AN EXPERIMENTAL TV GHOST CANCELLATION CIRCUIT WITH AUTOMATIC GAIN CONTROL

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ABSTRACT

Sometimes TV-reception is disturbed by reflections from objects as towers, buildings, etc. The development of CTDs with excellent high-frequency performance enabled us to design a full video bandwidth echo cancellation circuit. The circuit consists basically of a recursive filter which generates an echo with the correct amplitude, delay and polarity. A ghost-free picture is obtained by adding this synthetic ghost to the 'ghosty' video signal.

Automatic adjustment of gain, delay and polarity is highly desirable e.g. for dealing with time-varying echoes. Our experimental echo cancellation circuit is equipped with an automatic gain and polarity control. The echoes are measured in the field retrace period using the conventional signal there present. Extension of the concept to automatic time delaycontrol and multiple ghost cancellation will also be considered.

The circuit has been realised with PCCDS with various number of stages (e.g. 26,128) and has been used successfully to cancel artificially generated ghosts in the range of 0.6 to 8.5 μsec. The full video bandwidth (5 MHz) of a PAL colour signal was employed by varying the clock frequency between 15 and 40 MHz.

INTRODUCTION

An echo is usually due to the existence of a transmission path in parallel with the main path. Therefore the signal received at the TV-antenna consists of the sum of the 'direct' signal and a signal reflected by an object (building, mountain, etc.). The reflected signal is (mostly) delayed and attenuated with respect to the direct signal. The paper deals with undistorted echoes i.e. echoes representing a displaced representation of the original picture. Distorted echoes, however, can also occur. In the paper of P.Mertz (1) differentiated echoes are treated. For undistorted echoes we can write the received HF-signal as

$$V_r(t) = V(t)\cos\omega_c t + \alpha V(t-\tau)\cos\omega_c(t-\tau) \quad (1)$$

where V(t) denotes the video signal, ω_c is the carrier frequency and α and τ denote the attenuation and the delay of the reflected signal, respectively. Because receivers usually perform adequately as far as synchronization and audio are concerned only correction of the video needs to be considered. The amplitude of the detected video signal can be

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approximated by

$$V_r(t) = V(t) + \alpha V(t-\tau)\cos\omega_c\tau\,, \tag{2}$$

if the echo-amplitude is small compared to the modulated carrier amplitude and the synchronous detection is ideal. This amplitude can be seen to be not only a function of the echo-delay and amplitude but also of the HF-phase given by $\cos\omega_c\tau$. Its sign changes from plus to minus when the length of the direct and reflected path changes by one carrier period. Therefore we have to correct for positive and negative echoes.

In general, a signal $V(\omega)$ with a linear distortion $H_1(\omega)$ can be expressed as

$$V(\omega)[1+H_1(\omega)]\,. \tag{3}$$

For a video signal $V_{in}(\omega)$ distorted by one (undistorted) echo, $H_1(\omega)$ becomes

$$H_1(\omega) = \alpha_1 \exp(-j\omega\tau_1)\,,$$

where τ_1 is the echo-delay and α_1 is the relative attenuation of the echo and can be derived from eq. (2) as $\alpha_1 = \alpha\cos\omega_c\tau$ In order to recover the original signal the transfer characteristic of the correction circuit has to be

$$G(\omega) = \frac{1}{1+H_2(\omega)}\,, \tag{4}$$

with $H_2(\omega) = H_1(\omega)$. The transfer function $G(\omega)$ can be implemented by a recursive filter, as will be shown further on.

SUBJECTIVE EFFECTS

The subjective effects of echoes in monochrome or colour television should be taken into account when devising a ghost-cancellor for either of the categories. We shall first deal with the phenomena which monochrome and colour pictures have in common, and then discuss a typical colour effect.

a. Monochrome and colour

When the time displacement between the main signal and the echo signal is small the echo affects the apparent resolution of the picture. Close-in positive echoes decrease the apparent resolution, i.e. the picture will look blurry or out of focus. Close-in negative echoes cause an apparent increase in resolution but at the same time cause objects in the picture to take on a disagreeable appearance. Mertz (1) has investigated the subjective tolerance on echo amplitude as a function of the echo delay for monochrome pictures.
Fig. 1 shows an empirical curve of his results and those of others.

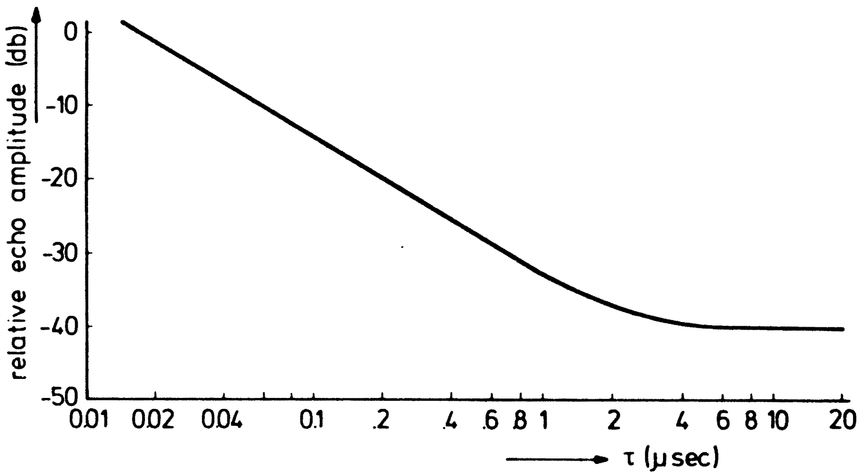

Fig. 1 Subjectively tolerated echo-amplitude as a function of the echo delay.

It appears that the tolerated echo-amplitude increases quite rapidly for echo-delays of less than 1 μsec. This is an interesting property when using CTDs for elimination of echoes because very short delay can only be obtained at a very high clock frequency (for given number of delay stages) if only one CTD is to be used.

b. Colour

Colour pictures may in addition be affected by close-in echoes in a different way (2). If the NTSC colour subcarrier of a positive echo is delayed by an odd multiple of half the time period of the colour subcarrier frequency, then the amplitude of the chrominance information in the signal will be reduced (without automatic chrominance control). For a negative echo an increase in the saturation of colours can be observed. It is clear that colour pictures are more demanding than monochrome pictures as far as tolerance on echo-delay is concerned for close-in echoes.

CIRCUIT DESCRIPTION AND RESULTS

A ghost cancellor for one undistorted echo was implemented using a PCCD (3) with 26,82 or 128 stages. The frequency of the VCO varied between 15 and 45 MHz. A full band width (5 MHz) PAL video signal was processed. Echoes of an amplitude of up to 40-50 % of the video signal were used. An echo cancellor using bucket-brigade delay lines with a bandwidth of 2 MHz was reported recently (4).

A TV ghost signal was generated artificially by passing the video signal through about 200 m of coaxial cable, thus obtaining a delay of about 1μsec. The block-diagram of the circuit with automatic gain and polarity control is shown in fig. 2.

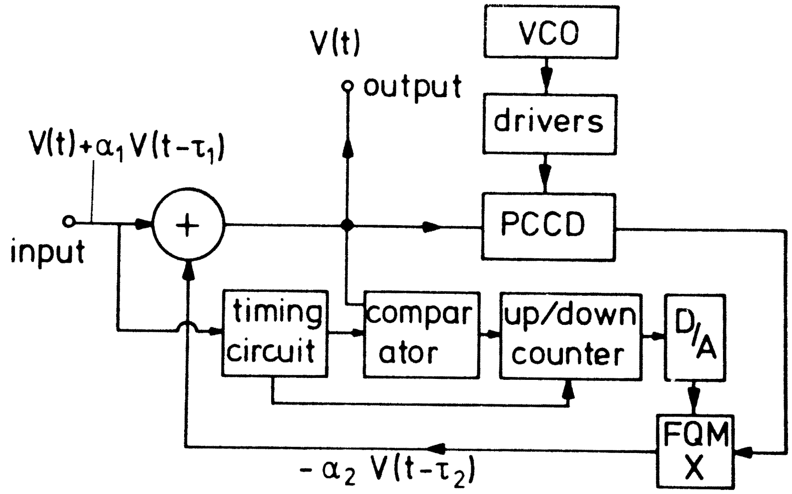

Fig.2. Block diagram of echo-cancellation circuit

The input signal $V(t)$ corrupted with an echo with relative amplitude α_1 and delay τ is fed to the PCCD and delayed by τ_2 secs. This signal is attenuated by the four-quadrant multiplier (multiplication between -1 and +1). The output signal of the FQM, $-\alpha_2 V(t-\tau\ )$, is added to the input signal. It can easily be shown that the transfer function of this first-order recursive filter is identical to the required function $G(\omega)$ of eq.(4). The echo is cancelled if the PCCD is set to τ_1 and the FQM to $-\alpha_1$. The delay line is manually set to $\tau_2 = \tau_1$. The amplitude and polarity of the echo should be determined from the signal itself. Several solutions are possible: one could transmit a special test signal in the field retrace period or line retrace period or use the test or synchronizations signals already available in the field retrace period for other purposes.
We took the second approach and chose the first unit step of the field synchronisation pulses as shown in fig.3.

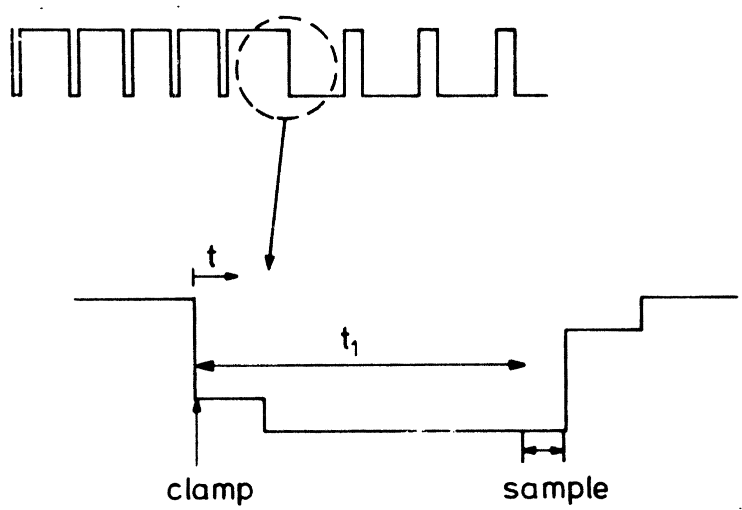

Fig.3. Synchronization pulses used for extraction of the control signal

Using the timing circuit we clamp the signal at the very beginning of the unit step and compare that level with the mean level of the unit step pulse during the 'sample' period.

This difference signal can be positive or negative depending upon the HF-phase. The unit step pulse lasts about 27 μsec, hence echoes displaced over about half the picture width can be eliminated. By comparing the clamp level with the mean level (instead of the instantaneous level at the sample moment) only the amplitude of the output signal is measured without interference by synthetic echoes generated by the recursive filter if the amplitude adjustment is in error. See fig.4.

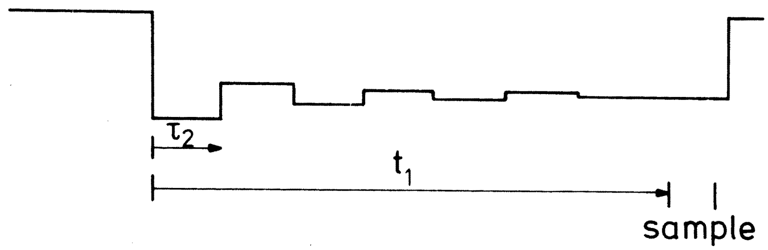

Fig.4. Output signal with wrong amplitude **adjustment**

The output signal from the comparator is applied to an up/down counter which is allowed to make only a limited amount of steps in order to get protection against clamp noise. The signal at the output of the PCCD is multiplied by the D/A converted state of the up/down counter and added to the 'ghosty' input signal. Once every field time (20 msec) the state of the up/down counter is adapted to the current echo situation. The photographs of fig. 5a,b give an impression of the capability of the circuit. Fig. 5a is a photograph of a TV picture with a synthetic echo. Fig. 5b shows the same picture but with an echo cancellation circuit added.

AMPLITUDE CONTROL CONSIDERATIONS

The suppression of an echo is dependent upon the accuracy with which the delay τ_2 and the amplitude of the echo cancellation circuit are adjusted. A number of effects influence these adjustments, such as the transfer inefficiency of the CTD, the parameter sensitivity of the transfer function of the echo-cancellation circuit for variations in τ_2 and α_2, the effect of incorrect delay adjustment upon the control signal. We will now deal with these effects in some detail.

a. parameter sensitivity

If the delay and the amplitude of the echo-cancellation circuit are not equal to the corresponding echo values, the output signal will be given by

$$V_{out}(\omega) = V_{in}(\omega)\,\frac{1+\alpha_1 \exp(-j\omega\tau_1)}{1+\alpha_2 \exp(-j\omega\tau_2)} \qquad (5)$$

The sensitivity of a function F for variations in element value e_k is defined as

$$S_{e_k}^{F} = \frac{\partial(\ln F)}{\partial(\ln e_k)} .$$

The maximum normalised sensitivities of the amplitude ($|V_{out}(\omega)|$) and phase ($\arg V_{out}$) for τ_2 and α_2 respectively are

$$S_{\tau_2}^{|V|} = \frac{\omega\tau_2\alpha_2}{1-\alpha_2^2} ; \qquad S_{\alpha_2}^{|V|} = \frac{\alpha_2}{1-\alpha_2} ;$$

$$S_{\tau_2}^{\arg V} = \frac{\omega\tau_2\alpha_2}{1-\alpha_2} ; \qquad S_{\alpha_2}^{\arg V} = \frac{\alpha_2}{1-\alpha_2^2} ; \qquad (6)$$

which indicates that the sensitivity to deviations of the delay and amplitude adjustments increases with the amplitude of the echo. Also, since $S_{\tau_2}^{|V|}$ and $S_{\tau_2}^{\arg V}$ vary linearly with frequency, high frequency signals will be more affected in amplitude and phase than low-frequency signals. This shows that, for example, colour signals may suffer more from inaccuracies of the amplitude and phase adjustments. In addition, saturation and hue of a colour picture may be affected even for undistorted echoes.

b. effect of transfer inefficiency

The transfer inefficiency ε of the CTD will distort the amplitude and phase characteristic of the echo-cancellation circuit. Using a dispersive delay line with N stages and a clock period T, we can approximate the ouput signal by

$$V_{out}(\omega) = V_{in}(\omega) \frac{1+\alpha_1 \exp(-j\omega\tau_1)}{1+\alpha_2 \exp(-j\omega\tau_2)\left[1-\frac{N\varepsilon}{1-N\varepsilon}+\sum_{n=1}^{\infty}(N\varepsilon)^n \exp(-j\omega nT)\right]} . \qquad (7)$$

Both maximum errors $|\Delta V_{out}|$ and $\arg(\Delta V_{out})$ are

$$\frac{2\alpha N\varepsilon}{1-\varepsilon} , \qquad (8)$$

for $N\varepsilon \ll 1$, $\tau_1 = \tau_2$ and $\alpha_1 = \alpha_2$.

Example: Suppose $N\varepsilon = 0.01$ and the relative echo amplitude is 0.25. Then, the amplitude error is 0.66 % and the phase error is 0.4°, which are both very reasonable values.

c. effect of incorrect delay adjustment

The value of the control signal is obtained by sampling the unit step synchronization pulse. However, it appears that the amplitude control signal is determined not only by α_2 but also by the time delay τ_2 . Assume a unit step pulse U(t) with echo of amplitude α_1 and delayed by τ_1 to be applied to the input of the circuit of fig.2. Then the rest-error signal at the output at sample moment t_1 is

$$\sum_{n=1}^{\infty}(-\alpha_2)^n\left[U(t-n\tau_2)-\frac{\alpha_1}{\alpha_2}U(t-\tau_1+\tau_2-n\tau_2)\right] . \qquad (9)$$

Suppose that the amplitude is correctly adjusted to $\alpha_2 = \alpha_1$. Then, with $\tau_2 = \tau_1 + \Delta\tau$, the rest-error signal yields

$$\sum_{n=1}^{\infty} (-\alpha_2)^n P_{\Delta\tau}(t - n\tau_1 - \frac{\Delta\tau}{2}), \qquad (10)$$

where $P_{\Delta\tau}(t')$ is the window function. For close-in echoes the error signal can be approximated by

$$-\frac{\alpha_2 \Delta\tau}{t_1(1+\alpha_2)} . \qquad (11)$$

This signal will give rise to an incorrect adjustment of the amplitude control signal. The conclusion is justified that the accuracy of the time-delay setting should be related to the values obtained from eqs(10) and (11).

AUTOMATICAL DELAY CONTROL/MULTIPLE ECHOES

The echo-test signal described in the previous section can also be used for the detection of the echo delay. Suppose the delay of a positive echo is τ and the delay of the CTD is equal to τ_1 ($\tau_1 < \tau$) or τ_2 ($\tau_2 > \tau$). In both cases an echo-rest signal will be generated. It can be seen that this echo-rest signal changes from a positive to a negative value if the delay of the CTD is increased from τ_1 to τ_2. For an echo with a negative polarity the echo-rest signal changes from a negative to a positive value if the delay is changed from τ_1 to τ_2. In this way a unique control signal can be obtained which can adjust the delay of the CTD in the most direct way. This control signal could be stored in an up/down counter and its D/A converted value could be put on the VCO in a similar way as discussed in the previous section.

If many echoes are present channel equalization seems to be the most appropriate way e.g. a tranversal or recursive filter with adjustable weighting factors in conjunction with a (mini- or micro-) computer could be used.

For a few echoes, parallel combination of circuits of the kind described could be feasible.

CONCLUSION

The development of CTDs with an excellent high-frequency performance has given rise to many new applications in the field of television. One possible application, the TV ghost cancellor has been described in this paper. The circuit uses a PCCD for the required time delay. Using the synchronization signals already present in the field retrace period it was found that with an automatical gain and polarity circuit we could achieve a good suppression of a single undistorted echo. It is pointed out that extension of the circuit towards automatical delay control is very well feasible.

REFERENCES

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Fig.5 a. TV picture with echo.
b. Picture as (a) but with echo-cancellor added.