CABLE HEAD END OPERATION WITH COPY-PROTECTED SIGNALS

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ABSTRACT

Pay Per View is emerging as a business capable of delivering programming which has substantial revenue potential from later markets. In order to preserve the value of later showings of program material, technology has been developed to inhibit taping of PPV signals. Copy-protected programming may be distributed by satellite or originated locally. In either case, some special provisions have to be made in the cable head end. This paper examines head end operation with Eidakized copy-protected video signals. Consideration is given to reception of copy-protected satellite signals, and to the origination of signals locally from tape or from copy-protected laser video discs.

Addressable scramblers used in cable head ends generally require some special attention when used to encode copy-protected video signals. Similarly, hub operation of PPV systems may require the use of special interfacing equipment. Following a discussion of the method of signal modification to achieve copy-protection, the paper describes the operation of head end equipment for various satellite and local origination distribution scenarios.

INTRODUCTION

The revenue potential for later markets for PPV programming has created a demand by program providers for some form of control over unauthorized copying of program material. Electronic copyright protection, already in use in a different form in the videocassette pre-recorded medium, is fast becoming a necessity to assure access to product, with timely availability, desired by cable operators to fuel the anticipated growth of PPV. Movies and some forms of live events have significant market revenue potential following a PPV exhibition, and thus are candidates for copy-protection of transmitted signals.

Electronic copy-protection is achieved by modification of the video signal in such a way that a program can still be readily displayed on a standard receiver or monitor, but an attempted recording using a video cassette recorder has no commercial or entertainment value. Copy-protection methods rely on differences in sensitivity on the part of VCR's and television receivers to modifications of the video waveform [1,2,3]. For the transmitted PPV signal, the Eidak technique uses modification of the television frame rate. It has been developed and tested specifically for operation in cable systems, with emphasis on security and compatibility with other equipment.

Projected application anticipates both satellite delivery to cable systems and standalone (locally originated) operation. The copy-protection process can be applied in any of the following ways:

- o At a satellite uplink--to the transmitted/encrypted signal.
- o At a cable head--to a signal received by satellite or originated locally on tape.
- o On a pre-recorded laser disc for use at a head end.

Because the copy-protected signal does not conform strictly to the NTSC 525 lines per frame standard, there are specific technical guidelines for proper head end operation. Reception of encrypted satellite signals,local program origination, and addressable scrambling all require attention when dealing with copy-protected programming.

THE COPY-PROTECTION METHOD[4,5,6,7,8]

The copy-protection method to be described exploits differences in the sensitivity of television receivers and VCR's to small changes in vertical frame rate. In particular, the electromechanical nature of the VCR causes it to be more sensitive to such disturbances. In order to most efficiently make use of the surface of magnetic recording tape, the VCR records video waveforms in stripes diagonally across the moving tape. Physically, this is accomplished by locating two or more recording heads on a rapidly spinning drum, around which the tape is wound in a helical fashion. At any one time only one recording head is actively recording and in contact with the tape. As the head moves diagonally across the tape it records one field of video. When one head reaches the edge of the tape a second head starts to record a next diagonal stripe corresponding to the next field. This operation is critically dependent upon careful synchronization of the rotational speed of the drum and the field rate of the video signal being recorded. A servomechanism system is used to achieve this precise synchronization.

The Eidak copy-protection technique varies the field rate in such a way that proper synchronization is upset, the servo loses lock, and the video signal is improperly applied to the recording tape. The effect on playback is to create gaps in the program material (i.e. goes to snow), onscreen artifacts due to non-synchronized head switching, and other video distortions. The variation in field rate is achieved by adding or deleting horizontal lines. For maximum effect, the technique is applied periodically as shown in Figure 1.

The all-electronic picture scanning system of the television receiver is able to respond properly to these variations in vertical scanning rate and thus provide a normal display. In order to maintain interlace and proper positioning of the displayed picture, horizontal lines are added or deleted in pairs, i.e. one line to or from each of the two fields in a frame. Additionally, adjustment is made to the timing of the first vertical sync pulse to assure proper display interlace when the line count is changing. The location of the active picture lines is adjusted dynamically within the field in order to keep the displayed picture centered on the vertical axis of the television screen. This centering compensation is accurate to within about +/- 1 line. In order to mask even this minimal effect, the time varying profile — as shown in figure 1 — is applied when significant changes in program content occur ... typically at scene changes. Other minor modifications are made to the vertical blanking interval to assure compatible operation of television receivers with digital and count-down synchronization signal processing.

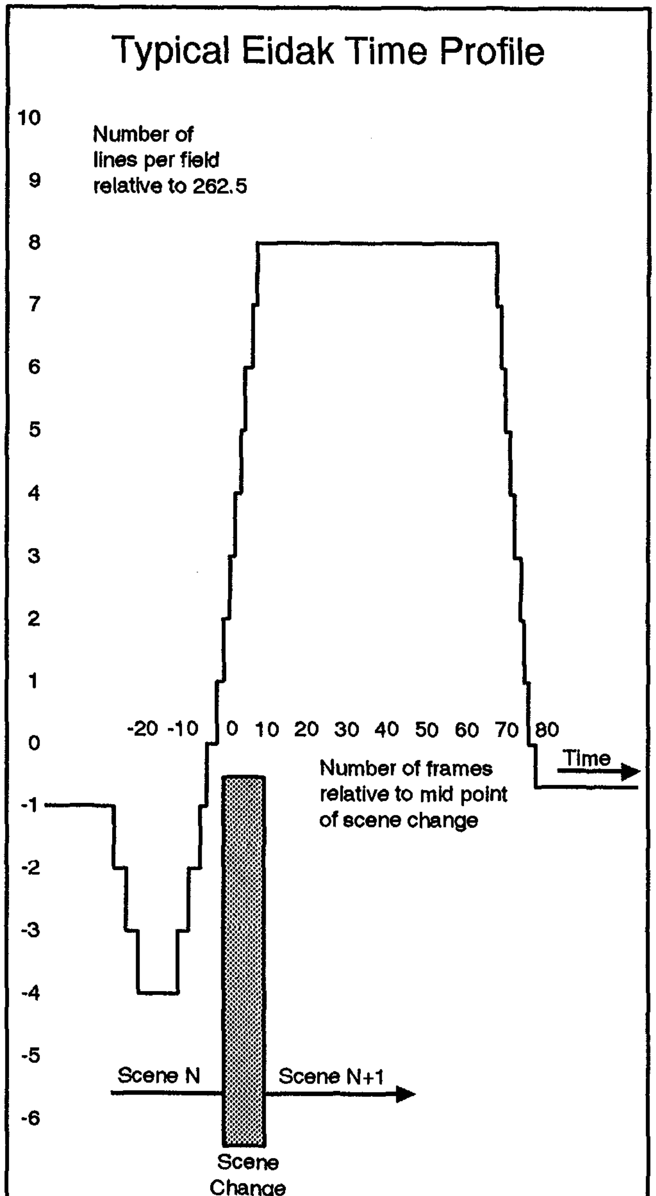
Typical Eidak Time Profile
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
Number of
lines per field
relative to 262.5
-20 -10
0 10 20 30 40 50 60 70
80
Time
Number of frames
relative to mid point
of scene change
Scene N
Scene N+1
Scene
Change

Figure 1.

Figure 2 compares the vertical blanking interval of the copy-protected video signal with NTSC per RS 170. The video field waveform differs only slightly from standard NTSC; normal horizontal line structure is maintained and color burst is locked to sync. The following are the differences between the copy-protected video signal and RS 170 NTSC:

1. Horizontal line count. The line count on any field may vary from 254.5 to 272.5 lines. Interlace and color phase coherence is maintained throughout. During the transit from one line count to another, the rate of change is one line more or less per field. Any resulting line count (except 525) may be held for an arbitrary period of time.

2. Vertical interval
   A. The last vertical sync pulse on a half line boundary is deleted from every field. The equalizing pulse on the half line boundary is deleted from lines 7, 8, and 9 in field 1 and from lines 6, 7, and 8 in field 2.

   B. The start of first vertical pulse in field 1 is advanced approximately 20 us while the field line count is increasing. The start of the first vertical in field 1 is delayed approximately 20 us while the field line count is decreasing.

3. Compensation
   The start of the active vertical display is delayed one TV line for each increase of two in the line count. The start of display is advanced one TV line for each decrease of two in line count. The advance or delay occurs in field 1 and never exceeds one line per change.

Analysis of program material to determine the optimum profile timing (e.g. scene changes) occurs prior to transmission -- for pre-recorded material. A data file is created which associates this information with the program's time code track. This information is then either added to a data track (or inserted in the VBI), on the pre-recorded medium, i.e. tape, or kept on file for use with the copy-protection processing equipment. For live events the scene change analysis is performed automatically in real time.

Variation of frame length is accomplished digitally by changing the rates at which frames of digitized video are written into and out of a multiple frame store buffer memory. Within the Eidak processor (figure 3), the control code reads the profile timing data and uses it to control the variation in number of lines per frame. (Alternately, the control code reader extracts this information from a data file and matches it to time code). Another important function of the processor is the scrambler interface. Because the copy-protected signal inherently contains non-standard vertical sync, some re-synchronization must be provided for cable scramblers which typically are dependent on precise VBI timing. For remote hub operations of scramblers, frame length data is encoded into the VBI, and at the hub location a scrambler interface (ESI) converts the frame length information into re-synchronization signals for the scrambler.

Although the copy-protection process for PPV is performed in real time for a transmitted signal, it can also be applied to a pre-recorded medium e.g. laser disc. In this case the copy-protection process is applied to the video signal during the mastering of the disc. When such a copy-protected disc is used later for program origination, the resulting video signal is is already copy-protected.

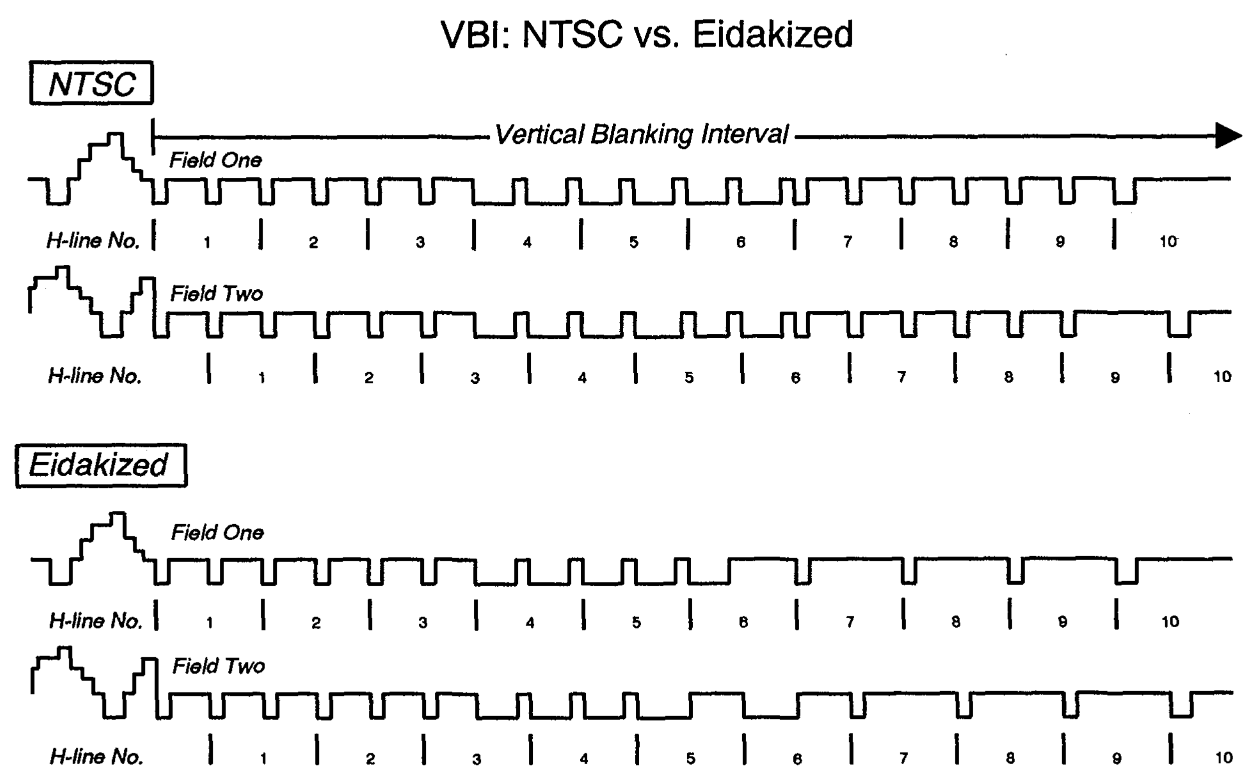
VBI: NTSC vs. Eidakized
NTSC
Vertical Blanking Interval
Field One
H-line No.
1
2
3
4
5
6
7
8
9
10
Field Two
H-line No.
1
2
3
4
5
6
7
8
9
10
Eidakized
Field One
H-line No.
1
2
3
4
5
6
7
8
9
10
Field Two
H-line No.
1
2
3
4
5
6
7
8
9
10

Figure 2.

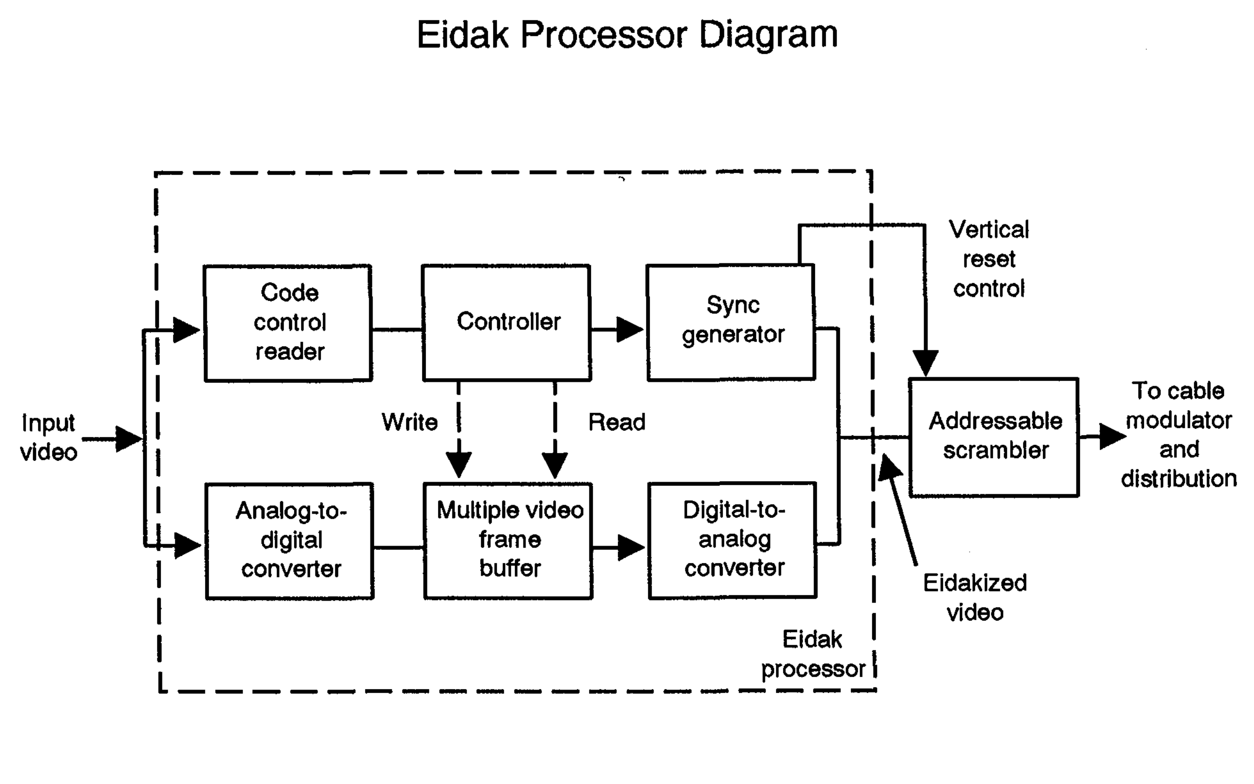
Eidak Processor Diagram
Input video
Code control reader
Controller
Sync generator
Vertical reset control
Write
Read
Analog-to-digital converter
Multiple video frame buffer
Digital-to-analog converter
Addressable scrambler
To cable modulator and distribution
Eidakized video
Eidak processor

Figure 3.

SIGNAL DISTRIBUTION/COMPATIBILITY

System operation with video signals which depart in any way from the NTSC standard of 525 lines per frame, requires attention to compatible operation of equipment. System segments in which particular care must be taken to assure compatibility are:

Satellite

- Satellite Link -- encoders and decoders.

Cable System

- Head end -- video processing equipment and addressable scramblers.
- Hubs -- link transmission equipment and addressable scramblers.
- Subscriber equipment -- addressable converters and television receivers.

Copy-protection of satellite-distributed PPV programming may be accomplished in either of two ways, depending upon the encryption system employed. If the encryption system is designed for compatibility with copy-protected video signals, then it is most efficient to apply the copy-protection treatment to the program material prior to satellite transmission. In the case of an encryption system which is not capable of passing copy-protected programming, the copy-protection process is applied at the cable head end.

Satellite encryption systems generally are sensitive to field or frame rate variations for two reasons. First, descrambling of video and associated sync is performed field by field and normally assumes the use of standard 525 lines/frame video. Secondly, control signalling is often synchronized to the standard video frame rate. These sensitivities are readily disposed of if frame length information accompanies the encrypted signal, provided the descrambler is appropriately equipped. Figure 4 shows the uplink configuration with a copy-protection processor providing frame length data for encoding into the encrypted signal. The satellite decoder includes provision for recognizing video frame length, and adaptively adjusting the descrambling function.

Operation with a satellite encryption system which is not designed for use with variable field length video requires the use of a copy-protection processor at the head end downlink. In this case, the satellite encryption and decryption equipment is standard. In order to ensure that PPV programming is copy-protected as required at the head end, the transmitted signal is subject to a scrambling overlay which can only be removed by passing the received video signal through a copy-protection processor (figure 5). The processor thus serves a dual role -- the scrambling overlay is removed at the same time the copy-protection processing occurs. In this scenario, the signal at the head end prior to the copy-protection processor is scrambled with the overlay (and is therefore not usable in the cable system); after processing it has the scrambling overlay removed and copy-protection applied.

Compatible operation with head end equipment is the key to satisfactory distribution of copy-protected signals within the cable system. Cable distribution equipment has been found to be transparent to protected signals. Cable converters generally operate satisfactorily provided certain precautions are taken with the head end scrambler. The copy-protection process is optimized to work satisfactorily with subscriber television receivers.

Addressable scramblers almost always use vertical field rate timing for one or both of two purposes. Frequently address-control and/or program-

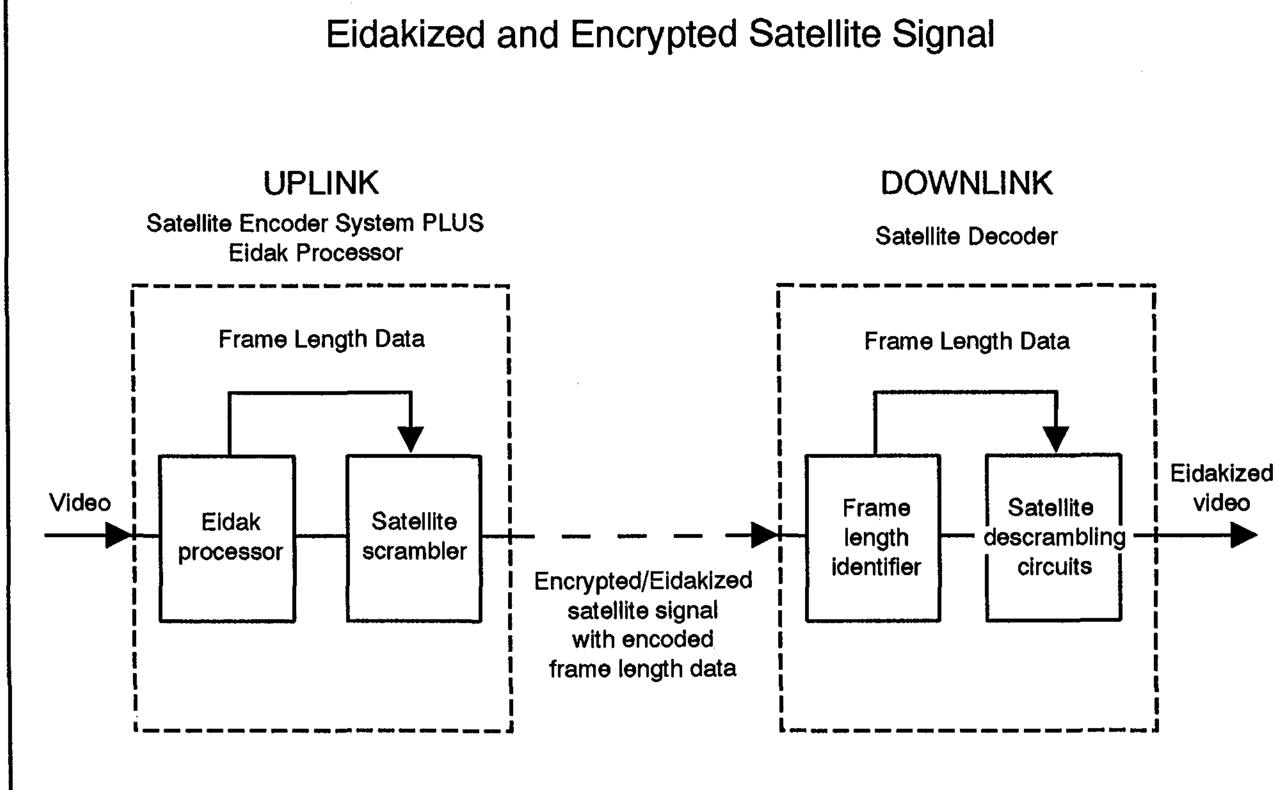
Eidakized and Encrypted Satellite Signal
UPLINK
Satellite Encoder System PLUS
Eidak Processor
Frame Length Data
Video
Eidak processor
Satellite scrambler
Encrypted/Eidakized
satellite signal
with encoded
frame length data
DOWNLINK
Satellite Decoder
Frame Length Data
Frame length identifier
Satellite descrambling circuits
Eidakized video

Figure 4.

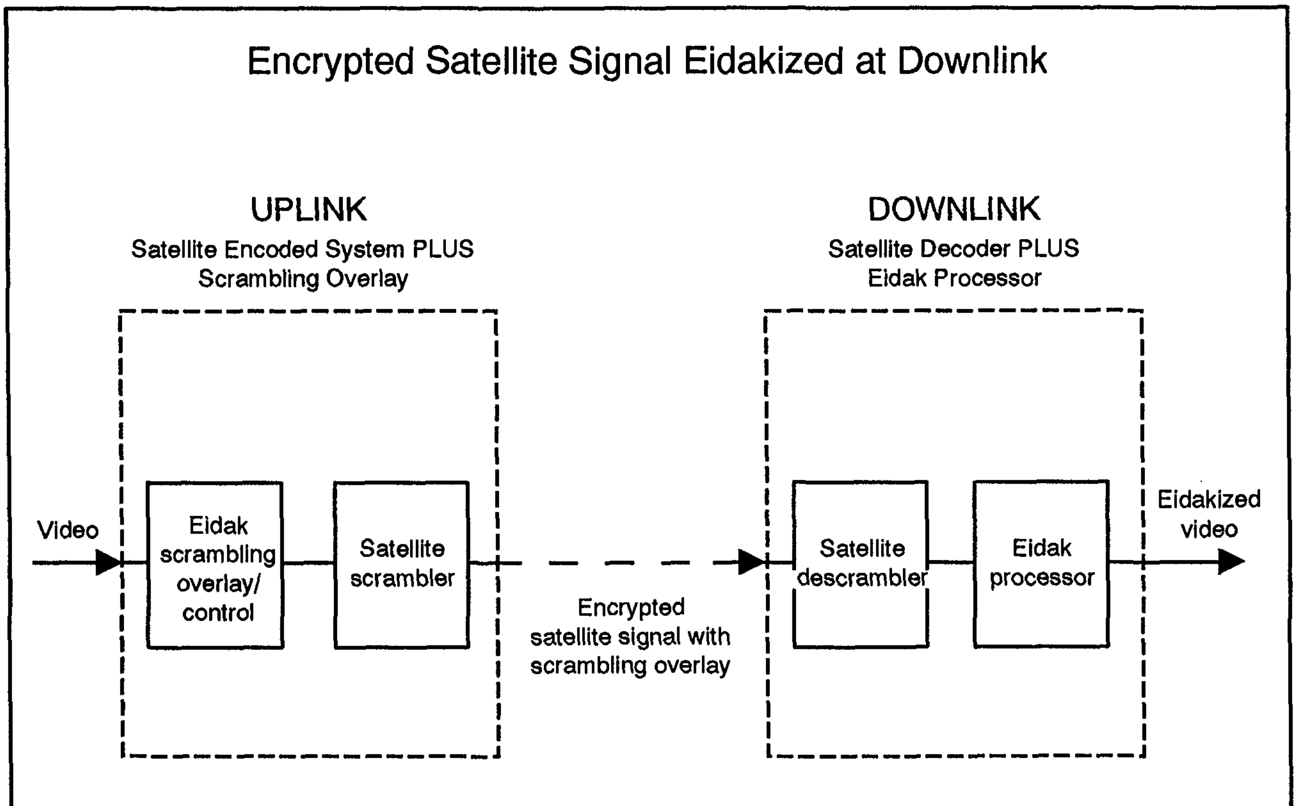
Encrypted Satellite Signal Eidakized at Downlink
UPLINK
Satellite Encoded System PLUS
Scrambling Overlay
DOWNLINK
Satellite Decoder PLUS
Eidak Processor
Video
Eidak
scrambling
overlay/
control
Satellite
scrambler
Encrypted
satellite signal with
scrambling overlay
Satellite
descrambler
Eidak
processor
Eidakized
video

Figure 5.

identification data is transmitted either within the VBI, or applied to the sound carrier and timed to coincide with the VBI. It is common practice for the scrambler to determine VBI timing by counting lines or clock pulses from a previous VBI, with the assumption that frame rate timing is standard 525 lines/frame. In order to accommodate video with variable field length, it has been found necessary to provide the scrambler with field reset information, either in the form of a reset timing signal, or by interruption of the scrambler's internal timing clock.

When the copy-protection processor is co-located with the scrambler, this vertical reset control output is provided by the processor -- configured for each specific scrambler type.

In cases when the copy-protection is applied remotely (e.g. satellite delivery of copy-protected signals, hubs, or origination from copy-protected laser disc), a separate scrambling interface device -- the ESI (fig. 6) -- is used to derive the reset control signals from the copyprotected video signal. The ESI consists of a data receiver which extracts the frame length data encoded in the VBI. The frame length data is used to generate properly timed reset or clock interruption pulses for the scrambler; the ESI interface is also figured for each specific scrambler type.

When a copy-protection processor is employed at a cable head end, information is required to cause the profile timing to coincide with scene changes. This data is provided either automatically by VBI signalling, or by means of a data storage device (either EPROM or floppy disk) sent to the head end site for use with program tapes or discs.

Standalone operation with a video laser disc player can be readily achieved by use of copy-protected discs (fig. 7). When the copy-protected disc is played at the head end, the resulting signal is already copy-protected, and is provided with the VBI data necessary to activate the ESI scrambling interface.

HEAD END EQUIPMENT

Configuring head end equipment to work with copy-protected video depends upon the program source and the location at which the copy-protection treatment is applied. If the program material is copy-protected prior to arrival at the head end (e.g. at a satellite uplink, at another head end, or on a pre-recorded copy-protected laser disc), only the scrambler interface is required. Should the copy-protection treatment be applied at the cable head end, then the copy-protection processor is used -- which also includes the scrambler interface function. In each case the addressable scrambler must be equipped for use with variable field length video signals. Wherever the Eidakized signal passes through a secondary hub equipped with another scrambler, the ESI scrambler interface is used.

Copy-protection of an encrypted satellite signal requires a compatible satellite descrambler at the head end receiver locations.

Table 1 shows the head end equipment requirements for operation with copy-protected PPV signals for each of these configurations.

In each configuration, operation is simple and automatic. Monitoring indicator lights on the copy-protection processor indicate its status (e.g. copy-protected video mode). Operation and adjustment of the cable scrambler and modulator are the same as with standard NTSC video. Operation of the laser disc player for local origination requires no additional adjustments or controls. **Important Note:** Once the video signal is copy-protected, it should not be passed through any other sync-sensitive or sync-restoring video processing equipment, for example video proc. amplifiers.

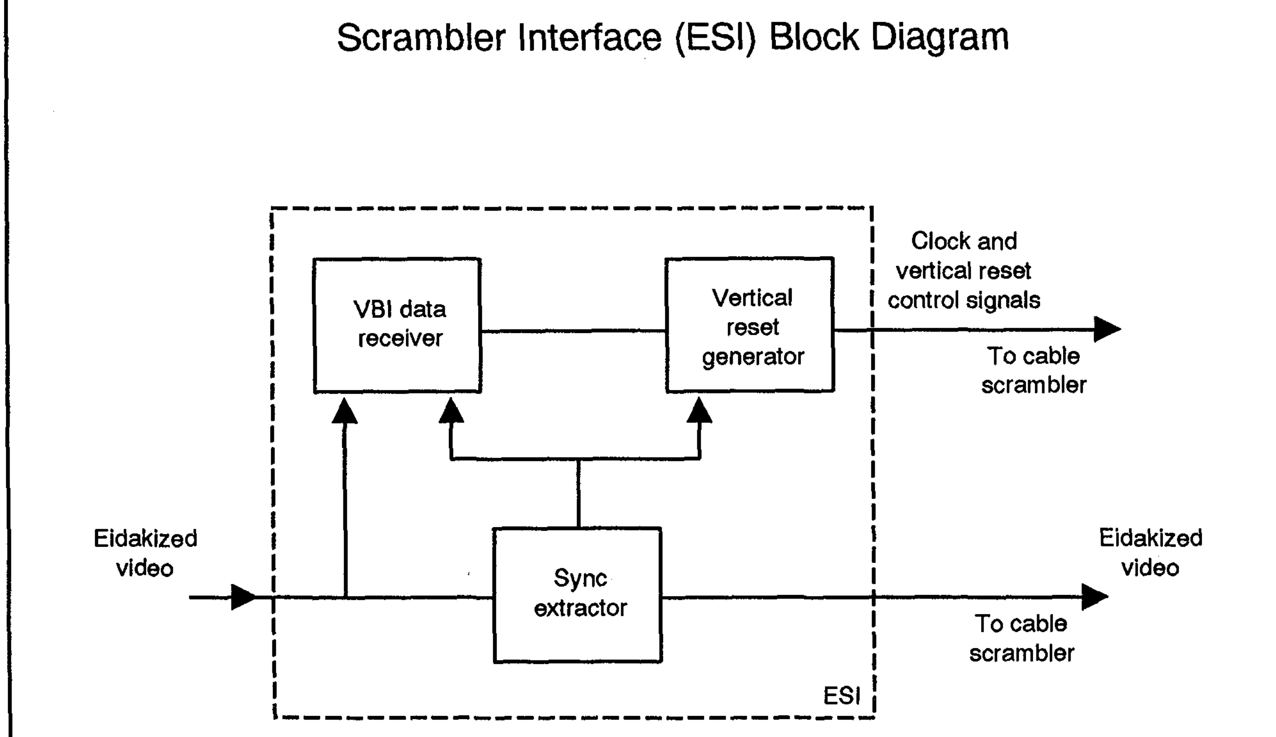

Figure 6.

	Programming Source	Satellite Receiver / Descrambler	Scrambler Interface: Head End	Scrambler Interface: Hub
1.	Satellite distribution — copy-protected at uplink	Eidak compatible	ESI	ESI
2.	Satellite distribution — copy-protected at head end	Standard	Eidak Processor	ESI
3.	Standalone — copy-protected laser disc	—	ESI	ESI
4.	Standalone — Non copy-protected tape or disc	—	Eidak Processor	ESI

Table 1.

CONCLUSION

The ability to prevent copying of PPV video signals is becoming a necessity to assure access to the kind of programming required to fuel the growth of PPV. Technology developed specifically for this purpose has been shown to work for cable distribution of PPV scrambled signals. In order to assure proper systems operation, special attention has to be given to equipment at cable head ends and hubs. Cable scrambling equipment generally requires some adaptation in order to permit operation with a video signal which has non-standard synchronization. As cable increasingly looks to PPV for revenue growth the cable PPV universe can now be equipped to provide access to those new program sources which require control of home copying to assure timely availability.

REFERENCES

1. "Unrecordable Video" A. Lippman & T. Hogue (MIT). IEEE Trans Broadcasting. Sept. 1987.

2. "Pay-per-view Copy-Protection", G.S. Stubbs, Communications Technology, March, 1989.

3. "A working Anti-Taping System for Cable Pay-Per-View" B. Perlman, IEEE Trans. on Consumer Electronics, August, 1989.

4. "Copy-Protection: What's in Store for PPV", G. S. Stubbs, CED Magazine, February 1989.

5. "PPV Copy-Protection in the Cable System Environment" G.S. Stubbs. NCTA Convention, May, 1989.

6. "Technical Issues for Copy-Protection in the Cable Television Environment.", B. Perlman. Paper to be presented at the 1990 ITE Annual Convention, Tokyo, Japan, July 25-27, 1990.

7. U.S. Patent Number 4,673,981 A. Lippman, et al. Issued June, 1987.

8. U.S. Patent Number 4,914,694. E. Leonard, et al. Issued April 1990.

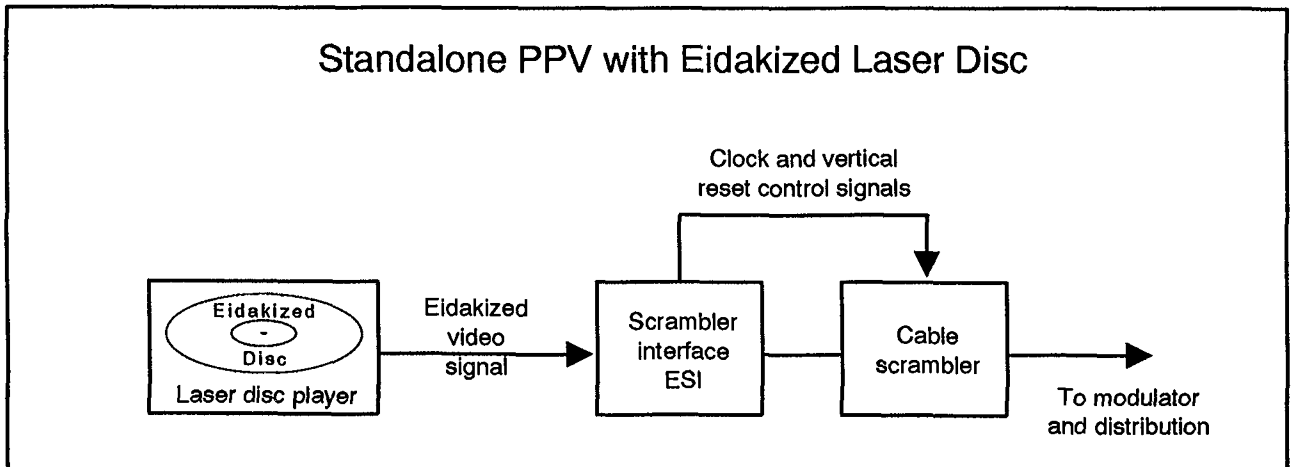

Figure 7.