A Novel Approach to Improving Picture Quality of Cable Television Converters

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Abstract

The quality of pictures sold to cable subscribers is of paramount importance. However, methods commonly used in cable to provide conditional access may worsen picture distortions caused by the cable plant. One such distortion, which we will refer to as scratch noise, is a result of an interaction between sync suppression scrambling and the automatic gain control of the television receiver.

This paper describes an innovative circuit design (patent application filed) to eliminate scratch noise. This circuit design produces a trade-off due to the effects of plant power supply hum on the cable signals. The paper concludes by presenting and evaluating one possible approach for dealing with hum.

INTRODUCTION

Cable television signals are prone to picture degradations from a variety of causes, both internal and external to the cable plant.[1] One example of interference resulting from external causes is co-channel interference. Co-channel may result from leakage into the cable plant from a broadcast channel sharing the same frequency as a channel on the cable. Internal to the plant, nonlinearities in amplifiers, for example, can cause intermodulation. Previous investigations have helped in many ways to minimize many of these types of interferences.

To secure cable television signals and prevent unauthorized reception, many cable systems scramble premium channels at the head end. They then restore the signal in the homes of paying subscribers using a de-scrambler. Although designed to be as benign to the de-scrambled signal as possible, these signal processing steps may, themselves, introduce additional types of interference.

RABBIT EARS AND SCRATCH NOISE

In particular, consider the effects of signal security methods which scramble the signal by suppressing the horizontal synchronization pulses. Such horizontal sync suppression is an integral part of most RF and baseband types of scrambling. Figure 1 shows the three stages of this scrambling and de-scrambling process. These stages are the original signal, the sync suppressed signal, and the final restored signal.

First, notice that the suppression window at the encoder is wider than the expansion window at the decoder. Because of manufacturing tolerances, it is not wise to try to make these two windows exactly the same width. Doing so would result in narrow and unpredictable spikes. Some of these spikes might extend in the direction of the sync tip causing erratic behavior of the television receiver. As a result, it is common to use a fixed overlap. This fixed overlap creates the characteristic sync suppression artifact commonly called rabbit ears.

Now, consider the effect of passing this sync suppressed television signal through the cable plant. Each amplifier through which the signal passes, will add some noise to the signal. This noise adds evenly to all parts of the video signal. However, restoration of the suppressed sync pulses in the decoder effectively amplifies the noise only in the

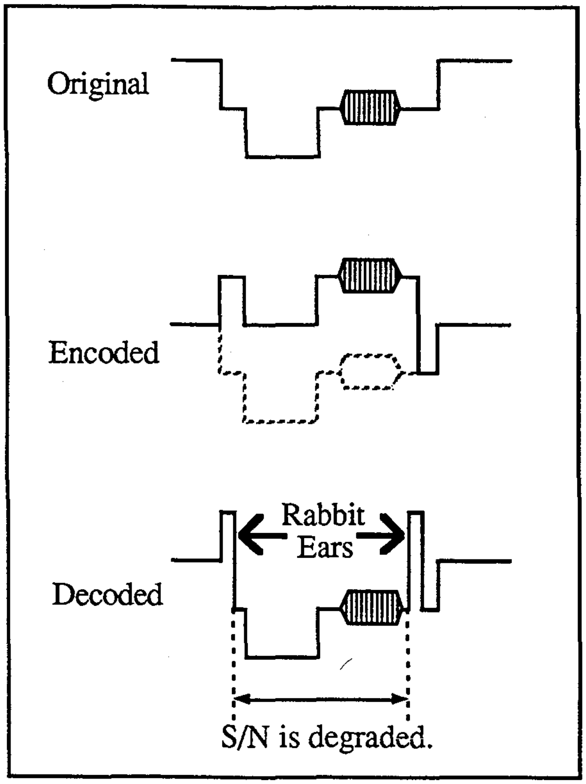

Figure 1: Rabbit Ears Resulting from Sync Suppression

sync portion of the signal. Because this noise affects primarily the sync and blanking area, and not the active video information, it is usually not considered to be a concern. However, careful investigation into the television receiver operation clarifies the problems caused by this noise.

Television receivers use Automatic Gain Control (AGC) circuitry to allow consistent reception of signals with varying strengths. The sync tip is the highest amplitude portion of the video signal. Therefore, additional noise there will affect an AGC level derived from signal amplitude. Figure 2 illustrates this.

Virtually all modern television receivers use a form of AGC called keyed or gated AGC.[2] This type of AGC samples the level of the received signal only once per horizontal line of video. Sampling occurs in the area of the color burst. The sampling is done on the luminance signal after separating the chrominance and luminance components. This location for AGC sampling is ideal for normal broadcast television because the sync and blanking area is the only predictable portion of the composite video signal.

Once sampled, this level determines the appropriate gain for the remainder of the horizontal line. However, for a de-scrambled channel, the noise riding on this area of the blanking pulse provides an incorrect gain for the entire line of video. Figure 3 illustrates the effect of such noise on the luminance signal. The result is a darkened horizontal line on the viewed picture. Each such darkened line looks like a momentary scratch. The rapid changes in these scratches have prompted the term scratch noise.

In addition, some television receivers may drift with age and sample part of the rabbit ear as well. This, too, can result in scratch noise effects.

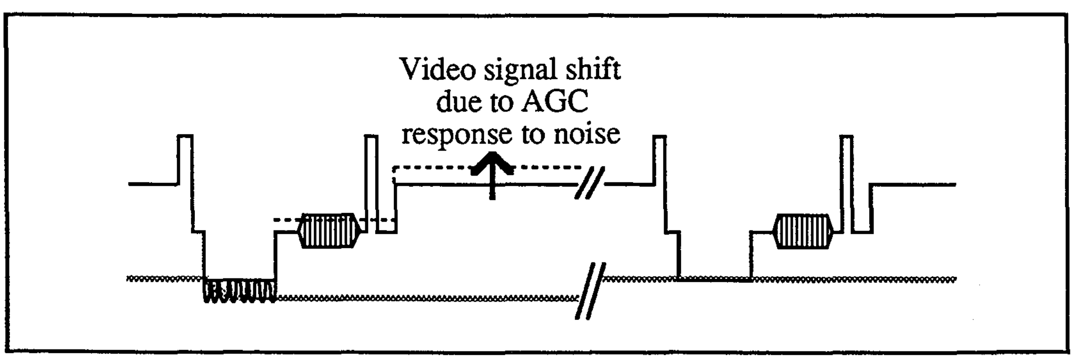

Figure 2: Sync Tip Noise Effects on AGC

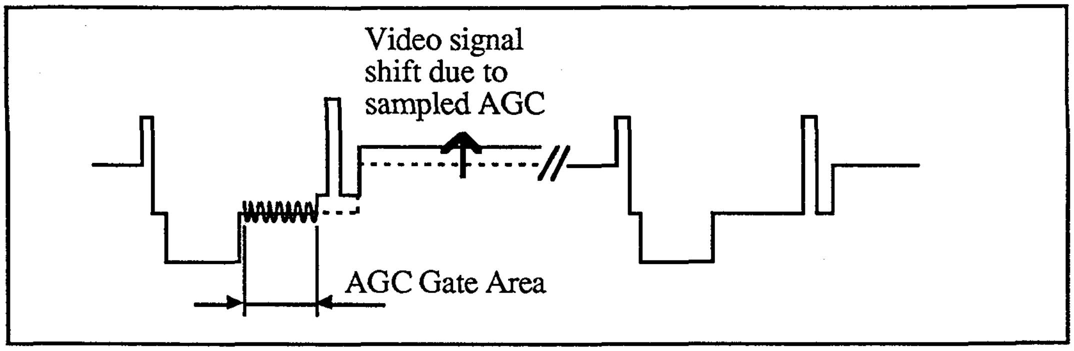

Figure 3: Noise Effects on Keyed AGC

EPQ CIRCUIT DESCRIPTION

Understanding this phenomenon has allowed development of an Enhanced Picture Quality (EPQ) circuit (patent pending). This EPQ circuit reduces scratch noise significantly and eliminates problems resulting from rabbit ears. To accomplish these two functions, the EPQ circuit consists of two sections for:

1) the removal of artifacts (rabbit ears)

and 2) improvement of signal to noise ratio on sync and blanking.

Rabbit ear removal

The first section of the EPQ circuitry uses sample and hold switching to replace rabbit ears with the immediately preceding signal level. Figure 4 shows the basic circuit. The associated timing diagram appears in Figure 5.

During active video, switch 2 is in the up, or bypass, position. Time T1 marks the beginning of the rabbit ear on the front porch of the horizontal sync. At time T1, switch 2 moves to the lower position selecting the pedestal level sampled at the previous horizontal sync's back porch. After the rabbit ear, at time T2, switch 2 moves back to the bypass position.

At the beginning of the back porch, time T3, switch 1 closes. This causes a sample and hold of the level just prior to the next rabbit ear. At time T4, switch 1 opens and switch 2 changes to the lower position. In this way, the pedestal value just sampled replaces the rabbit ear. Finally, at T5, switch 2 moves back to the bypass position. As a result, the sampled pedestal level substitutes for both rabbit ears.

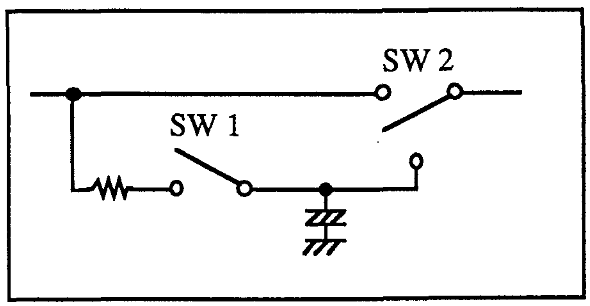

Figure 4: Rabbit Ear Removal Circuit

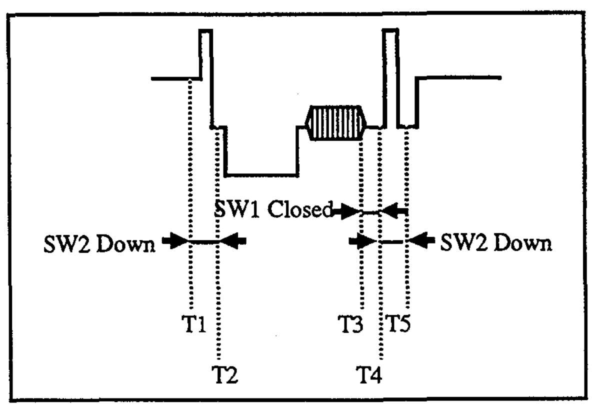

Figure 5: Rabbit Ear Removal Timing

S/N improvement on sync and blanking

The second section of the EPQ circuitry switches in filtering circuits to remove noise on the sync tip and blanking. Figure 6 shows the basic circuit. The associated timing diagram appears in Figure 7.

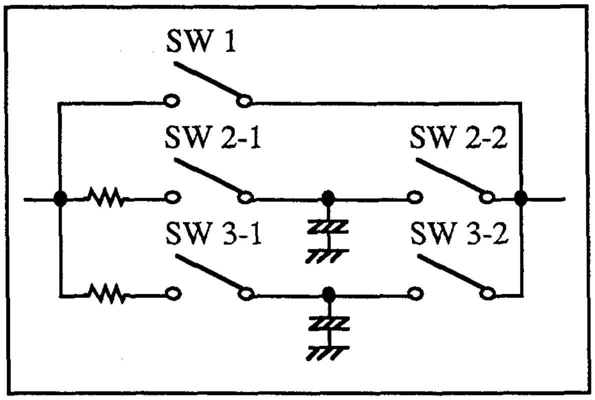

Figure 6: Noise Reduction Circuit

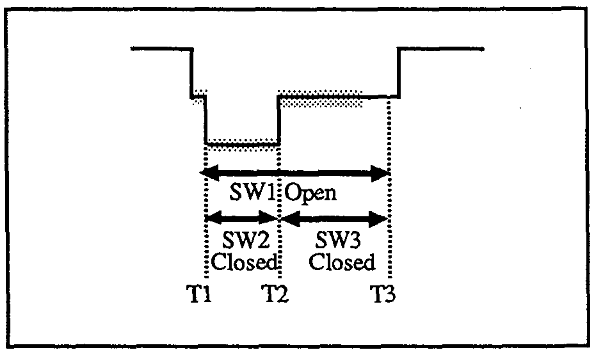

Figure 7: Noise Reduction Circuit Timing

Because of the presence of the color burst, we must position this circuit after the chrominance/luminance (Y/C) separation. The luminance signal then passes through this switch and filter circuit. During active video, switch 1 closes to bypass the signal. At the beginning of the horizontal sync tip, time T1, switch 1 opens and both sections of switch 2 close. This switches in a filter circuit of the appropriate value for the sync tip.

At T2, the transition from sync tip to breeze way, both sections of switch 2 open and both sections of switch 3 close. This switches in a filter circuit of the appropriate value for the breeze way and back porch. Finally, at T3, both sections of switch 3 open and switch 1 closes to pass the active video portions of the signal unfiltered. Thus, appropriate circuitry separately filters the sync tip and breeze way/back porch portions of the signal.

TRADE-OFFS IN DESIGN

Of course, the television receiver is not the only device involved which uses AGC. The cable converter also has it's own AGC. Selection of a slower than normal AGC further improves the immunity of the converter to fast, random noise.

System Power Supply Hum

However, there is one additional consideration. Cable systems employ long cascades of amplifiers. Power supply failures in any one of these active devices may cause power supply hum modulation to appear on the television signal. Excessive current drain due to overloaded system power supplies can also have a similar result.

If the hum includes sharp transitions like a square wave or spike, it will become more noticeable on the television receiver. In such cases, the NCTA recommends that systems limit hum modulation to 2 percent or less; otherwise 4 percent or less is acceptable with smooth sinusoidal hum.[3] The Federal Communications Commission proposed a limit of 3% in their technical requirements docket of last year.[4] With modern switching power supplies, well maintained systems may achieve hum levels below 0.3 %.

What effect does this hum modulation have on the subscriber's picture ? Normally, television receivers cancel any hum. The keyed AGC in the receiver samples the signal at a frequency much higher than that of the hum. Thus, the AGC rises and falls with the hum detected on the horizontal sync.

With the EPQ circuit, however, the converter removes the power supply hum only from the sync, not from the active video. The keyed AGC in the television receiver never detects the hum remaining on the active video. As a result, the television receiver displays the hum directly in the picture, with no cancellation.

Viewers can tolerate moderate amounts of hum in the viewed picture, while still enjoying the noise reduction benefits of the EPQ circuitry. However, as hum increases, the benefits of EPQ become completely masked by the objectionable hum bars in the picture.

Hum detector and AGC Control

One way around this problem is to use the converter's AGC as a surrogate for the television receiver's. However, the slow AGC chosen to complement the EPQ circuitry now becomes a disadvantage. Ideally, we would like to combine the benefits of EPQ with AGC speeds appropriate to the changing conditions of hum. Figure 8 shows the circuit proposed to do just this.

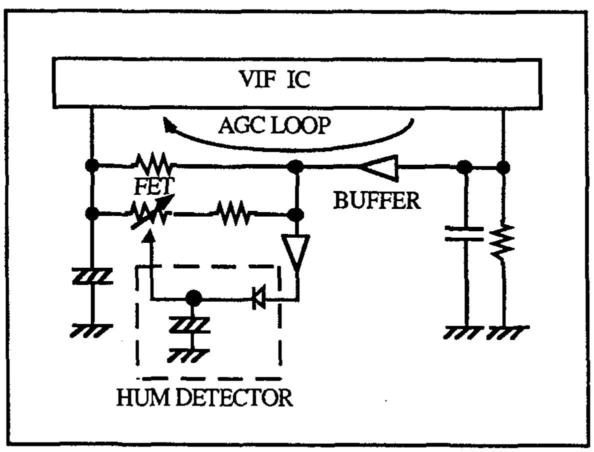

Figure 8: Hum Detection and AGC Speed Control

This circuit senses the amount of hum on the signal. It then adjusts between the slow AGC needed for EPQ, and the fast AGC to deal with the hum distortion. Based upon subjective tests to determine the optimum points, the control points chosen for AGC speed are as follows:

Slowest AGC 0.3% and below
Fastest AGC 1.2% and above

Between these two values, the speed of the AGC increases linearly.

CONCLUSIONS

Conditional access to cable programming requires a method of denying programming to non-subscribers. Signal scrambling involving sync suppression has become a common means of providing this control. However, the added noise introduced by sync suppression has adverse affects on television receiver AGC. The EPQ circuit provides a method to avoid the resulting scratch noise, while still handling hum modulation on the cable signals.

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