IMPROVED METHOD FOR VIDEO INVERSION SCRAMBLING SYSTEMS

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ABSTRACT

This paper presents an improved method for inverting and re-inverting video signals. The new technology uses a concept which divides the sync into two levels, which permit calculation of the axis of inversion. The divided sync signal consist of splitting the horizontal sync into a -40 IRE and +100 IRE pulses before baseband inversion. The transmission of the split sync signals eliminates luminances errors when re-inverting the video signal. Splitting the sync greatly improves overall system dynamics, thus increasing security. Deficiencies relating to current video inversion technology, along with a description of the scrambling method will be discussed.

INTRODUCTION

Video inversion involves a process which reverses the light and dark levels in a video signal. The light and dark levels are swapped by rotating the video signal around a reference located between white and sync tip. Ideally in the re-inversion process the video signal is restored to its original integrity by rotating the inverted signal around a reference equal to the axis of inversion. The reference establishes an axis of inversion, which is an essential component in the process of re-inversion. The importance of an accurate axis of re-inversion is best shown through an example. Consider the example waveform shown in figure 1 rotated between points (a) and (b). Figure 2 illustrates the inversion being performed around a 30 IRE axis of inversion. The 30 IRE axis of inversion was chosen primarily for ease of calculating an axis of re-inversion, which will be discussed later. However, it is possible to invert the video signal about any axis, providing the re-inversion axis is identical to the inversion axis. Figure 3 illustrates the consequence of re-inverting around a 40 IRE axis instead of the desired 30 IRE axis. Note that the re-inverted waveform

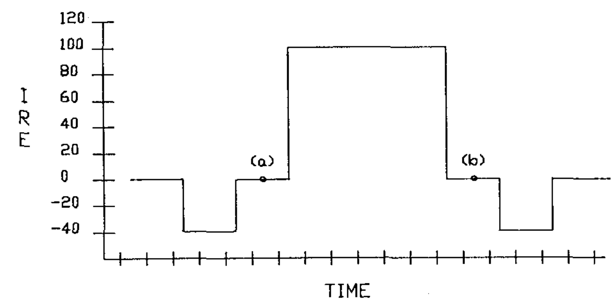

Figure 1. Example video waveform.

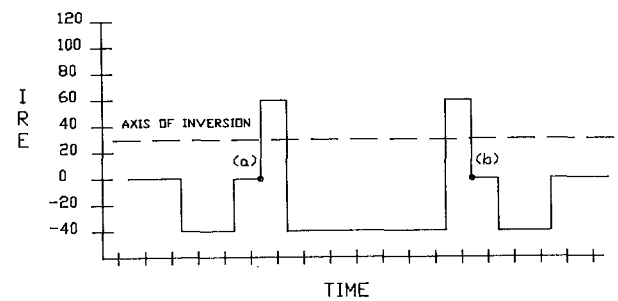

Figure 2. Example video waveform inverted around a 30 IRE axis.

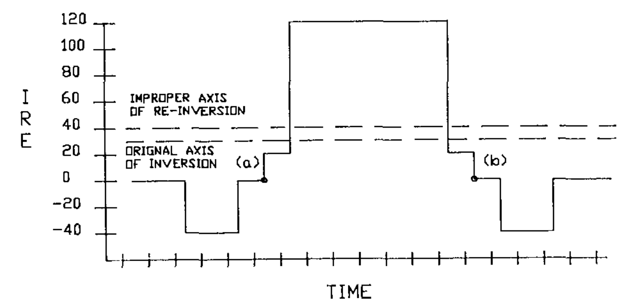

Figure 3. Inverted waveform re-inverted around a 40 IRE axis.

has been expanded with respect to the non-inverted waveform. Note the portion of the signal that initially was at blanking and is now at 20 IRE. Also, observe that the white level is now at 120 IRE. If the axis of inversion was lower than the desired axis the re-inverted waveform would have been compressed with respect to the original signal.

Mathematically the basic equation for inverting a signal can be written as

INV SIG = 2 X AXIS OF INVERSION - SIGNAL TO BE INVERTED.

Similarly the equation for re-inverting a signal can be shown as

RE-INV SIG = 2 X AXIS OF RE-INVERSION - INVERTED SIGNAL,

where the axis of re-inversion is equal to the axis of inversion plus any error between the two axes.

An important relationship in the inversion process shows that the difference between the re-inverted signal and the signal before inversion is equal to twice the axis error. This is illustrated in figure 3 where a 10 IRE axis error expanded the re-inverted signal by 20 IRE compared to the non-inverted signal. In addition it should be pointed out that a precise axis of inversion is equally important as an accurate axis of re-inversion.

There are basically three inversion modes possible for inverting a video signal. The first mode, shown in figure 5, depicts active video inversion only, with normal horizontal blanking. Figure 6 represents sync inversion, which technically is inverted horizontal blanking with normal active video. The third mode, all inversion, shown in figure 7, inverts both the horizontal blanking and active video.

Examination of active video inversion with normal horizontal blanking shows that inverted active video could become the most negative level of the video signal. Since sync recovery circuits in television receivers rely on the most negative level of video for synchronization, reliable synchronization is virtually impossible. Without horizontal synchronization the television picture will tear and become unviewable. In the event synchronization is established the recovered video will be the negative of the original signal. Also, as a result of the inversion process the color information will be rendered incorrect because the phase of the color subcarrier is shifted by 180 degrees. Since the horizontal sync is inverted in both sync inversion scrambling and all inversion scrambling there is no possibility of horizontal synchronization.

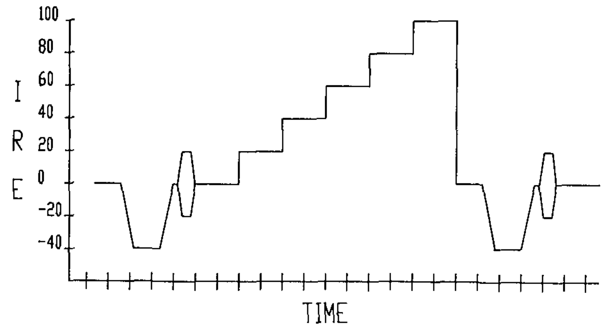

Figure 4. Example waveform.

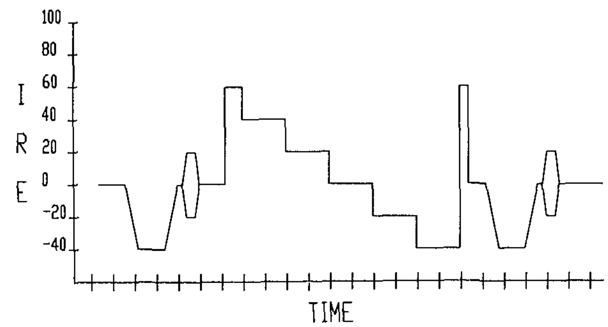

Figure 5. Active video inversion with normal horizontal blanking.

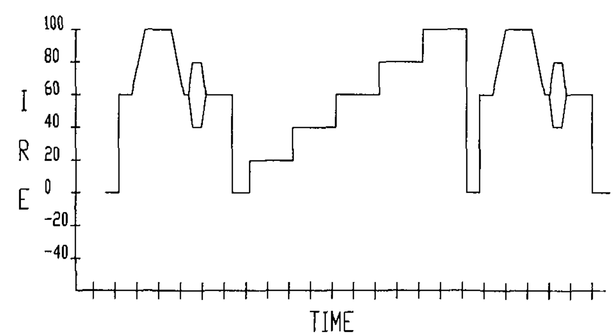

Figure 6. Inverted horizontal blanking with normal active video.

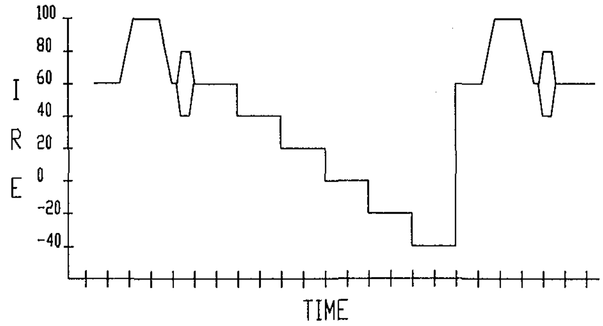

Figure 7. Inverted active video and horizontal sync (all inversion).

DEFICIENCIES OF PAST SYSTEMS

At first glance it would appear that inverting video or horizontal sync would be the ideal method for scrambling a video signal. This would be partially true if the transmission and receiving media was baseband to baseband. However, the baseband signal is transmitted at RF and therefore needs to conform with RF transmission limitations, particularly the modulation and demodulation process. This limitation is the source of one of the two major deficiencies associated with past systems. The deficiency arises when horizontal blanking is inverted and modulated as indicated in figure 8. After modulation, sync tips are no longer the highest amplitude of the RF envelope. Video demodulators rely on sync tips to be the highest RF amplitude for automatic gain control (AGC). Proper AGC is necessary in order to establish correct video level proportions. Systems have been developed that compensate for this deficiency by incorporating very slow time constant AGC circuits that respond to the non-inverted sync pulses in the vertical interval. However, very objectionable artifacts are generated in the recovered signal when utilizing such a measure. The most obvious artifact is a luminance shift when changing channels or scrambling modes. Due to the nature of scrambling systems in which non-inverted sync pulses and inverted sync pulses are used, a video demodulator that AGC's to the most negative amplitude level will not work. Dual video demodulators can be used but basic economics and the inability to match gains and clamping level preclude this approach.

In addition to the demodulator not responding to the inverted horizontal blanking, video modulators react in a similar fashion. Video modulators rely on the sync tip amplitude to clamp the video signal to assure constant peak modulation with varying input levels. Essentially, sync tips are not present when the horizontal blanking interval is inverted. Without costly modifications to dedicated modulators this limitation precludes the utilization of this type of scrambling.

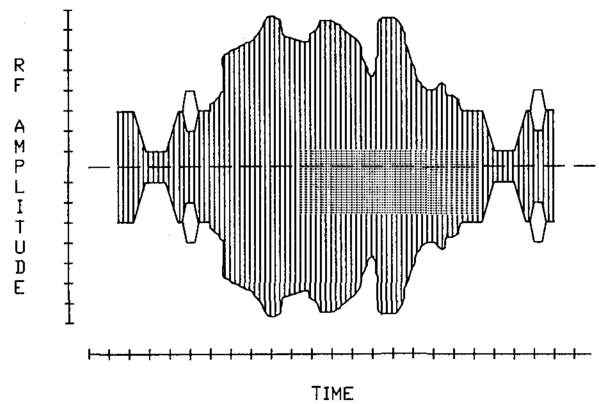

Figure 8. RF envelope of an inverted horizontal blanking waveform.

The second deficiency manifests when the descrambled axis of inversion fails to equal the scrambled axis of inversion. This scenario becomes a reality when headend or descrambling conditions change. Older systems do not have the dynamic capability of maintaining identical axis between scrambling and descrambling with varying conditions. Since any error in axis between scrambling and descrambling will cause a luminance shift of twice the axis error, axis integrity is very essential. In some systems axis integrity relied on factory calibration settings to match inversion and re-inversion axes. Figure 9 illustrates a descrambler configuration which is used in past systems. This type of configuration, which relies on fixed factory calibration, poses a serious axis problem. Consider a calibration signal from the factory's headend which is inverted about a 30 IRE axis and transmitted at a set depth of modulation (DOM). The descrambler can then be calibrated to measure from sync tip a set axis of re-inversion which equals

SYNC TIP LEVEL + (70/140) X (VIDEO LEVEL),

where the video level is from reference peak white to sync tip. If the video level remains equal to the level of video when calibrated, the descrambled signal will match the original signal before inversion. Now consider the consequence when the field modulator DOM differs from the calibration modulator DOM. A change

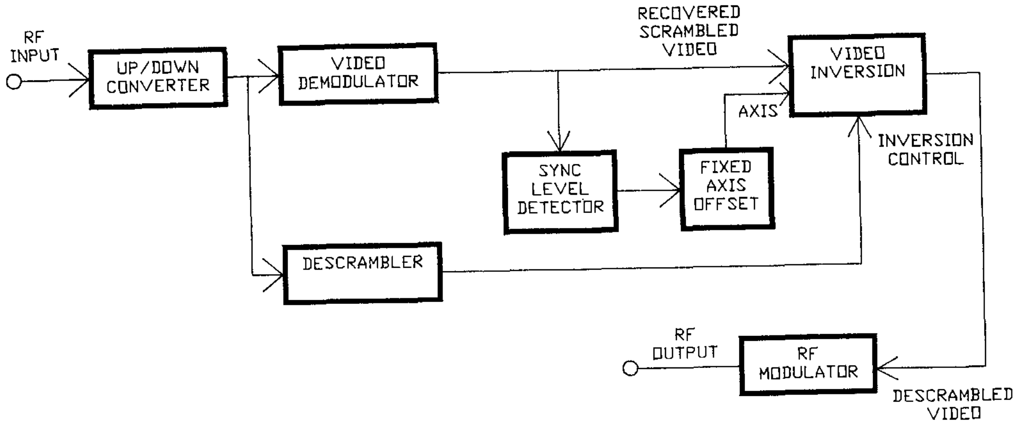

Figure 9. Descrambler configuration which determines axis of re-inversion by fixed offset.

in headend DOM causes the recovered video level to be different from the level of video when calibrated. As would be expected the re-inversion axis is in error by

(70/140) X [(NEW VIDEO LEVEL) - (CAL VIDEO LEVEL)]

For example, if the calibration video level is 1 volt and the video level in the field is .9 volts the axis error will equal 7.78 IRE. By virtue of inversion the 7.78 IRE axis error will cause a 15.56 IRE luminance shift, thus resulting in brightness variations in the television picture.

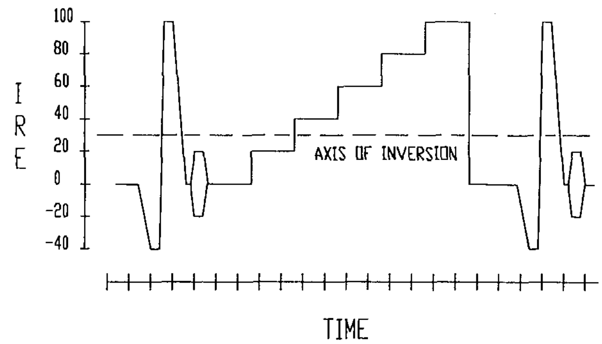

Figure 10. Example waveform with split sync signal.

SPLIT SYNC INVERSION

Fortunately, there is an economical method for overcoming the deficiencies of past video inversion systems. The new method involves utilizing a technology which transmits a modified sync signal during the conventional sync time. The signal is transmitted by splitting the sync interval into two components. Figure 10 illustrates an example waveform which incorporates the split sync signal. The first component of the signal is the conventionally transmitted -40 IRE sync. After a time equal to about 2.0 microseconds the -40 IRE signal level increases to the peak amplitude of 100 IRE. The 100 IRE signal pulse remains at 100 IRE for about 2.0 microseconds before returning to 0 IRE.

The split sync signal is then used in an analog computation by the descrambler to calculate an axis of re-inversion. As previously mentioned a 30 IRE axis of inversion is used in order to facilitate a simple axis of re-inversion calculation.The axis is calculated by simply computing the difference between the peak sampled 100 IRE and -40 IRE signal. The absolute axis which equals

SYNC TIP LEVEL + (.5) X [(100 IRE LEVEL) - (-40 IRE LEVEL)],

is then applied to the inversion amplifiers, which precisely re-inverts the inverted signal to its original integrity. The utilization of a technology that dynamically calculates a re-inversion axis, instead of a fixed axis offset, makes the re-inversion process immune to recovered signal level. For example, assume if the waveform in figure 10 was inverted around a 30 IRE axis and transmitted at a set DOM. After recovering the signal in the descrambler the example waveform would resemble that in figure 11. With the -40 IRE and 100 IRE signal levels equal to 4.0 and 6.0

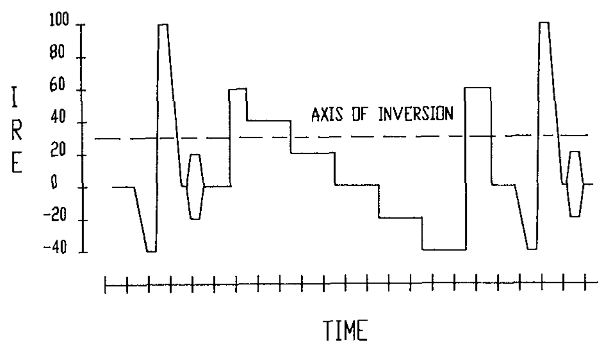

Figure 11. Recovered (inverted) signal.

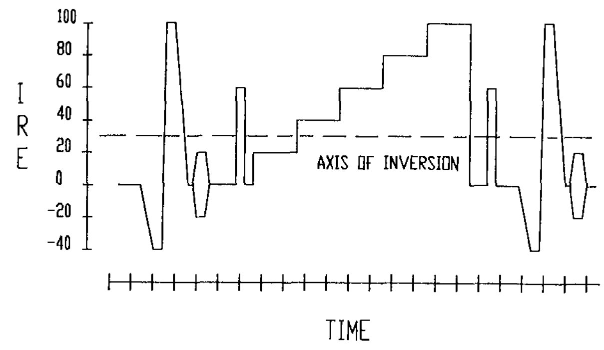

Figure 12. Re-inverted signal.

volts respectively, the calculated absolute axis of re-inversion would equal 5.0 volts. The calculated axis of 5.0 volts lies exactly centered between the peaks of the split sync signal, which correspond to a 30 IRE axis. Re-inverting the inverted signal around this calculated 30 IRE axis will restore the signal to its original integrity, as shown in figure 12. Now consider that the headend DOM changes, resulting in recovered signal split sync peaks of 4.0 volts and 5.5 volts. The calculated absolute axis of re-inversion would equal 4.75 volts, again placing the axis centered between reference white and sync tip. As demonstrated by varying the headend DOM one can see that the axis of re-inversion is independent of DOM. The ability to dynamically calculate an axis of re-inversion not only removes the dependency on headend DOM adjustments, but also improves the systems ability to dynamically change scrambling modes.

An advantage of scrambling a signal by splitting the sync is that many television receivers require the entire 4.7 microsecond sync to establish synchronization. However, in the descrambling process the signal transmitted to the suscriber's television must be capable of working with all television receivers. Therefore, the descrambler must restore the split sync signal so that the horizontal blanking interval complies with the NTSC video signal standard. This is accomplished by replacing the split sync signal in the descrambler with the proper sync level prior to re-modulation. The diagram in figure 13 illustrates a portion of a descrambling system which dynamically calculates the axis of re-inversion along with restoring the split sync signal.

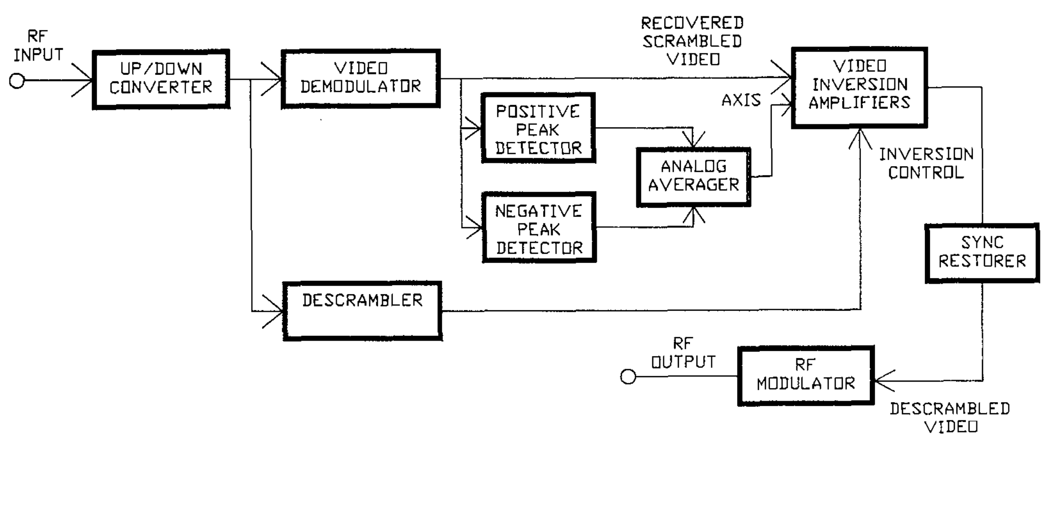

Figure 13. Descrambler configuration which calculates axis of reinversion.

An inherent advantage to splitting the conventional sync with a 100 IRE and -40 IRE signal is that headend modulators do not require any modifications. Modifications are not required because adequate sync tip always remains to permit proper clamping. Traditionally, the inversion modes that a modulator would have trouble with are sync inversion and invert all. Inspection of the example waveforms shown in figures 14 and 15, which represent sync inversion and invert all respectively, shows that the modulator will always have a -40 IRE signal required for proper operation. This is possible due to inverting the 100 IRE split sync signal around a 30 IRE axis. As illustrated the 100 IRE signal becomes -40 IRE and the -40 IRE signal becomes 100 IRE.

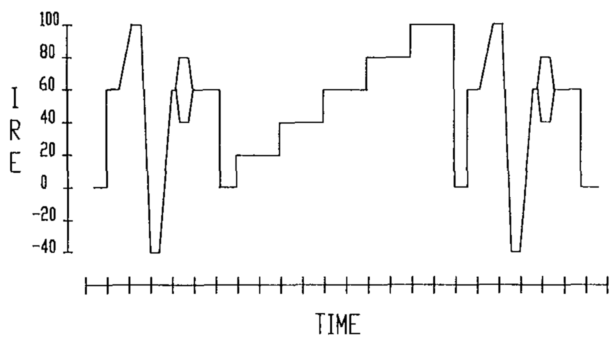

Figure 14. Sync inversion with split sync.

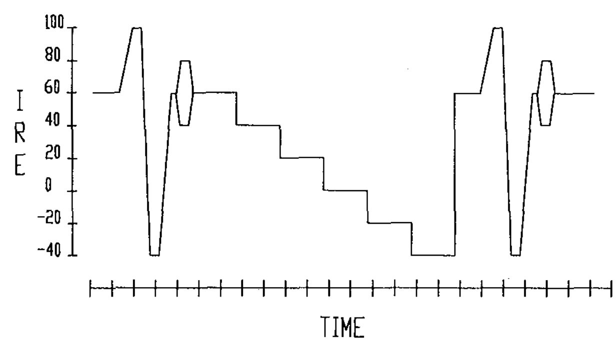

Figure 15. Invert all with split sync.

In addition to furnishing the headend modulator an adequate signal for modulation, the split sync signal also allows the descrambler's demodulator to function properly. The inverted 100 IRE signal establishes the required signal necessary for proper demodulator AGC operation. Figure 16 shows an example of an RF envelope that has been modulated with an all inverted split sync video signal. Note that when modulating the inverted 100 IRE signal it becomes the most positive amplitude of the RF envelope. This positive signal is what is required by the demodulator for reliable operation. By always having a peak signal level present reliable demodulator performance is maintained in all modes of scrambling.

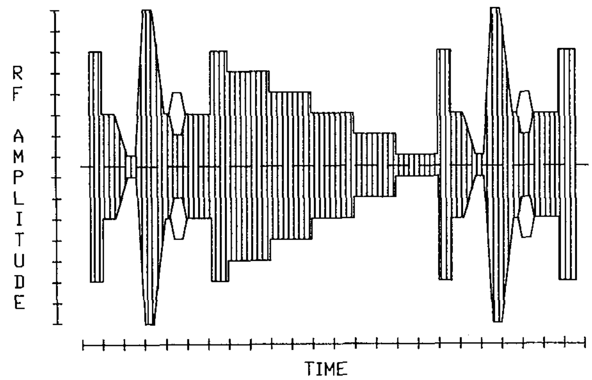

Figure 16. RF envelope of inverted sync & active video with split sync signal.

CONCLUSION

This improved method of video inversion eliminates many of the limitations affecting some previous video inversion systems. Besides eliminating deficiencies the improved inversion system increases overall system performance and capability. Dynamic generation of the re-inversion axis eliminates the need for precise factory modulator adjustments. Axis integrity in all modes of inversion allows for dynamic changing of scrambling modes without any chrominance or luminance artifacts. The ability to dynamically scramble increases system security, which is becoming a major concern throughout the industry. The new technology increases security further when integrated with older scrambling techniques such as sync suppression.