The Effects of Signal Delay on Scanning Velocity Modulation in CRT

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Abstract

The effects of time delay between a video signal and a current signal applied to velocity modulation coil on free-spot movement and beam size were measured and analyzed quantitatively in this study. The result shows that it is the most important to avoid signal mis-matching in order to achieve the optimal velocity modulation performance.

1. Introduction

A scanning velocity modulation is one of the ideal solutions for improving picture sharpness and contrast in CRTs [1]. An additional coil is placed on CRT neck for an auxiliary deflection of an electron beam and the first derivative of a luminance signal is amplified and then applied as a driving current.

Accordingly, the edge slope is stiffened due to the variation of deflection velocity at the luminance transient boundary, so sharper edge can be obtained. Moreover, the changes of peak brightness and width of luminance transient region cause a beam spot to be smaller and brighter. Therefore, the overall picture quality of a reproduced image can be highly enhanced.

Generally, VM efficiency is drastically decreased at higher frequencies because of the eddy current loss [2,3]. Here, VM efficiency is defined by the ability to shift a beam per Ampere given by the unit of mm/A. Although many efforts have been focused on how to improve it [4,5], if this efficiency exceeds a certain optimal value, an opposite effect may be occurred which results in degradation of the picture quality on the contrary. In this paper, we verified the existence of the optimal beam movement and the relationship between a video and VM signal by using quantitative measurement.

2. Experimental

The correlation between free-spot movement and resulting horizontal beam size due to a scanning velocity modulation was evaluated quantitatively. In order to measure an oscillating distance of free-spot movement, specially designed test equipment was used. A sine-wave current having the same amplitude and frequency as a current signal from VM circuit is applied to VM coils in 29-inches color picture tubes. We used mask-less green tubes that have no shadow mask and only green phosphor is coated through the entire screen to obtain the exact beam profile. By varying a peak-to-peak current up to 1 Ampere and its frequency from 100 kHz to 10 MHz, the oscillating distance is measured. The luminance distribution of a beam spot is measured automatically by using a PC control synchronized to a moving stage with a camera. We generated a spot pattern without DY deflection and called it as free-spot. And then, an oscillating distance of free-spot movement is measured by a peak-to-peak distance from the luminance profile when a sine-wave current applied. Besides, horizontal beam size is measured for the case of VM circuit turned on and the results are correlated to the free-spot movement. The luminance profile of a horizontal beam is excellently fitted by the summation of two Gaussian functions and then the image quality is evaluated by comparing the resolution derived from the modulation transfer function. On the other hand, in order to investigate the effects of a signal delay the variation of free-spot moving distance and horizontal beam size is analyzed as a function of coil inductance.

3. Results and discussion

3.1 The correlation between free-spot moving distance and horizontal beam size

Figure 1(a) and (b) shows a sine wave current used in this study and a beam profile due to the oscillation of free-spot, respectively.

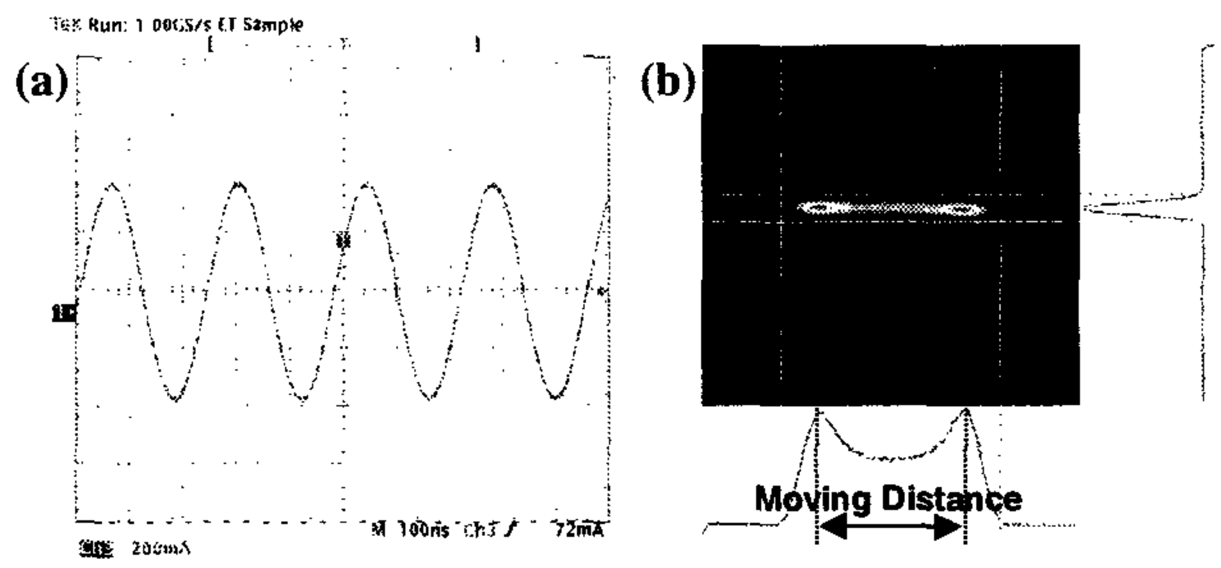


Figure 1. (a) Sine-wave current and (b) measured free-spot moving distance, respectively.

The VM efficiency (mm/A) is also measured as a function of signal frequencies and the result represents a tendency to decrease rapidly down to nearly 1MHz regardless of test conditions (Figure 2).

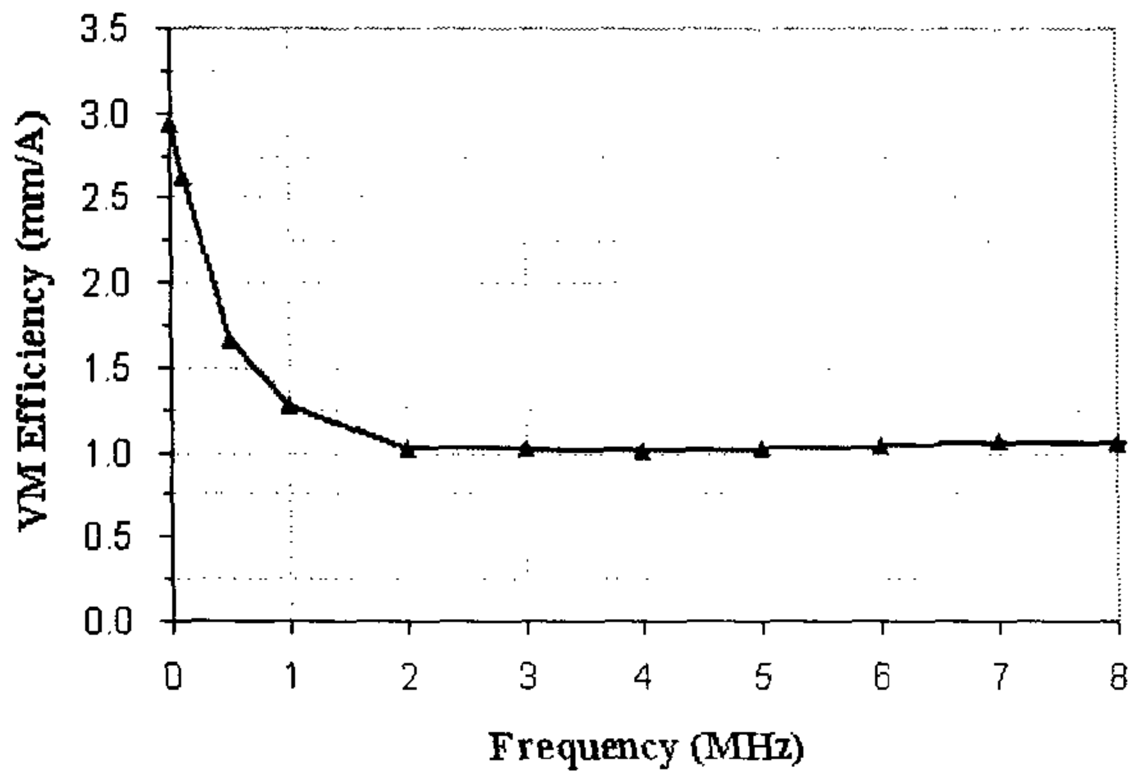


Figure 2. The variation of VM efficiency as a function of signal frequencies.

Besides free-spot movement, horizontal beam size is measured for both cases of VM circuit turned on and off as can be seen in Figure 3 for the case of a center and side beam, respectively. Then, the results are correlated to free-spot movement at the same current condition.

The correlation of free-spot moving distance and horizontal beam size indicates that there exists a minimal condition in which horizontal beam size is no more decreased even though VM efficiency (*i.e.* free-spot moving distance per Ampere) is increased as can be seen in Figure 4.

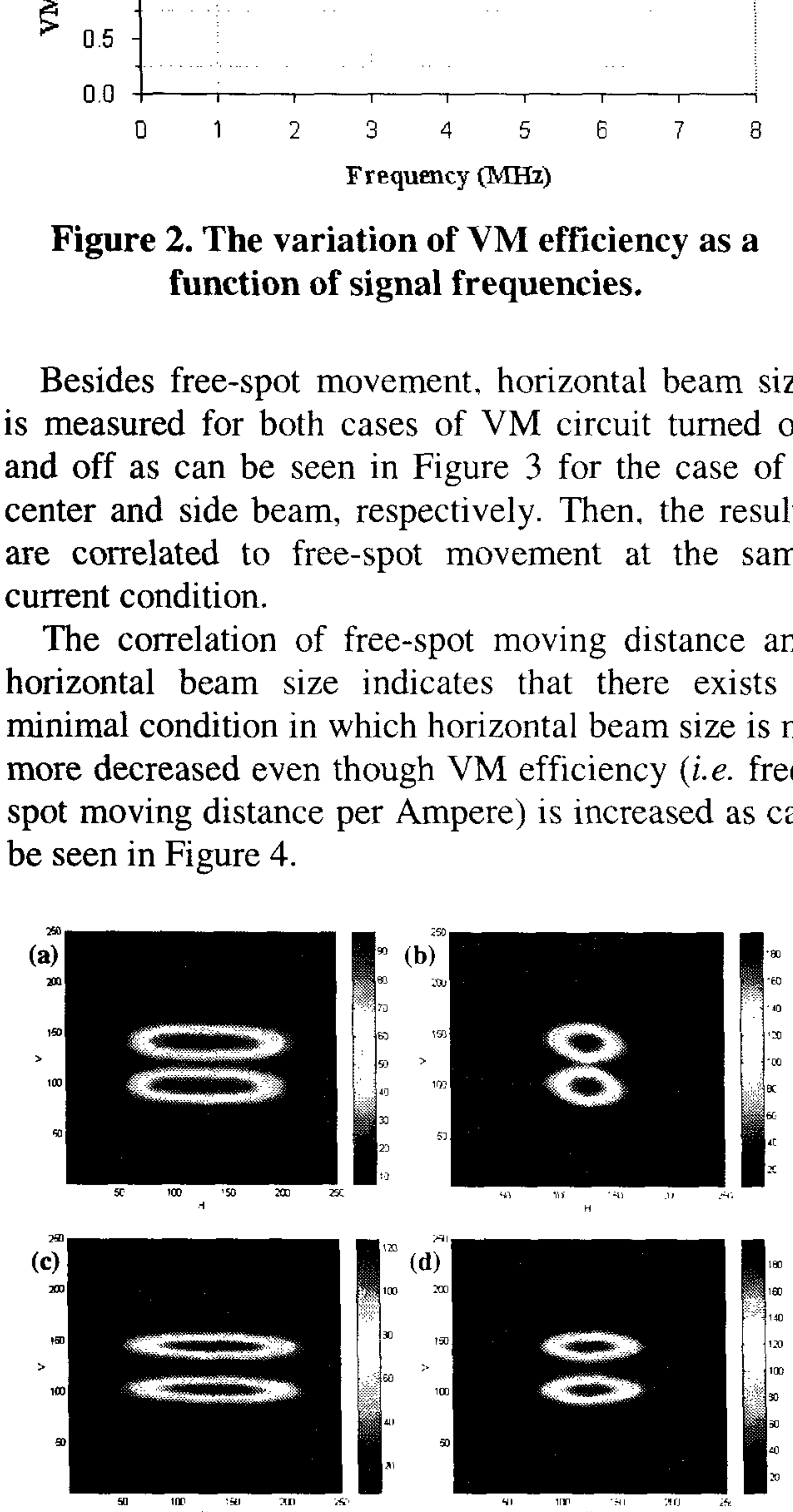


Figure 3. Horizontal center beam profile in case of (a) VM off and (b) VM on, and side beam profile in case of (c) VM off and (d) VM on, respectively.

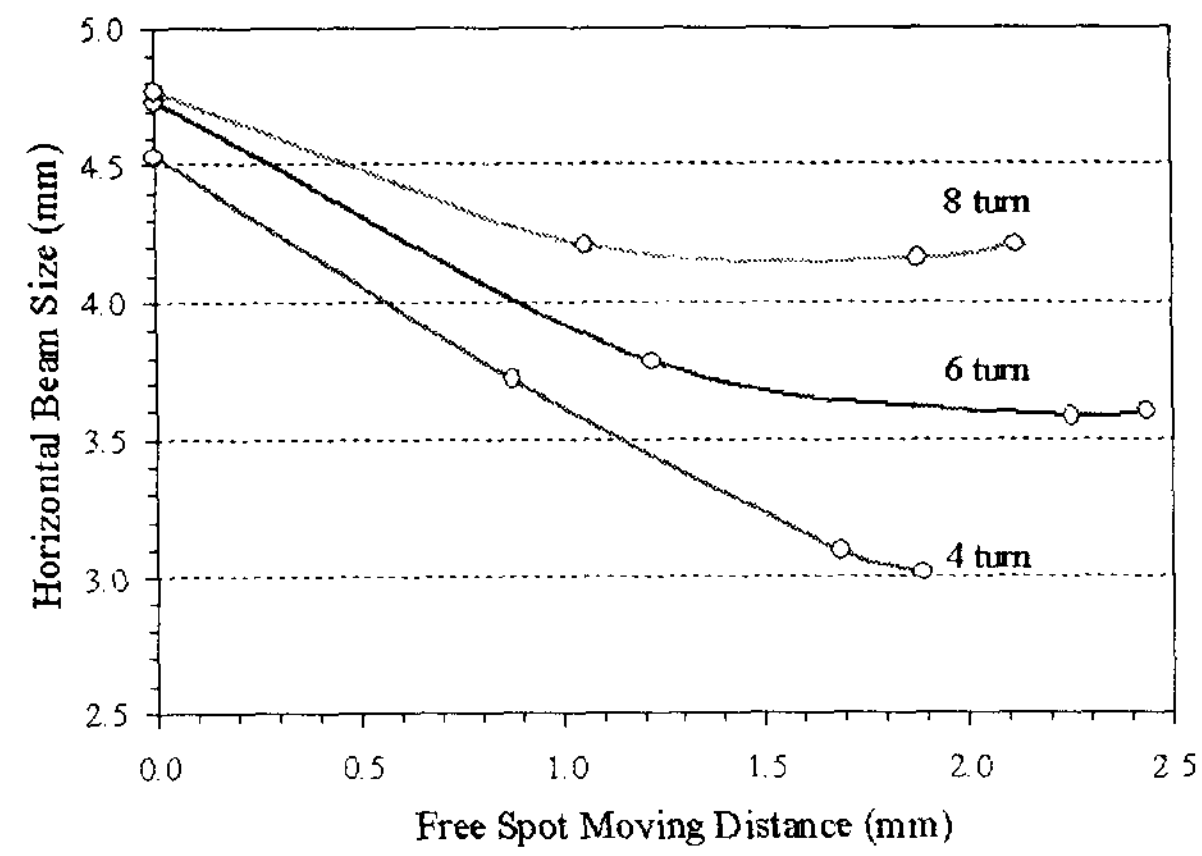


Figure 4. The correlation between free-spot moving distance and resulting horizontal beam size at screen center.

3.2 The modulation transfer function of non-Gaussian beam profile

In terms of the picture quality, modulation transfer function (MTF) can be used effectively to evaluate the resolution capability of a CRT. The MTF is defined as the Fourier transform of a spot profile [6,7].

Because the measured luminance distribution of horizontal beam is noticeably non-Gaussian, we used the summation of two Gaussian functions as a non-Gaussian luminance profile, $l(x)$ at location x, for x= {0,1,2,...N-1}.

$$l(x) = a_1 \exp\left(-k_1 (x-c_1)^2\right) + a_2 \exp\left(-k_2 (x-c_2)^2\right)$$

A simple Gaussian fitting is not adequate to this case. But 2-Gaussian function matches well with the measured data with R-square value of 0.99827.

Figure 5 shows the fitted plot by using Levenberg-Marquardt algorithm. From this beam profile function, $l(x)$, the complex-valued Fourier coefficient at spatial frequency, w is given as follows.

$$L(w) = \sum_{x=0}^{N-1} l(x) \exp\left(-j2\pi xw/N\right)$$

Then, the MTF can be expressed by the absolute value of $L(w)$ multiplied by K which is a normalizing constant such that MTF(0)=1. Therefore,

$$MTF(w) = K\|L(w)\| = K\sqrt{L_{\mathrm{Re}}(w)^2 + L_{\mathrm{Im}}(w)^2}$$

Figure 6 shows the results of the MTF for center and side beam in case of VM turned on and off, respectively. The resolution of each beam is compared

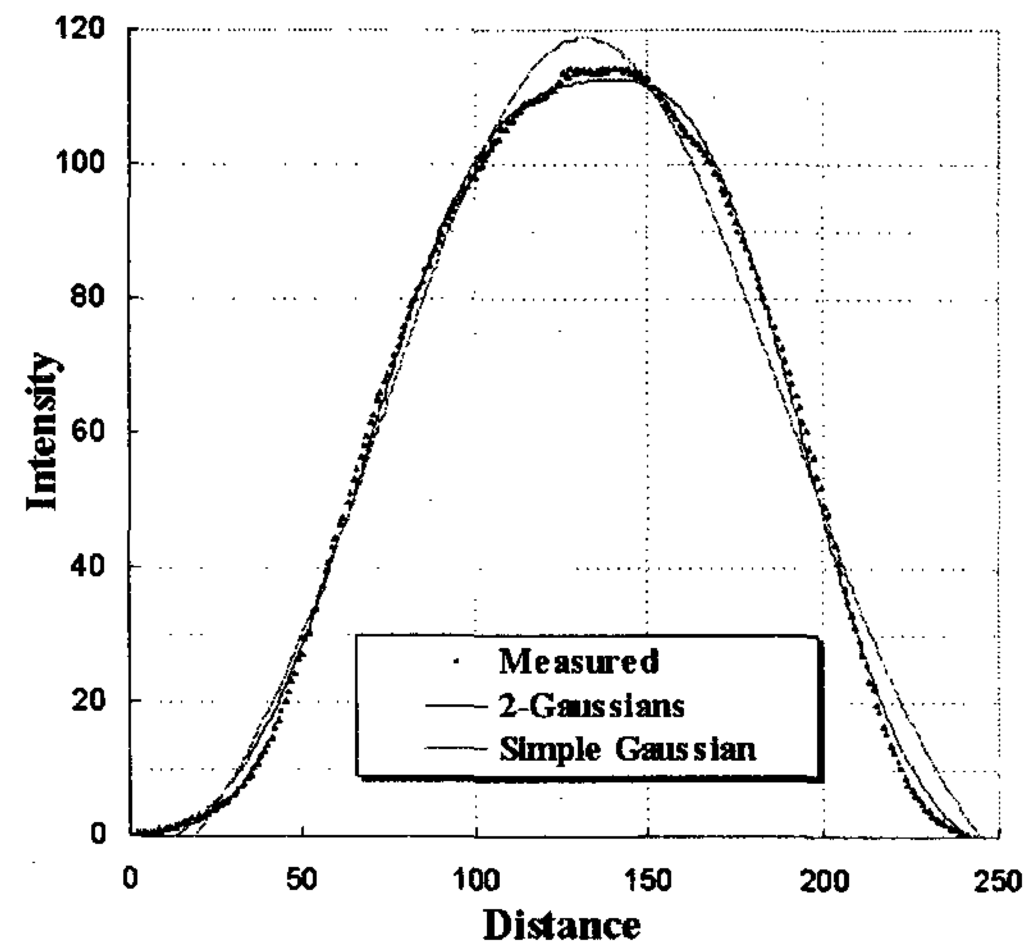


Figure 5. The measured (dot) and fitted plot (solid lines) of non-Gaussian beam profile.

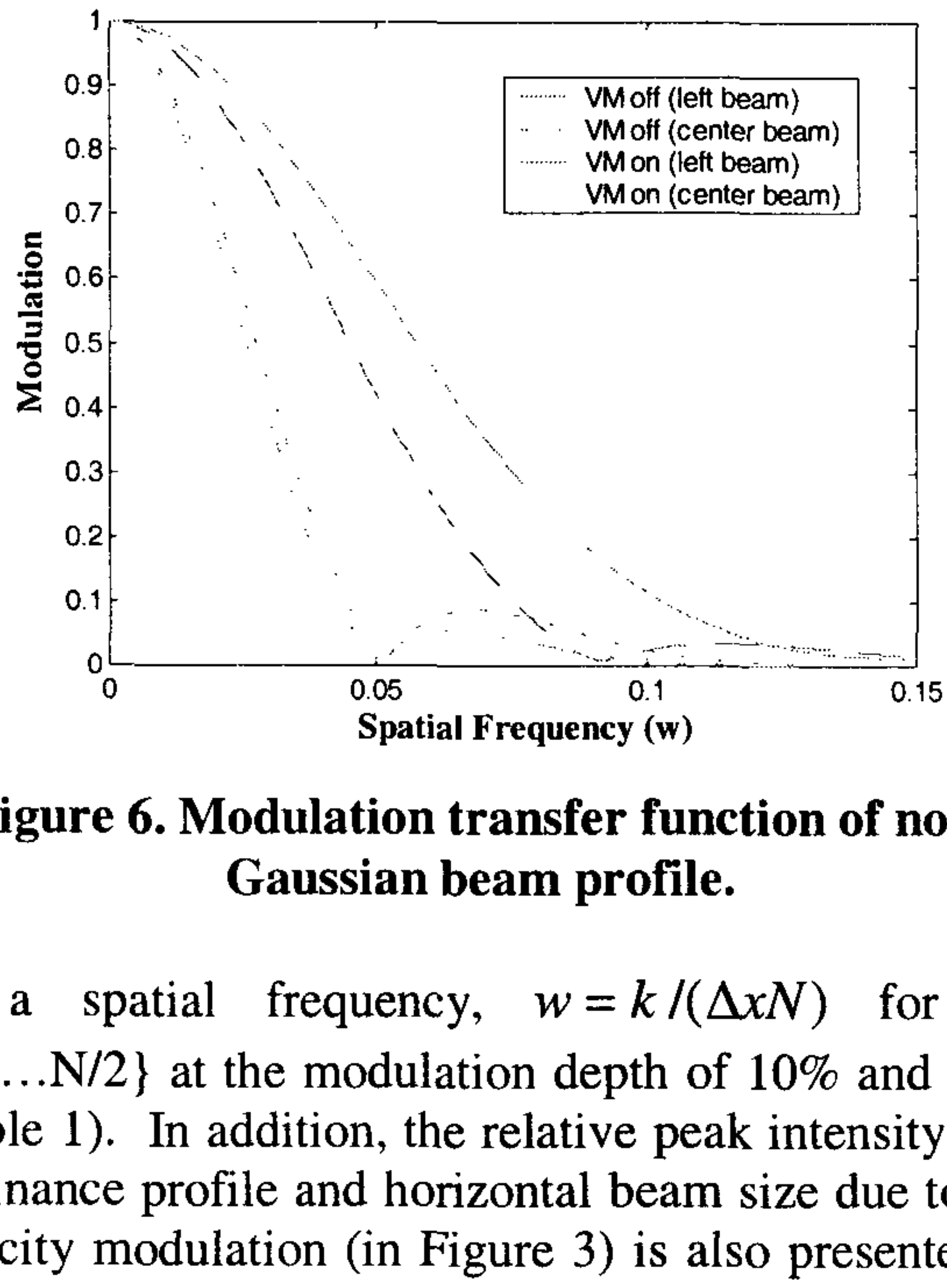


Figure 6. Modulation transfer function of non-Gaussian beam profile.

by a spatial frequency, $w = k/(\Delta x N)$ for k= {0,1...N/2} at the modulation depth of 10% and 50% (Table 1). In addition, the relative peak intensity of a luminance profile and horizontal beam size due to the velocity modulation (in Figure 3) is also presented in Table 1.

Table 1. The comparison of relative intensity and horizontal beam size as well as spatial frequencies at 10% and 50% modulation depth.

	Center Beam		Side Beam	
Velocity Modulation	OFF	ON	OFF	ON
Relative Intensity	100%	200%	100%	160%
Relative H-Beam Size	100%	56%	100%	59%
w at 10% Modulation	0.044	0.103	0.042	0.075
w at 50% Modulation	0.027	0.057	0.025	0.045

As a result, the relative resolution of a reproduced profile due to VM effect is improved up to 180% for side beam and more than two times (230%) of the original one for center beam regardless of modulation depth. Such an enhanced resolution comes from the combined effects of beam size and peak brightness.

3.3 The effects of signal delay on beam shift

Figure 7 demonstrates a typical video signal and corresponding VM current signal. The amplitude of VM current signal is increased in proportion to the frequency of a luminance signal.

When we consider the effects of VM coil turns as in Figure 4, one can conclude that horizontal beam size is proportional to the coil turns as well as the existence of a minimal point discussed previous section. However, this result is unusual because horizontal beam size should be equal at the same distance of free-spot movement in principle. We found that this result is originated from signal mismatching. If turns of coil increase, inductance is increased as shown in Figure 8.

Increasing inductance results in time delay at high frequency. If signal mismatching exists, the harmful effects occurs such as an abnormal beam shift from the proper addressing point and increased horizontal beam size, which has something to do with the degradation of resolution and sharpness eventually. Figure 9 shows the abnormal growth of beam size in such a case.

In regard to VM efficiency, it can be improved by suppressing the eddy current loss and by increasing applied current. Therefore, an electron gun and a VM coil design should be optimized to reduce the eddy current loss. However, it is also important to avoid signal mis-matching giving rise to a serious trouble.

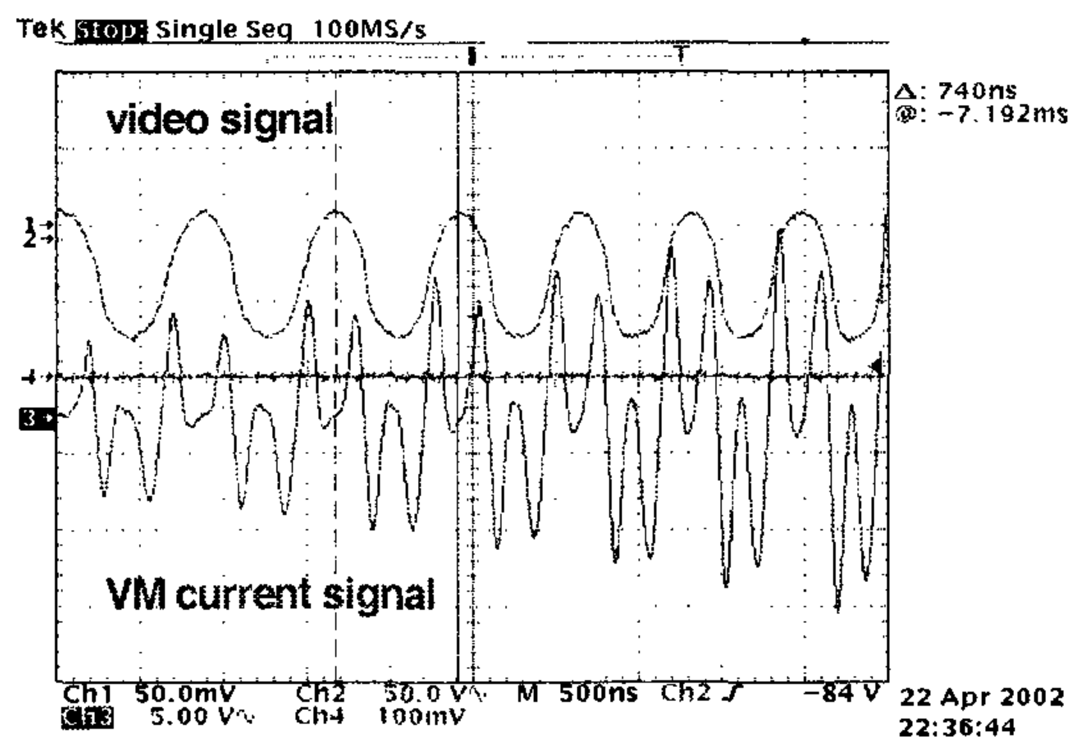


Figure 7. A Typical video luminance signal and VM current signal.

In conclusion, we suggested that a coil inductance should be carefully selected even though it is possible to increase the beam moving distance by increasing it.

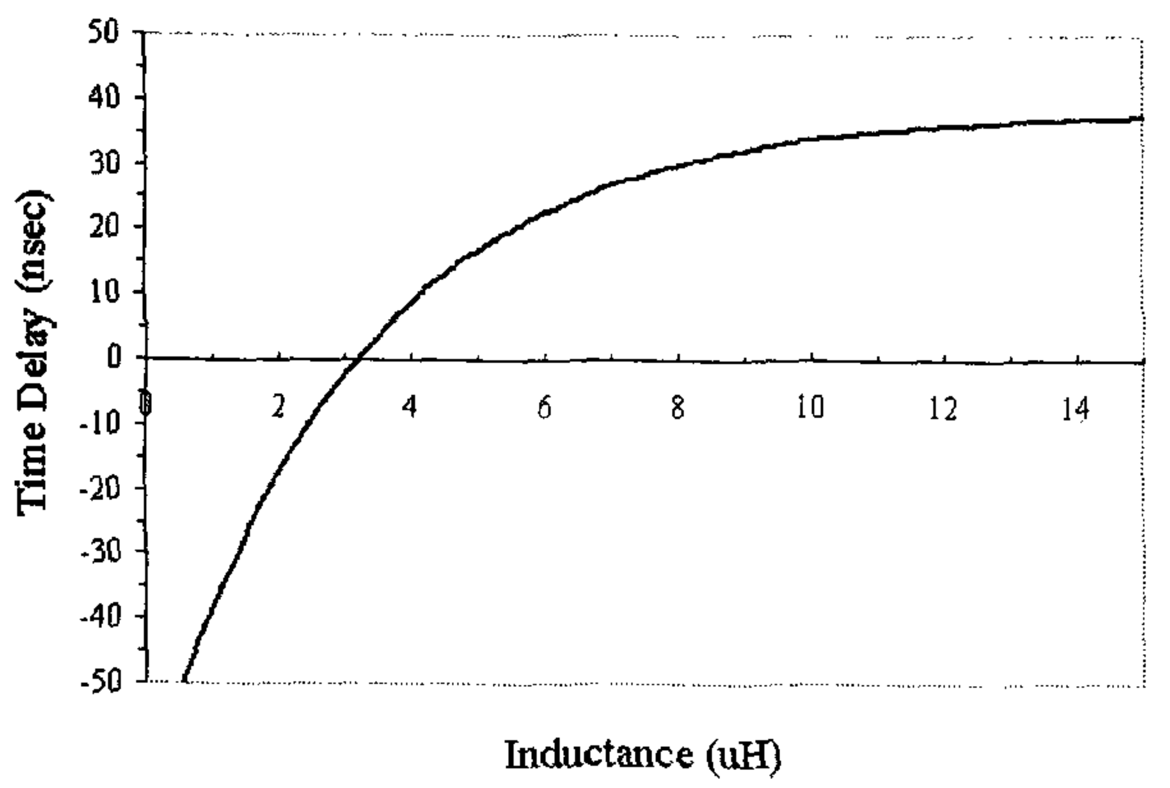


Figure 8. The relationship between VM coil inductance and time delay.

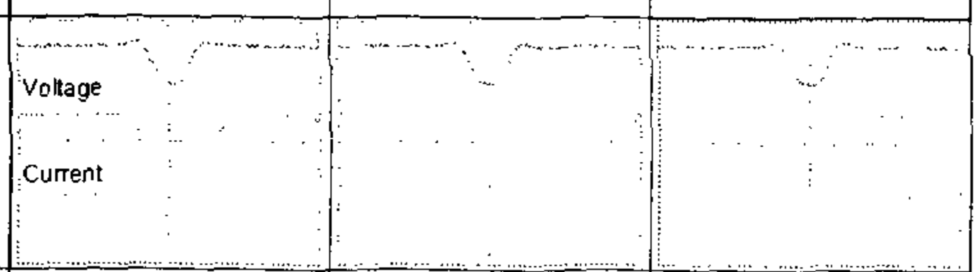
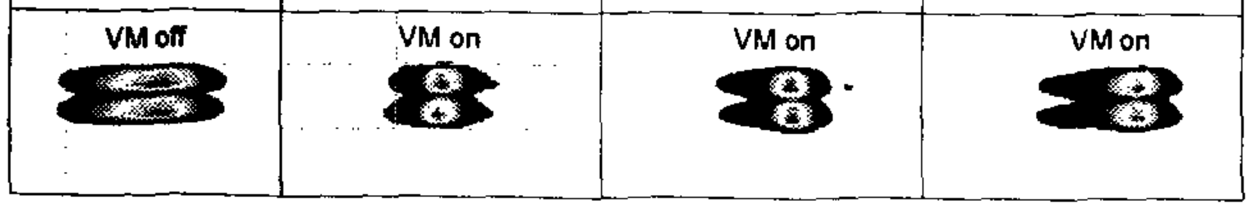
VM Coil	4 Turn	6 Turn	8 Turn
Signal	 Voltage Current		
Time Delay	-5.77 ns	16.76 ns	32.00 ns
VM off 	VM on	VM on	VM on

Figure 9. The Variation of signal delay and beam profile at screen center due to the change of VM coil turns.

4. Conclusion

In the present study, the correlation between free-spot moving distance and horizontal beam size due to a scanning velocity modulation was investigated quantitatively. The results demonstrated that there exists the minimal condition in which horizontal beam size is no more decreased even though VM efficiency is increased. Furthermore, from the MTF analysis it was proved that a reproduced beam profile has the resolution above 200% of original one, so the overall picture quality can be enhanced significantly.

However, if signal mis-matching exists, the harmful effects occurs such as an abnormal beam shift from the proper addressing point and increased beam size, which results in the degradation of resolution and sharpness eventually. From this point of view, we suggested it is very important to avoid signal mis-matching as well as the gun design optimization for minimizing eddy current loss.

In order to obtain the best image quality over the entire screen, further study should be continued in regard to the optimal velocity modulation conditions.

5. References

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