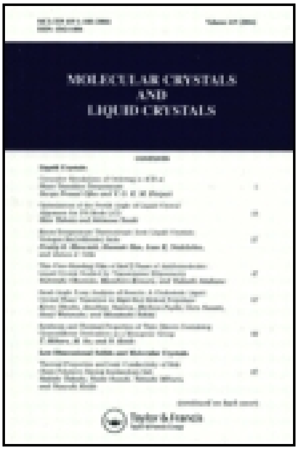

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On the Crosstalk in Direct-Driving of Large Area TN-LCDs

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The crosstalk phenomenon is a serious problem in multiplex-driving of LCDs. It is not supposed to occur in direct-driving of a TN-LCD, because the non-selected segments are not energized directly from the external power source. However, this phenomenon appears as the display segment area becomes larger, and it is often observed in large area LCDs.

This report is the result of an analysis of this crosstalk phenomenon in the direct driving of large area TN-LCDs, using test LCDs and an equivalent circuit in a simulated test.

It was found that the driving waveform is distorted by the electrodes. This distorted driving waveform, inside the liquid crystal display cell, causes crosstalk to appear on the unenergized display segments. The crosstalk phenomenon appears readily with increase in the common electrode resistance, capacitance between common and segment electrodes, driving voltage, and driving frequency, and with a decrease in the threshold voltage of the liquid crystal material.

A few proposals for improving the crosstalk situation are also presented.

1 PREFACE

Nowadays, small and medium sized liquid crystal displays (LCDs) are used. Large area LCDs are now, however, required because of the increase in the amount of information which must be presented. However, new problems for large area LCDs have arisen, e.g., control of cell-gap uniformity and mechanical strength due to the increase in base plate size, increase in inter-electrode capacitance and complexity with increased number of segment leads.

LCDs, especially TN field effect LCDs, require only a very small current for driving. Therefore, the driving current effect has not been taken into account in designing displays. Once the display area is enlarged, however,

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this effect is not negligible, even in FE LCDs, and it must be taken into consideration in designing large-sized TN LCDs.

This paper reports an analysis of the crosstalk phenomenon which takes place in a non-selected segment due to the increased interelectrode capacitance and electrode resistance on directly-driving TN LCDs that have a large display area. Some considerations on methods of counteracting the phenomenon are also proposed.

2 CROSSTALK PHENOMENON

The crosstalk phenomenon at a half-selected point in multiplex-driven LCDs has often been discussed.[1,2] A driving method to minimize the crosstalk phenomenon by an "Amplitude Selective Multiplexing Method" has also been proposed. In direct driving of LCDs, however, the crosstalk phenomenon had not yet been found.

However, even in direct-driving of LCDs, the crosstalk phenomenon may take place under some conditions. Especially in large-sized LCDs, this problem is often in evidence. This is a significant defect which may lead to reading errors. This phenomenon was analyzed using an experimental LCD cell and its equivalent circuit.

3 EXPERIMENTAL CONDITIONS

Figure 1 represents the experimental LCD cell that was used. In the cell shown in Figure 1, the crosstalk phenomenon is most marked at the 10th segment, which is furthest from the common electrode power supplying point. In addition, the phenomenon is more liable to take place as the number of selected segments is increased. Therefore, under the driving condition wherein only the 10th segment is not selected, other segments are selected and crosstalk is observed at a low angle from the cell surface; these conditions are adopted as criteria of crosstalk appearance.

Driving circuit

CMOS buffers were used as drivers. The common signal was applied to the selected segments through inverting buffers. It was also applied to the non-selected segment through a non-inverting buffer. Crosstalk voltage, which appeared at the 10th segment, was measured with an RMS-voltmeter (Hewlett–Packard Model 3403C).

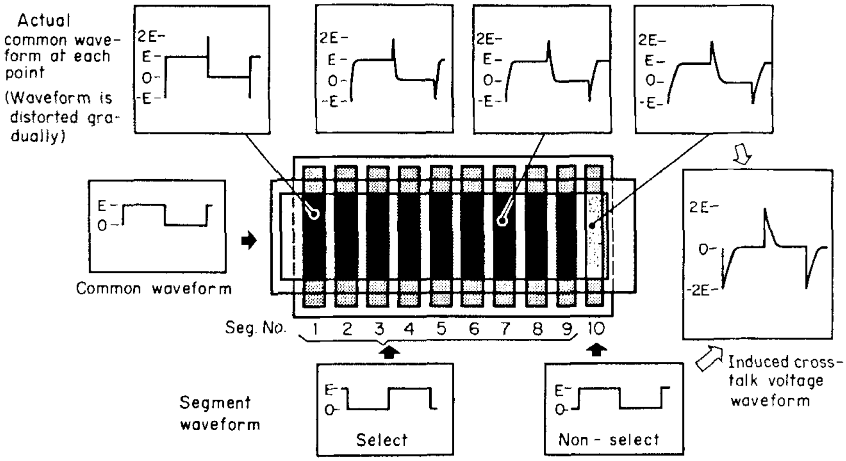

FIGURE 1 Cell and waveform at each point.

4 RESULTS

The crosstalk frequency (*fct*), or crosstalk voltage (*Vct*), was adopted as a figure to evaluate the crosstalk; "*fct*" is the frequency at which the crosstalk starts to take place and "*Vct*" is the voltage between the common and the segment electrode in the non-selected segment.

Voltage and frequency characteristics

The higher the driving voltage or driving frequency, the more liable the crosstalk is to take place. The relationship

$$fct \propto 1/E^2$$

is found from Figure 2. Here $E(V_{o-p})$ is the driving voltage and *fct* (Hz) is the crosstalk frequency.

Temperature characteristics

The higher the temperature, the lower the *fct* will be. Therefore, crosstalk becomes more liable to take place, due to liquid crystal material characteristics, such as the temperature dependence of the threshold voltage (*V*th).

Waveform

As shown in Figure 1, waveforms for the common input signal and segment input signal are almost completely square wave. However, the actual common

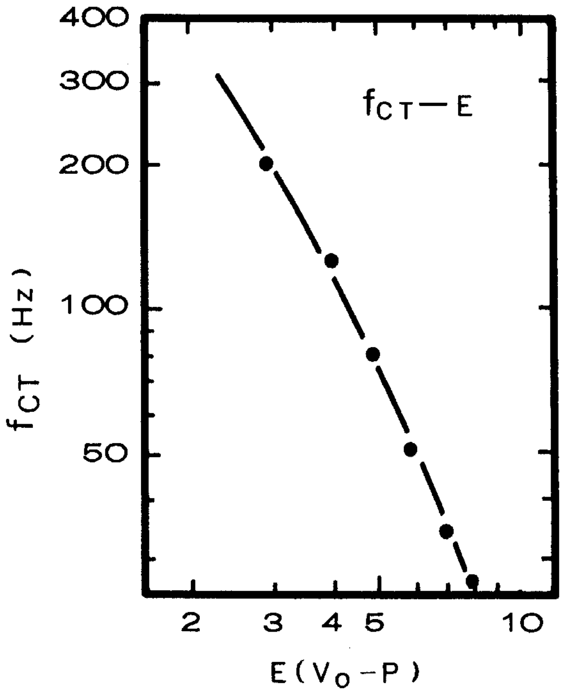

FIGURE 2 Applied voltage dependence of crosstalk.

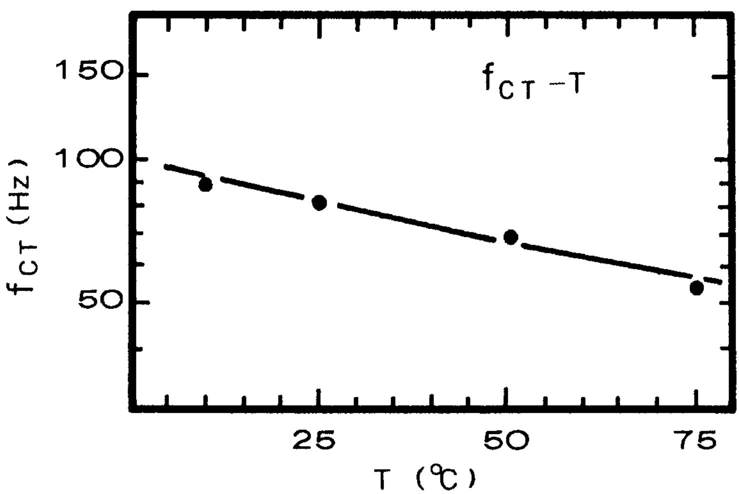

FIGURE 3 Temperature dependence of crosstalk frequency.

waveform at each segment is distorted, and sharp pulses are superimposed on the shoulders of the common input signal. This distortion induces the crosstalk voltage waveform shown in Figure 1. The peak-to-peak voltage of an actual common waveform ($3E$) is three times as high as the common input signal (E). The difference between the actual common waveform and the non-selected segment rises to four times ($4E$). When this induced crosstalk voltage exceeds Vth (1.1 Vrms), the crosstalk phenomenon is observed.

If the time-constant of the waveform is approximately $2Ee^{-t/\tau}$, the crosstalk voltage RMS value is calculated as follows.

$$Vct(V\text{rms}) = \sqrt{\frac{\int_0^{1/2f}(2Ee^{-t/\tau})^2\,dt}{1/2f}} \approx 2E\sqrt{\tau f} \tag{1}$$

$Vct = 1.2(V\text{rms})$ is obtained as the calculated Vct by substituting $f = 100$ Hz, $E = 5V_{o\text{-}p}$, and $\tau = 175\ \mu$s (observed value) in Eq. (1). Therefore, the crosstalk RMS voltage becomes higher than Vth of the liquid crystal material, and crosstalk takes place.

The conditions under which the crosstalk takes place can also be calculated from Eq. (1) with $Vct = V\text{th}$, as follows.

$$fct \approx \frac{V\text{th}^2}{4\tau E^2} \tag{2}$$

This equation coincides with the observed results already referred to.

At a high temperature, the crosstalk is more liable to take place, and this is because Vth drops with the temperature change, as Eq. (2) shows.

The waveform distortion time-constant can be considered to be attributed to the electrode resistance, to the capacitance between the common and the segment electrodes, etc. For analysis, simulated experiments were made, using an equivalent circuit.

5 EQUIVALENT CIRCUIT

Figure 4 shows an equivalent circuit of the cell shown in Figure 1. This circuit is too complicated for simulation of the crosstalk phenomenon, and a simplified circuit is shown in Figure 5.

A slight difference was observed in the input current waveform between the circuits shown in Figure 4 and Figure 5, but no effect in the crosstalk phenomenon was observed. Thus, the simplified equivalent circuit was used.

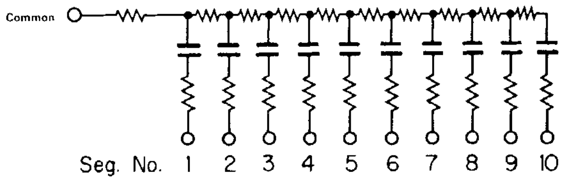

FIGURE 4 Equivalent circuit.

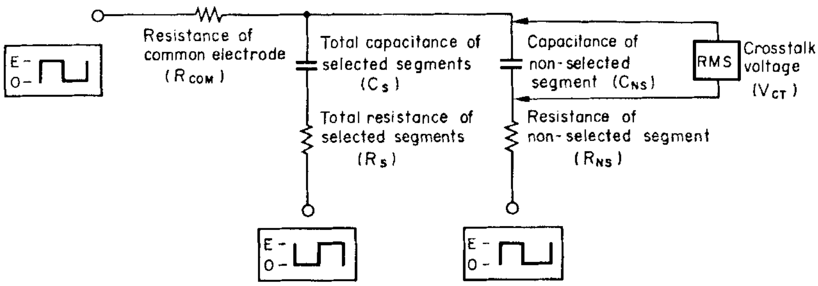

FIGURE 5 Simplified equivalent circuit.

In Figure 5

Rcom: Common electrode resistance
Rs : Total selected segment resistance
Rns : Non-selected segment resistance
Cs : Total selected segment capacitance
Cns : Non-selected segment capacitance

are used.

According to measured values on the cell shown in Figure 1, these circuit constants are:

$Rcom = 25\ \text{k}\Omega$
$Rs = 0.2\ \text{k}\Omega$
$Rns = 2\ \text{k}\Omega$
$Cs = 7000\ \text{pF}$
$Cns = 700\ \text{pF}$

The waveforms at each point in this equivalent circuit with these values, are the same as those shown in Figure 1. From this evidence, it can be considered that the equivalent circuit is reasonable.

To examine the effects of cell parameters on the crosstalk, voltage values at both ends of *Cns* were measured while changing *Rcom*, *Rs*, *Cs*, and drive voltage. From the cell construction viewpoint, it is desirable that both the common electrode resistance and the capacitance between the common and the segment electrode are small, as shown in Figures 6–10. For this purpose, it is preferable that the cell gap is large, while the dielectric constant ($\varepsilon_{\parallel}$) of the liquid crystal material is low.

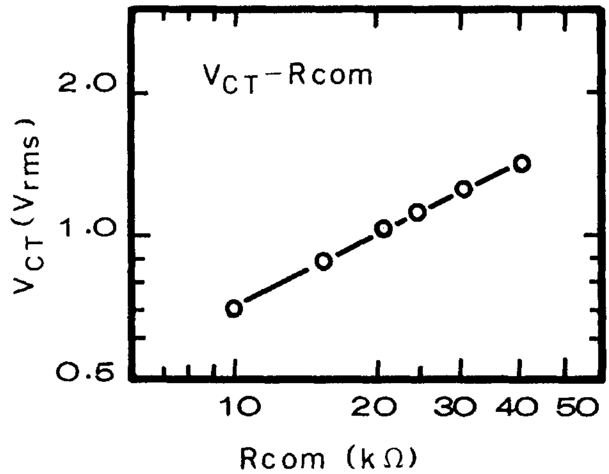

FIGURE 6 *Vct* vs. common electrode resistance.

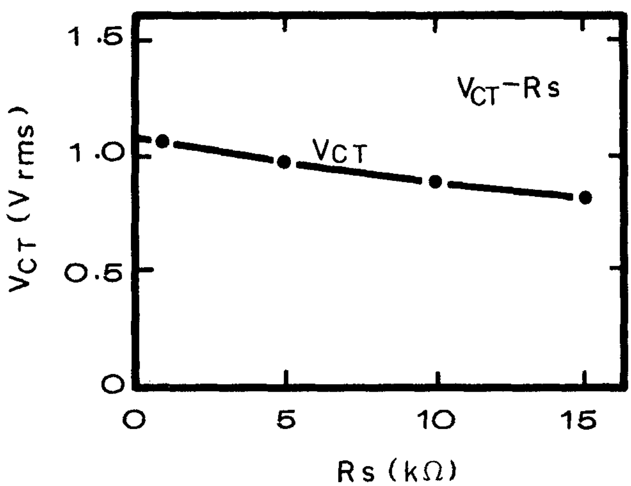

FIGURE 7 *Vct* vs. segment electrode resistance.

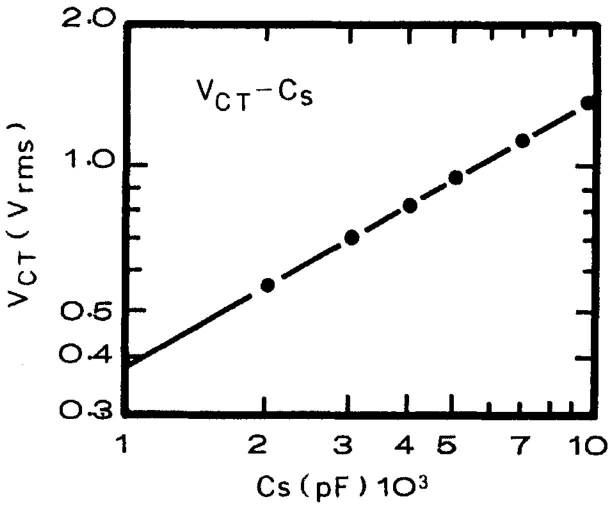

FIGURE 8 *Vct* vs. capacitance of display segments.

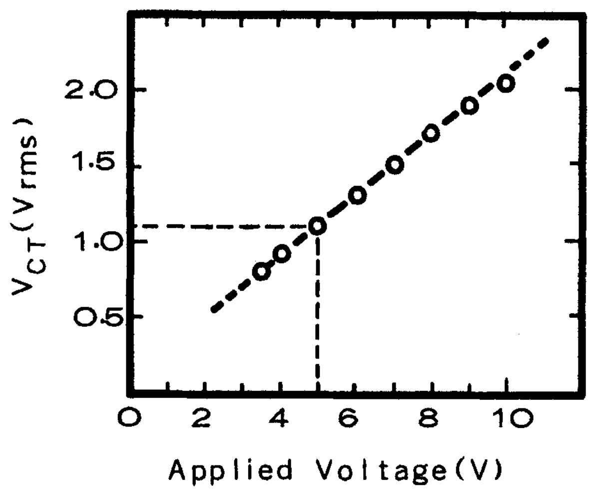

FIGURE 9 *Vct* vs. applied voltage.

It is also obvious that, in LCDs with liquid crystal materials with higher *V*th, crosstalk does not easily appear. Moreover, liquid crystal materials with a high *V*th often have a small $\varepsilon_{\parallel}$, and this is especially advantageous from the crosstalk viewpoint.

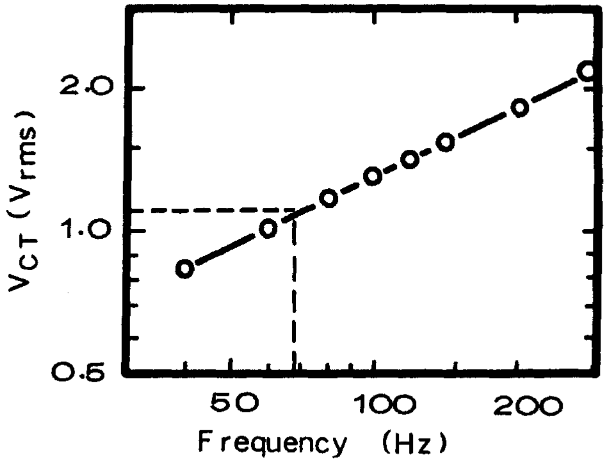

FIGURE 10 *Vct* vs. drive frequency.

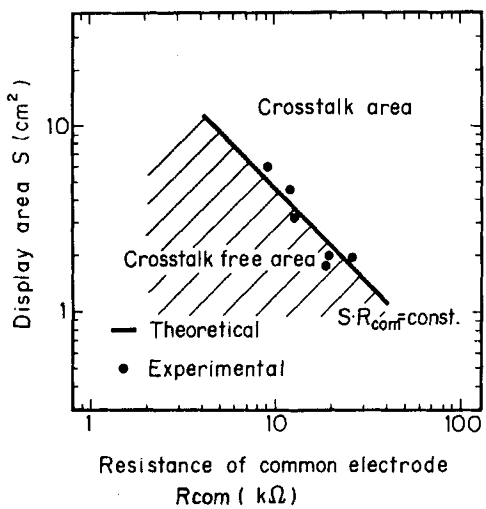

FIGURE 11 Crosstalk free condition.

For the common electrode resistance, it is necessary to minimize the sheet resistance to an extent such that transmittivity is possible, and avoid a narrow portion in the common electrode pattern. In this case, however, attention must be paid to the driver circuit, because the input impedance also decreases.

6 CONCLUSION

1 Crosstalk free condition

From the results of the analysis mentioned in this paper, it could be concluded that there is a certain restriction concerning display area. The relation between display area and the common electrode resistance is shown in Figure 11. The hatched area in this figure is the crosstalk-free region.

In order to enlarge the display area, it is necessary to reduce the common electrode resistance.

2 Considerations for crosstalk reduction

With the points mentioned above, some considerations will be given to reduce the crosstalk.

a) A method to improve the crosstalk, protecting the drive circuit, is considered. For this purpose, the common electrode resistance should be lowered as far as possible. It is also necessary to adjust the segment lead electrode resistance, which suppresses the peak current.

An example of an electrode pattern, which was designed under the above conditions, is shown in Figure 12. In this cell, the segment lead electrode is purposely made slender to provide appropriate resistance, while the common electrode pattern is sufficiently widened.

By this method, crosstalk can be reduced without lowering the input impedance. However, since the effective voltage applied to selected segments is lowered, both the common and segment electrode pattern should be designed appropriately in consideration of contrast ratio and response time.

b) Since the cause of crosstalk is distortion in the signal waveform in the common electrode, it is possible to average the crosstalk and extend the crosstalk-free area by delaying the segment signal appropriately.

Figure 13 shows an example of the drive circuit using a delay circuit. The segment signal, which is delayed, in comparison with the common signal, is supplied to the segment driver.

Figure 14 shows the waveforms at each point, when experimental cells are driven by the circuit in Figure 13.

Figure 15 shows the experimental result for crosstalk frequency (fct) *vs.* delay time, when the delay time is changed by varying the delay CR constant. The experimental cell has an optimum delay time of approximately 300 μs. The cell could be driven without crosstalk up to approximately twice the frequency, in comparison with a cell without the delay circuit.

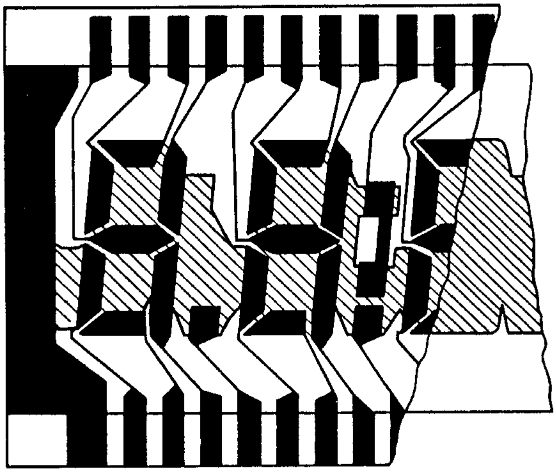

FIGURE 12 Example of electrode pattern.

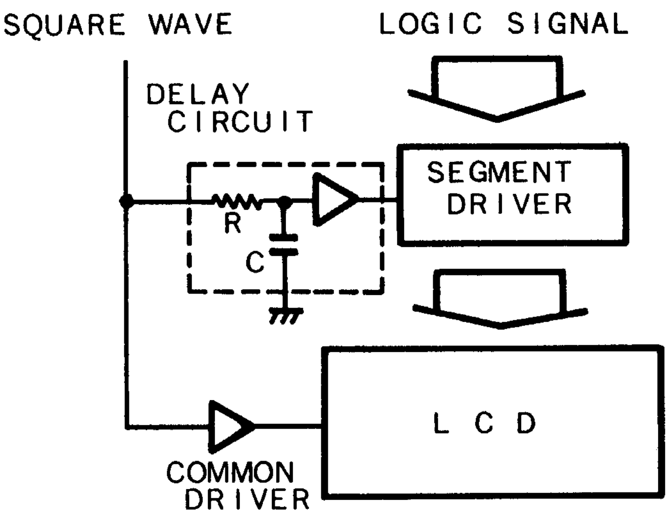

FIGURE 13 Example of drive circuit using a delay circuit.

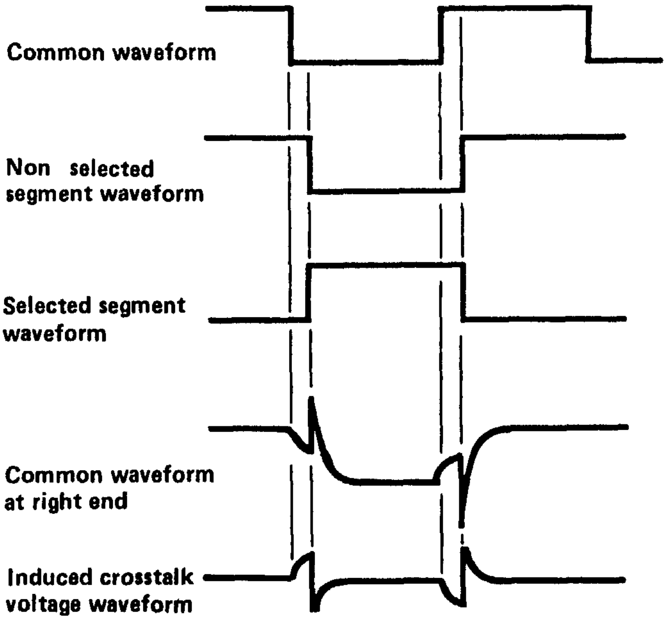

FIGURE 14 Waveforms in improving drive circuit.

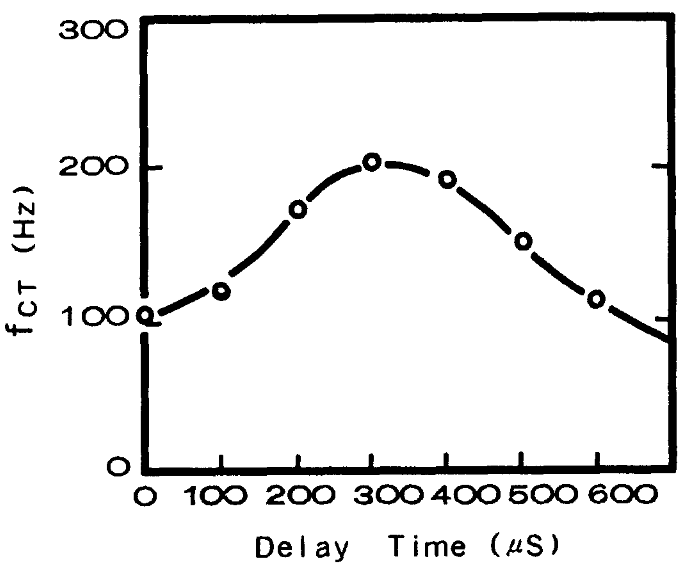

FIGURE 15 Relation between delay time and crosstalk frequency.

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