CRT SPOT SHARPENING by SPOT-GROWT-INDUCED MICRODEFLECTION

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Introduction

The interdependence of video signal bandwidth, spot size, scanning velocity, and MTF were clearly set down by C. Infante[1]. Fairly complete models, including the attributes of observers, have been described by C. Infante and P. Barten[2]. Only recently, with J. Hagerman's work[3], has a published model of CRT resolution performance included elements of drive-dependent spot growth.

Although properly incorporated into the model, the mechanism by which drive-dependent spot growth affects resolution has not been described. Hagerman presented a plot showing that the modulation depth of alternate on and off pixels, as a function of the ratio of risetime to pixel width, peaked before becoming asymptotic to the limiting MTF of the spot. It was suspected that this peak is the result of drive-dependent spot-growth-induced microdeflection of the spot edges along the axis of the horizontal scan.

The Approach

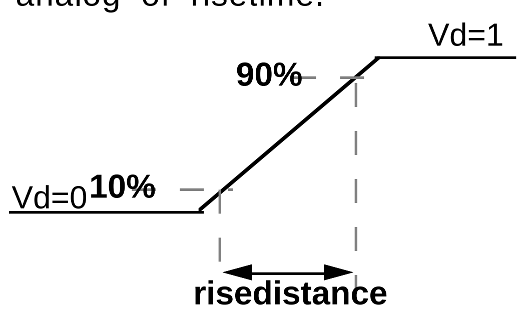
A spatial-domain model was constructed for the purpose of running simulations with an eye toward explaining how resolution is affected by the relationship between drive-induced spot growth, risetime, and scan rate. The model then was used to generate the leading edge of a pixel for multiple iterations while the ratio of risedistance (the distance the spot's center travels while a trapezoidal drive pulse traverses the range from 10% to 90% of full drive) to 50% spot width was varied. The resulting information was used to evaluate the behavior of the scanned spot and the sharpness of the resulting pixel edge.

The Model

The model simulates the scanning of a CRT spot across the faceplate. As the simulated spot is scanned, drive fraction (the absolute value of the ratio of drive voltage to cutoff voltage) changes as a function of spot position, the amplitude and width of the spot change as a function of drive voltage, and the Spot Spread Function is a function of spot width.

Drive Fraction

Drive fraction is represented by a trapezoidal function of spot position in that it changes linearly from cutoff to full drive as a function of spot position. The distance the spot moves while the drive fraction changes from 10% to 90% of full drive is the signal's risedistance and is the spatial domain analog of risetime.



(fig. 1)

The unit of distance is spot width, thus a risedistance of 1.0 corresponds to a distance equal to 1.0 times the width of a spot measured at its 50% amplitude points.

Amplitude of Spot

Beam current is an exponential function of drive fraction as given for cathode drive by Oess[4], similar to grid drive expressions by Moss[5], which can be simplified to:

$$i_b = V_d^{\gamma} \quad (1)$$

where i_b is beam current and γ ranges from 3/2 at low drive levels to 5/2 for much higher drive levels; 3/2 is used in this model. V_d is the cathode drive fraction.

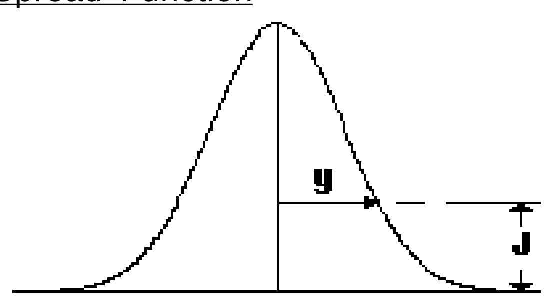
Spot Size

With cathode drive, spot size is a function of drive fraction. According to Moss, this phenomenon is less pronounced where grid drive is used. A relationship showing drive-dependent spot growth was given by Oess[6] and simplified by Hagerman to:

$$S = k_1 V_d^{0.75} \quad (2)$$

where S is spot size, k_1 is a constant of proportionality, in this model unity. Vd is the cathode drive fraction. Experimental evidence of drive-dependent spot growth to this approximate extent has also been published recently[7].

Spot Spread Function



(fig. 2)

Under moderate drive conditions, and in the absence spherical aberration in the gun, deflection defocusing, and other sources of distortion, the distribution of current falling on the back of the phosphor on a CRT faceplate is close to Gaussian. Taking this as the nominal case, the current density, J, at any point along the spot profile can be found by:

$$J = e^{-\left(\frac{y^2}{2\sigma^2}\right)} \quad (3) \quad \text{where} \quad \sigma = \frac{d_{50}}{2.35}, \quad (3A)$$

y is the distance from the center of the spot to the point of interest, and d_{50} is the width of the spot taken at 50% of peak amplitude. At the levels used in many applications, phosphor is usually quite linear and luminance, b,therefore is proportional to beam current, J.

Luminance as a Function of Distance

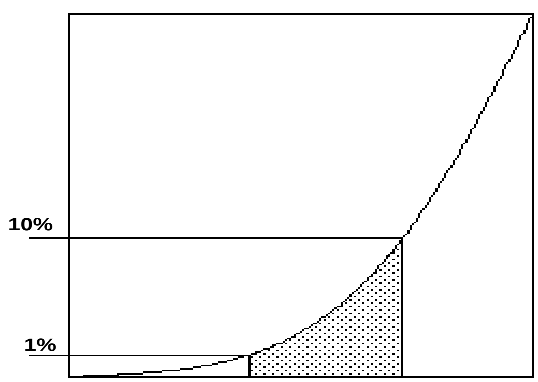
Combining formulas 1, 2, and 3, we get an expression for luminance, b, for any point along the spot's profile as a function of drive fraction, V_d.

$$b = V_d^{\frac{3}{2}} e^{-\left[\frac{2y^2}{\left(\frac{S_{50} V_d^{0.75}}{2.35}\right)}\right]} \quad (4)$$

Because the spot is scanned, the luminance of any given point on the edge of a pixel is found by integrating this expression with respect to spot position. All luminance values resulting from the calculations are normalized so that the peak luminance equals unity. Numerical integration was used with a resolution of 100 samples for each 50% spot width. Pixels are approximately 7 spot widths wide (16.5 σ).

Measuring Sharpness

A sensitive indicator of the sharpness of the edge of a pixel is the area beneath the curve over a specified interval of that curve.

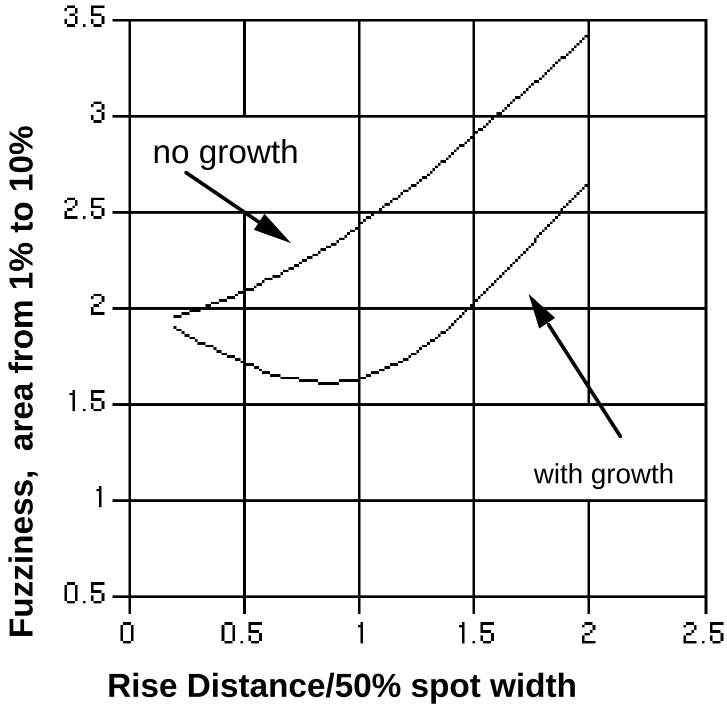


(fig. 3)

Spot growth has most of its effect near the base of the pixel edge because the shape of the peak is dominated by the full-drive spot size. The interval between 1% amplitude and 10% amplitude was chosen as an indicator of sharpness at the pixel base.

Results

The area under the curve from the 1% to 10% amplitude points along the rising edge of pixels generated with the complete model (labeled *with growth*) and for pixels generated with a modified model where spot size was held constant (labeled *no growth*) is plotted against risedistance figure 4.



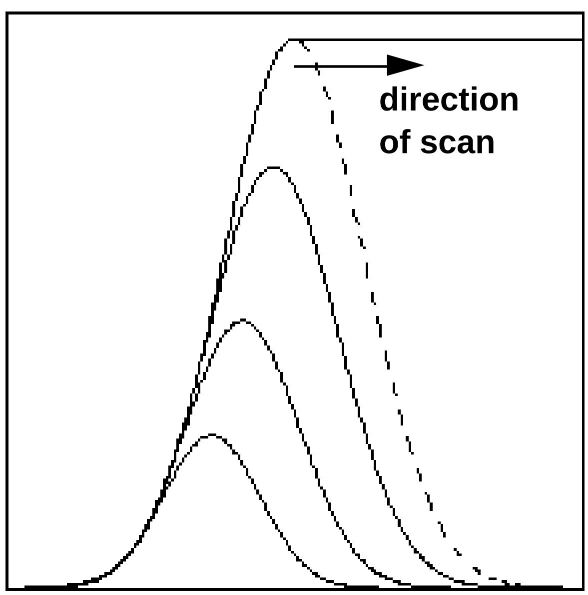
(fig. 4)

The upper trace represents the area under the curve between the 1% and 10% amplitude points of the leading edge of a pixel generated by a spot with the size held constant. The lower curve represents the same spot with normal drive-induce growth. The broad minimum shown in the lower curve represents the region in which maximum sharpness is achieved. This minimum coincides with the broad peak in modulation depth shown by Hagerman where the amplifier's risetime is corresponds to the 50%

spot width.

Notice that the sharpness of the pixel resulting from the spot without drive-induced growth has no such minimum and, for all rise distances plotted here, has less sharpness (greater area under the curve) than the spot with growth.

This illustration also shows that the increased sharpening resulting from drive-dependent spot growth microdeflection occurs over a small range of risedistance-to-spot-width ratios. As the risedistance is decreased from the ratio of maximum sharpness, the two curves appear to converge on the limiting sharpness of the full width spot.

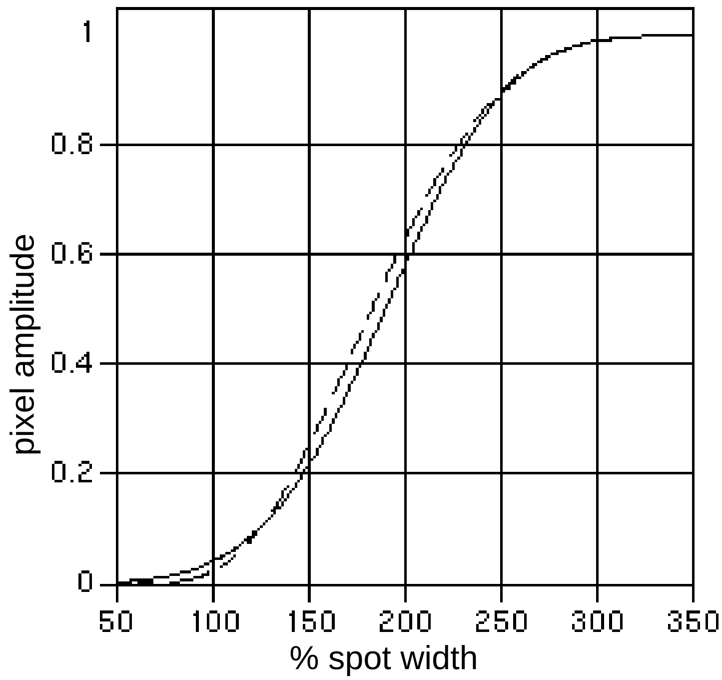


(fig. 5)

A condition in which the risedistance is equal to the 50% spot width is illustrated as a series of Gaussian “snapshots” in figure 5. The Gaussian “snapshots” occur at 60%, 75% , 90%, and 100% of full-drive amplitude. Each of the Gaussian shapes was generate with formula (4). Notice that the left-hand edge of all of the Gaussian shapes are in phase., freezing that edge of the spot as the spot center traverses the line.

The left-hand is frozen because of drive-dependent spot-growth-induced microdeflection of the spot's edge. As the spot grows in amplitude, its radius (measured at 50% amplitude) increases according to formula 2. In the example in figure 5, the increase in the spot's radius results in microdeflection toward the left that compensates for the motion of the center of the spot toward the right, due to scanning of the beam. The result is that the left-hand edge of the spot freezes during the rise in cathode drive as the spot center traverses the line. When the spot is driven back toward cutoff, the collapsing radius compensates for the forward direction of the center of the spot, freezing the right-hand edge of the spot. Thus, both edges of the spot are sharpened in this manner.

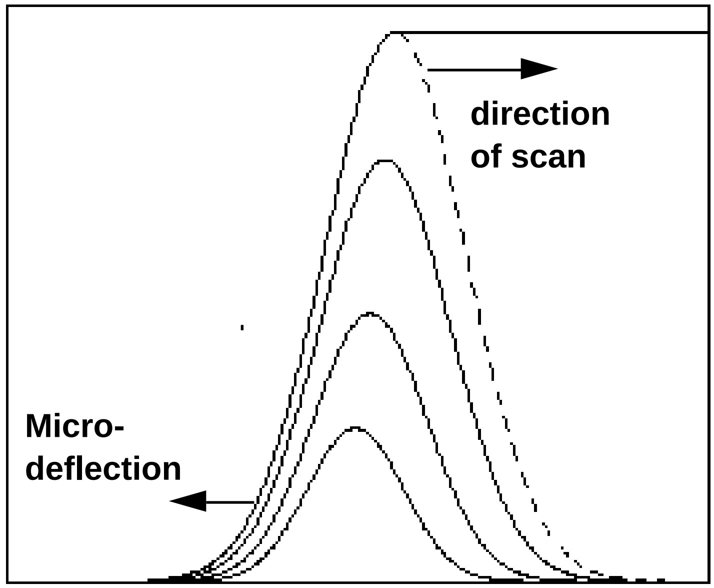
Because the edge of the spot is frozen, the edge is not smeared as the spot is scanned across the screen.



(fig. 6)

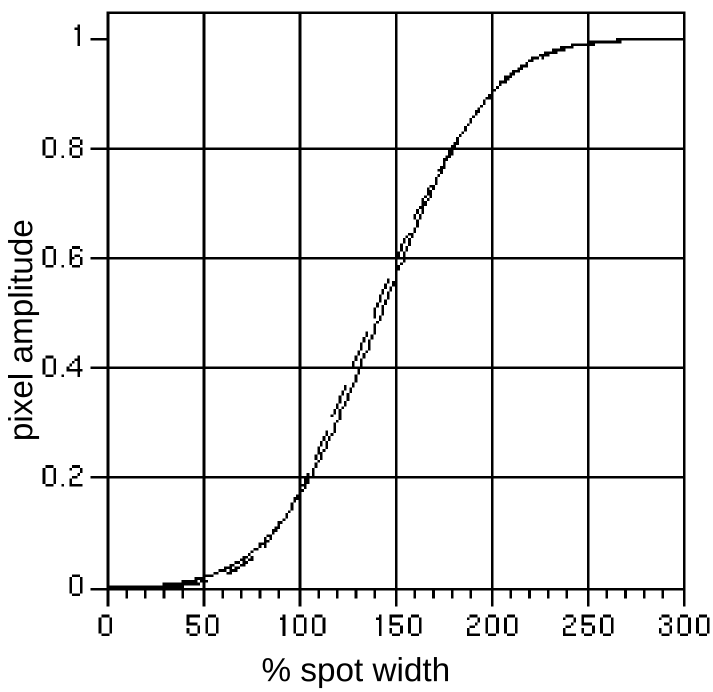
The edge of the pixel generated by integrating formula (4) over spot position, for a risedistance of 1.0, is shown above (broken line) compared with the the same edge with spot size held constant (fig. 6). Significant sharpening of the pixel edge can be seen up to about 80% of the pixel's amplitude. The shape of the peaks of the pixels match very closely, indicating that drive-dependent spot growth had no effect on the shape of the peak.

For edges generated by risedistances away from the minima, such as that illustrated below (fig. 7), with risedistance = 0.48, the risedistance is too fast for the left-hand edges to remain stationary. Instead, the average microdeflection velocity of the left-hand edge toward the left is actually slightly greater than the scanning velocity of the center of the spot, toward the right, smearing the edge.



(fig. 7)

The edge of the pixel generated using a risedistance of 0.48 is shown below (fig. 8).



(fig. 8)

When the spot without growth is compared to that with growth, there is much less evidence of sharpening than in the case of the velocity-matched spot occurring at risedistance =1.0 (fig. 6).

Conclusions

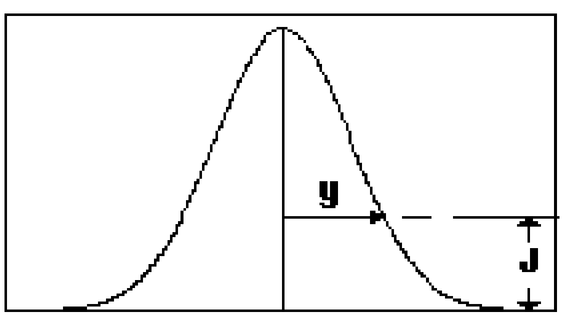
Drive-dependent spot growth results in sharpening of the base of pixel edges.

When drive-dependent spot-growth-induced microdeflection velocity is matched to horizontal deflection velocity, the pixel edges freeze, thus sharpening the pixel edges.

Drive-dependent spot growth contributes little to the shape near the peak of a scanned pixel.

Acknowledgement

The author would like to thank Dr. Carlo Infante for stimulating discussions and suggesting the concept of risedistance.



tech notes: set in Helvetica 12 pt.
formulas are times bold italic

[1] Carlo Infante, *On the Resolution of Raster-Scanned CRT Displays*, Proceedings of the SID, Vol. 26/1, 1985.

[2] Peter G. Barten, *The SQRI Method for the Evaluation of Visible Resolution on a Display*,Proceedings of the SID, Vol. 28/3, 1987.

[3] James G. Hagerman, *Video Risetime Requirements for Computer-Driven Raster Scan CRT Displays,* SID International Symposium Digest, Volume XXI, 1990.

[4] Frederick G. Oess, *Notes On the Evaluation of Cathode Emission Quality*, Clinton Electronics Corporation Publication No. 005.

[5] Hilary Moss, *Narrow Angle Electron Guns and Cathode Ray Tubes*, The Academic Press, Inc., 1968.

[6] Frederick G. Oess, *CRT Considerations for Raster Dot Alpha Numeric Presentations*, Proceedings of the SID, Vol. 20, no. 2, 1979.

[7] Nic P. Lyons, Joyce E. Farrell, *Linear Systems Analysis of CRT Displays*, SID International Symposium Digest, Volume XX, 1989, figure 6.