# THE PERCEPTION OF CLAMP NOISE IN TELEVISION RECEIVERS

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## *ABSTRACT*

Clamp circuits in television systems adjust the black level of each scan line to a reference voltage derived from the "back porch" of the TV signal. If the TV signal is noisy, then the derived black level can vary from scan line to scan line, resulting in a displayed streaking effect called "clamp noise." This paper reports on clamp noise research performed on a video processing supercomputer at the National Institute of Standards and Technology (NIST). This research measured the average input video signal-to-noise ratio (SNR) at which human observers can just begin to perceive clamp noise against a background of moving color pictures. This threshold was measured as a function of two parameters: two-dimensional scintillation noise due to broadband video noise, and the time constant of the clamp circuitry. These results may give TV system designers guidance in choosing tradeoffs between scintillation noise processing and clamp noise reduction.

## *SUMMARY*

Noise processed and displayed in television receivers is objectionable to the extent that it can be perceived by human viewers. Earlier research developed a test procedure to quantify the perception threshold of the human visual system to broadband scintillation noise as a function of the first two statistical moments of the background [1]. This methodology has been extended here to study how clamp noise in TV receivers is perceived by human viewers.

The broadcast TV signal carries a reference to be used by the receiver clamp circuitry to establish a DC zero voltage level. This clamp level is derived line-by-line by the receiver, after sampling the received signal. Typically, the "back porch" region of the video signal that includes the color burst is sampled for about 4 μs by the clamping circuit. Most clamping systems can be modeled by an RC circuit. During the clamp sampling period, a series capacitor charges up to the average voltage derived from the TV signal reference. This bias is subtracted from the active part of the video, thereby restoring the DC reference. The time constant of this RC circuit is a design parameter of the clamp system.

If there is noise on the received TV signal, the clamp voltage on the series coupling capacitor can vary from line to line. This variation produces the streaking-type artifact called clamp noise. Increasing the time constant of the RC circuit softens the effect of clamp noise at the expense of making the picture more susceptible to brightness variations due to AC pickup.

In many transmission scenarios, such as off-the-air received broadcasts, the noise presented to the clamp circuit may be the same as the noise that exists during the active video part of the received video signal. In this paper we refer to the noise presented to the clamp circuitry as *clamp noise* and the active video noise as (time varying broadband) *scintillation noise*. These two noise levels are often the same, but they do not have to be. Possible causes for a difference in noise levels may be: peaking filters, composite transmission and decoding, cascading of clamp circuits coupled with reinsertion of clean blank signals, or horizontal bandwidth limitations in the video chain. For example, home VCRs often generate new, clean blanking levels. On the other hand, some noise reduction processing could act only on the active part of the video and leave the clamp noise relatively high.

Broadband scintillation ("snow") type of time-varying noise in the picture was found in this study to mask the effects of clamp noise. A challenge to the TV system designer is thereby presented. If circuitry is added to reduce the scintillation noise, then previously masked clamp noise may become objectionable, requiring additional circuitry to further reduce the clamp noise. Since reduction of noise is a desirable goal, the designer faced with the cost constraints of consumer electronics products must make a decision on how to apportion resources between reducing scintillation noise and clamp noise.

Our research investigated the extent to which time-varying scintillation noise that is superimposed on TV image is effective in masking the clamp noise. We implemented a real time model of the scintillation noise and the clamp circuit characteristic on the Princeton Engine video simulation supercomputer at NIST. Test subjects were asked to rate the objectionability of the clamp noise as a function of the scintillation noise and also as a function of the RC time constant of the clamp circuit.

The responses compiled from seven observations (six observers, one of whom repeated his tests) were averaged for each test case. Each observer viewed 50 separate test conditions. The RC time constant was given two values, 1 µs and 10 µs. For each value of the RC time constant, the standard deviations of the scintillation and clamp noise were allowed to take on 5 values, for a total of 25 combinations. In each case, the standard deviations of the noise were 20, 26, 32, 38, and 51 dB. (The dB levels used here represent the peak signal supported by the system, usually expressed as 100 IRE units, divided by the rms noise. Here 20 dB would represent the noisiest picture.)

In the absence of any special processing and in the absence of noise generators other than the noise on the received video, the noise level in the video (scintillation noise) may be identical to the clamp noise–the noise seen at the input to the circuit of Figure 1. For such cases, Figure 2(a) shows the

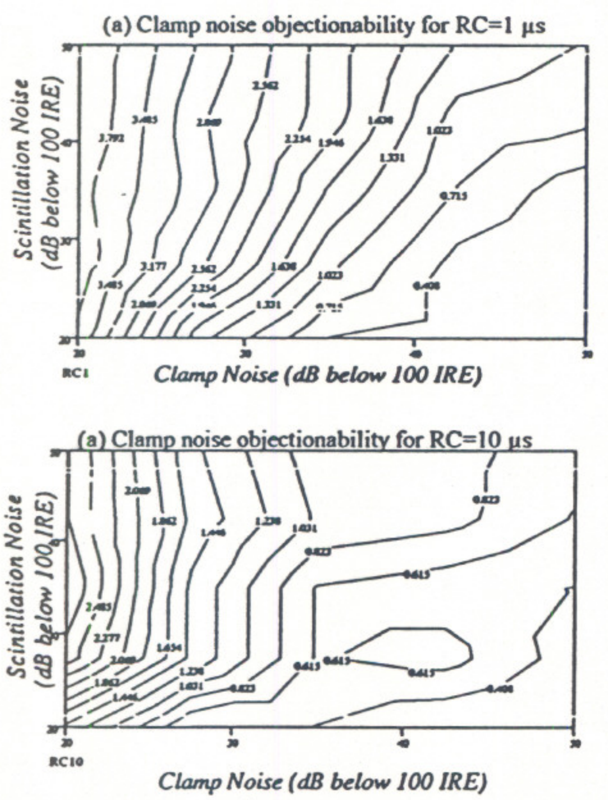


*Figure 3. Objectionability of clamp noise when clamp noise does not equal scintillation noise*

objectionability of the clamp noise for RC=1 µs and Figure 2(b) for RC=10 µs. The horizontal axis is the signal-to-noise ratio (SNR) of the clamp and scintillation noise, defined in dB as 100 IRE divided by the rms noise. The vertical axis is the 0-5 clamp-noise objectionability scale defined above. For RC=1 µs, as the SNR increases from 20 to 40 dB, the clamp noise objectionability drops from a very objectionable (distracting) value near 4 to a barely noticeable value near 1 for SNR greater than 40 dB. When the RC time constant is increased to 10 µs, the increased noise filtering improves the perceived picture by masking the clamp noise artifacts, as shown in Figure 2(b). Even for the worst-case, noisiest picture of SNR of 20 dB, the objectionability of the clamp noise is only a mildly disturbing 1.5.

In the more general case, scintillation noise will not be the same as clamp noise. For such cases, Figure 2 becomes a function of two independent variables, clamp noise and scintillation noise, as shown in Figure 3.

The two axes represent SNR: the horizontal axis is the SNR of the clamp noise and the vertical axis is the SNR for scintillation noise. The contours are drawn for constant values of the 0-5 objectionability scale. The precise shape of the shown contours should be interpreted with caution. As was noted above, the data were taken for 25 combinations of the SNR: five increments in the horizontal direction and five in the vertical direction, taken at SNR= 20, 26, 32, 38 and 51 dB. The sparseness of the data may contribute some inaccuracies in these plots. However, it is believed that the trends indicated in the plots are credible.

Consider first Figure 3(b), for RC=10 µs. The contour lines show a marked change in slope at a scintillation SNR of nominally 27 dB. In the noisier region where the scintillation SNR less than 27 dB, further increases in the scintillation noise (decreasing the scintillation SNR) with fixed clamp noise decrease the clamp noise objectionability value. One reason for the apparent sharp change in the contours in the neighborhood of scintillation noise=27 dB is possibly due in part to the sparseness of the data points, as noted above. Nevertheless, this part of the contour curves does confirm the qualitative observation that was noted during the experiments, namely that the more noticeable masking of the clamp noise occurs in this region of operation. For the region where the scintillation SNR is above 27 dB and the clamp noise SNR is below 35 dB, essentially vertical contour lines indicate no change in the clamp noise objectionability value with change in scintillation noise. This shows that the scintillation noise essentially does not mask the clamp noise in this region.

The situation is different for the case of RC=1 µs, shown in Figure 3(a). Here, the contour lines are almost never vertical, indicating that increases in the scintillation noise usually have some visible effect in masking clamp noise. For RC=1 µs, the objectionability of the clamp noise can be reduced by masking by about 1/2 point on the 0-5 point scale for clamp SNR near 20 dB and by as much as about 1.5 points for clamp SNR near 40 dB, over the range of 20 to 50 dB scintillation noise SNR.

## CONCLUSIONS

We investigated the visibility of clamp noise in the case when the noise at the input to the clamp circuitry, as well as the time varying noise superimposed on the active video, are both white and Gaussianly distributed. The TV system designer

## THE EXPERIMENTAL PROCEDURE

The Princeton Engine was programmed to simulate an NTSC (National Television Systems Committee) television system. A clean NTSC composite video signal was sampled and digitized by the Princeton Engine. Temporal Gaussian random noise of known (and adjustable) standard deviation was generated by software and was added to the digitized signal. The "noisy" composite signal was then software decoded into red, green and blue signals. A single Gaussian random noise value was also calculated for each video scan line and was linearly scaled to obtain the desired magnitude of added clamp noise. This value was then integrated in a weighted fashion over a number of video scan lines to correctly simulate the effect of a single-pole low-pass RC filter with a specified time constant. The final clamp noise value was added equally to the red, green and blue signals to produce a constant luminance shift over the entire video line. This was similar to the effect caused by an actual clamp circuit operating under noisy conditions.

An effort was made to have the experiment approximate as closely as possible the conditions specified in the CCIR Recommendation 500-4 [2]. A Sony 19 inch monitor with a pitch of 0.4 mm and a gamma of 2.2 was viewed at 5 times vertical screen height. The monitor had a peak white output of

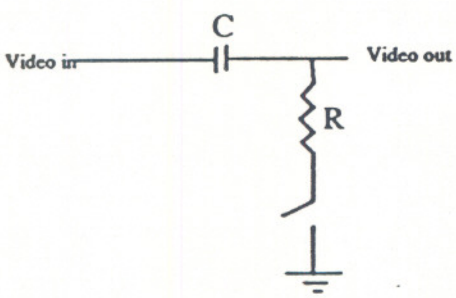


*Figure 1. A model of the clamping circuit*

75 cd/m$^2$. The output for 0 IRE input was 0.05 cd/m$^2$ and for 7.5 IRE units the output was 0.29 cd/m$^2$. The room lighting was incandescent, with 4 cd /m$^2$ of illumination falling on the monitor face. The wall behind the monitor was at approximately 15% of peak monitor luminance.

## A MODEL OF THE CLAMP CIRCUIT

A simplified model of the clamp circuit is shown in Figure 1. The "back porch" of the NTSC composite video signal is the part that follows the horizontal sync pulse, and includes the color burst. The switch of Figure 1 is closed during the back porch of each horizontal line, for a duration of about 4 μs. While the switch is closed, the series capacitor charges up to the value of the input video signal, as averaged over the RC time constant. Once the active part of the video signal begins, the switch opens and the average voltage stored on the capacitor is subtracted from the input video signal, thus clamping this signal.

If the input video signal is noisy then the noise, as integrated by the RC circuit, will possibly cause a different DC value to be subtracted from each input video scan line. This produces a streaking artifact that is called *clamp noise.*

## EXPERIMENTAL RESULTS

The visible effects of clamp noise are decreased if: (1) the clamp noise is masked by scintillation noise (i.e. white, broadband time varying noise that is superimposed over the displayed picture), or (2) the RC time constant is increased. The visibility of the clamp noise is also a function of the content of the actual image being displayed. The purpose of the experiments here was to measure quantitatively how objectionable the clamp noise is to human observers, as a function of the RC time constant and the standard deviation of the masking scintillation noise. Each observer viewed a long enough moving image sequence so that the effect of the background image was averaged out.

The objectionability of the clamp noise was defined over a six-point scale: 0=clamp noise is invisible, 1=possibly visible clamp noise (unsure), 2=definitely visible clamp noise but not very objectionable, 3=moderately objectionable clamp noise, 4=very objectionable clamp noise (distracting), 5=image rendered useless by excessive clamp noise.

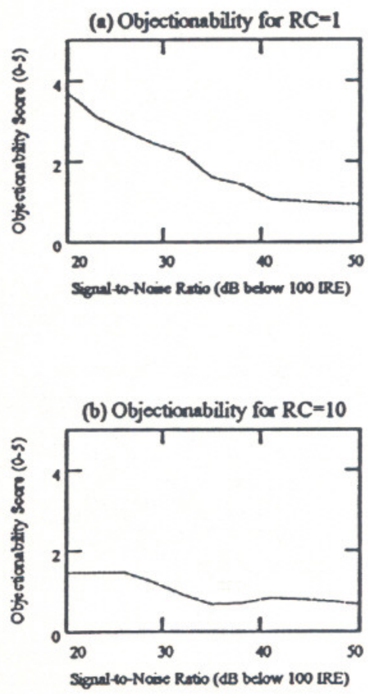


*Figure 2. The objectionability of clamp noise for the case of clamp noise equaling scintillation noise*

would normally try to design a system in which the objectionability of the clamp noise is 2 (noticeable but not very objectionable) or lower. If the SNR at the clamp input is the same as the video SNR superimposed on the picture, then this SNR must be 32 dB or higher if the RC time constant of the clamp circuit is 1 μs. Increasing the time constant to 10 μs would guarantee that the objectionability would always be better than 2. However, such a high RC value could make the display susceptible to visible brightness fluctuations due to causes such as AC pickup.

In the more general case where the SNR of the two noises may be independent due to separate noise processing, the situation is more complex. For the same goal of a clamp noise objectionability of 2 or lower, one would have to stay to the right of and below the "2" contour in Figure 3. Thus, considering the example where RC=1 μs, if the scintillation SNR is 50 dB (no masking of the clamp noise by the scintillation noise), the clamp SNR must be 36 dB or higher. On the other hand, if the scintillation SNR drops to 30 dB, then the clamp SNR may be allowed to fall to 32 dB, since the clamp noise is somewhat masked by the scintillation noise.

## REFERENCES

[1] S. Herman, B. F. Field, and P. Boynton, "Quantification of Temporal Noise Threshold in Television Displays," presented at the SID '94 International Symposium, San Jose, CA, June, 1994 Digest of Technical Papers, pages 869-872

[2] "Method for the Subjective Assessment of the Quality of Television Pictures," CCIR Recommendation 500-4, 1990