clear channel to the receiver.

When a scrambled channel is received and acquired, the unscrambling circuits will:

a) Open switch S4 interrupting the incoming video signals path to the output.

b) Close switch S5 allowing the unscrambled video signals to pass through output driver B and on out to the receiver.

c) Reset the one-shot multivibrator.

d) Close switches S6 and S7 to send the restored sync signal to output driver C and on out to the receiver.

The operation of S1-S3 and U1-U3 has been described in the previous section. The rest of the functions are self evident.

Final Performance

The decoder, upgraded to the configuration described in the last two sections was used during the field tests conducted in November 1985.

Overall the performance was quite satisfactory. The previously experienced sensitivity to variations in different receiver's outputs was no longer a problem. The worst thing observed, with some receivers, was a barely perceptible flicker in the picture displayed. This was considered a prototype phenomena to be resolved in producing equipment for operating with this interface.

The first public demonstration was the operation with a modified Sony receiver, during the Western Cable Show, in Anaheim CA., during December 4-6, 1985.

SUMMARY AND CONCLUSIONS

The specifications of the EIA developed interface standard relative to decoder design and a review of the development of a compatible decoder have been presented.

The specification has other applications not covered by this paper.

The process of developing a standard of this type through a committee effort is sometimes a tedious experience. There were the expected conflicting interests among the participants. But necessities often imposed by the marketplace do provide a positive drive towards achieving the benefits of standardization.

The final standard developed has many good attributes and with further communication among future users, it should be effective and acceptable. Actions and conditions necessary for successful adoption of the interim standard have been discussed elsewhere (reference 4). Because of this and the pleasant relationships established with other participants, the overall participation was a rewarding experience.

Note: Any opinions stated in this paper are those of the author and are not intended to represent those of other participants or of the EIA.

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