

## Tracking and Deflection Coil Design for Vertical Colour Selection

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### Abstract

Vertical Colour Selection (VCS) is an option for slim CRTs with increased sharpness and brightness. The direction of self-convergence of the DY is changed to vertical in order to obtain better spot uniformity, but the line scan direction remains horizontal. Hence, no video conversion is needed, contrary to transposed scan. In this paper we address two issues: First, there is a high risk of moiré, since the scan lines and the phosphor stripes are parallel. We propose a feedback mechanism guiding the electron beams towards the middle of the mask slots. As positive side effects, the brightness is improved and the shadow mask can be made of a cheap type of steel. Secondly, VCS deflection coils have to satisfy different requirements than coils in ordinary CRTs. We discuss the design rules for self-convergent VCS coils and present simulation results.

### 1. Introduction

At the IMID'02 conference we proposed transposed scan (TS) as an evolutionary approach to reduce the depth of the CRT while maintaining good image quality [1,2]. On the other hand, a revolutionary approach has been presented with FIT, a CRT without a shadow mask [3,4]. Both methods have their drawback: TS requires transposition of complete video frames, while FIT imposes extremely high demands on the spot size to prevent colour errors. In this paper, a hybrid approach is investigated for CRTs of reduced depth, which avoids the typical disadvantages of TS and FIT.

Similarly to TS, the direction of self-convergence is changed from horizontal to vertical, allowing a better spot uniformity [1]. Also the electron gun, the shadow mask pattern, and the phosphor stripes are rotated by 90 degrees (Figure 1). Contrary to TS, the line scan direction is kept horizontal. This CRT concept is called Vertical Colour Selection (VCS). The presence of the shadow mask ensures that each beam lands on the correct phosphor.

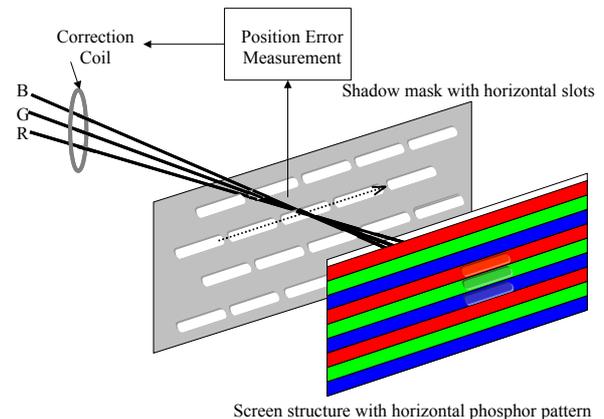


Figure 1: Vertical Colour Selection (VCS)

Without extra measures, the picture of a VCS CRT would be severely distorted by moiré, because the line scan pattern and the mask pattern are both periodic in the vertical direction. We propose to prevent moiré by using a position feedback system as illustrated in Figure 1. The position of the beam on the shadow mask is measured, and the error signal is used to drive a correction coil that aligns the beams with the center of the slots. In section 2 we discuss position detection and a method to transfer the position error signal from the interior of the tube to the outside.

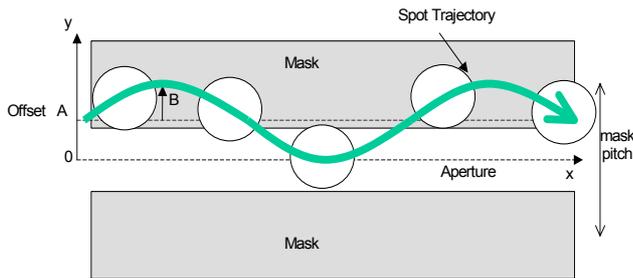
Tracking has two additional advantages: (1) brightness is improved due to the fact that a large part of the spot is transmitted and (2) a cheaper type of steel can be used for the shadow mask, since doming problems are reduced by the high transmission.

In normal scan (NS) and TS, line scan and self-convergence are in parallel. In VCS, however, they are perpendicular to each other. This combination of straight horizontal scan lines and vertical self-convergence imposes unusual constraints on the DY. In section 3 we discuss the consequences for deflection coil design. This analysis shows that satisfying convergence and geometry constraints simultaneously is harder for VCS than for normal scan. We present simulation results showing that DYs for VCS are nevertheless feasible.

## 2. Beam positioning feedback signal

### 2.1 Position Detection

It is assumed that the electron beams are already coarsely tracking the rows of slots after an initial adjustment step [5].



**Figure 2: Spot trajectory with wobbling**

A so-called spot wobbling technique can be used to find the deviation of the beam spot from the middle of the slots [6]. During horizontal scan, a vertical position wobble is applied (Figure 2). Due to the wobble, the part of the beam current absorbed by the shadow mask  $I_{mask}$  and the part reaching the phosphor screen  $I_{mirror}$  vary periodically with time. In the amplitude of the term at the fundamental wobble frequency  $\omega_w$ , both the absolute value and the direction of the position offset  $A$  are preserved:

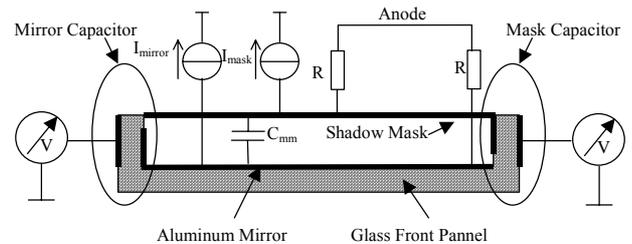
$$I_{mirror} - I_{mask} = AB \cos(\omega_w x)$$

Therefore, this is a suitable position feedback signal.

### 2.2 Signal Output

To transfer the position information from the interior to the outside of the tube, a capacitive method is proposed, avoiding a costly additional high-voltage feedthrough through the glass. To this aim, the shadow mask is electrically isolated from the aluminium mirror and the phosphor screen (Figure 3).

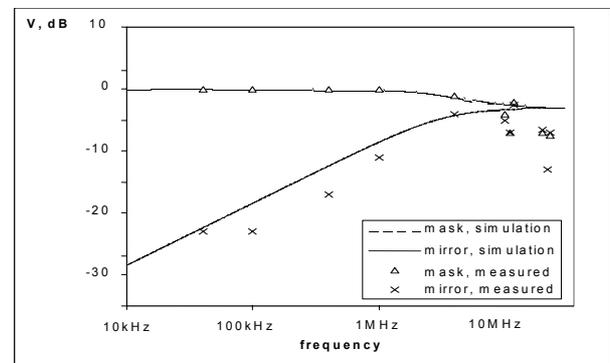
At both sides of the front panel, metal coatings are applied, forming two capacitors with one plate at the inside of the tube and one plate at the outside. One inner plate is connected exclusively to the shadow mask, while the other one is connected exclusively to the mirror. Resistors connect the shadow mask and the mirror to the anode. If the mask or the mirror is hit



**Figure 3: Front panel with output capacitors**

by the electron beam, the electrons will flow to the anode via the resistor, causing a voltage drop. These voltage drops are detected at the exterior plate electrodes.

An undesired capacitor  $C_{mm}$  is formed by the shadow mask and the aluminium mirror. Being a short-circuit at high frequencies,  $C_{mm}$  limits the detection bandwidth.



**Figure 4: Simulated and measured voltages at the mask and mirror electrodes; current injected exclusively into the mask**

A simulation has been carried out to investigate the electrode signals as a function of the frequency of a current  $I_{mask}$  injected exclusively into the shadow mask of a 28" wide screen CRT (Figure 4). Up to about 10MHz, crosstalk is considerably lower than the desired signal. Also the measured electrode voltages are plotted in Figure 4. Again, up to approximately 10MHz, crosstalk is lower than the desired signal. The measured transfer characteristics agree well with the simulation results.

It is concluded that the maximum frequency of the position wobble is limited to about 10MHz, the useable bandwidth of the capacitive signal output method.

## 3. Self-convergent deflection coils for VCS

### 3.1 Design rules

The main convergence error of a DY is astigmatism in the in-line direction [7]. This error occurs due to the increased path length upon deflection. It is due largely to the dipole component of the magnetic field. The dipole also causes pincushion geometry distortion. A significant part of these errors can be corrected by applying line and frame sixpole fields with the correct sign and magnitude. In VCS, where the in-line direction is vertical, the effect of sixpole fields on convergence errors differs from NS. (The influence on geometry is identical, since the position of the green beam does not change.) Tables 1 and 2 show how line and frame sixpole affect the Front-Of-Screen (FOS) performance. The effect is obtained in a two-dimensional model by expanding the magnetic scalar potential  $\Phi(x,y)$  around the off-center point of passage (X,Y) through the field and then calculating the forces on the three beams. The sixpole potentials are given by

$$\Phi_{line}(x,y) = -I_x \text{Im}(x + iy)^3$$

$$\Phi_{frame}(x,y) = -I_y \text{Re}(x + iy)^3,$$

where  $I_x$  and  $I_y$  are the line and frame current. Expansion around (x=X, y=Y) leads to additional local dipole and quadrupole terms, affecting geometry and astigmatism. The magnetic field is given by  $\mathbf{B} = -\nabla\Phi$ . The Lorentz force is  $\mathbf{F} = e\mathbf{B} \times \mathbf{v}$  with  $e$  the electron charge and  $\mathbf{v}$  the velocity. By choosing the red beam to have positive y-coordinate in the gun and blue negative, tables 1 and 2 are obtained. The notation " $\Delta BR$ " stands for "blue minus red".

In order to reduce the main convergence error, positive y-astigmatism, we need negative line sixpole and positive frame sixpole, because we have to defocus the side beams in the y-direction. This is exactly opposite to NS. In order to have straight scan lines, y-geometry should be eliminated (x-geometry is

corrected by controlling  $I_x$  as a function of y-position). Negative line sixpole causes pincushion geometry and positive frame sixpole causes barrel. However, from Tables 1 and 2 we see that the line sixpole is twice as good at distorting North-South geometry as the frame sixpole. Consequently, for good FOS performance we need an exceptionally strong frame sixpole.

In NS the compromise between straight scan lines and convergence is much easier. There the main convergence error is x-astigmatism, curable by positive line sixpole and negative frame sixpole. The line sixpole simultaneously reduces convergence errors and strongly reduces y-geometry. We conclude that coil design for VCS is harder than for NS.

### 3.2 Simulations

We have simulated deflection coils for VCS and their FOS performance using the Ducad software package [8]. Without going into details we mention preliminary results.

Below 110° deflection, self-convergent coils with very good geometry and convergence are easily designed. At 110° and beyond, we need extra means, e.g. a dynamic multipole. With such a multipole we have been able to design coils for 120°. An example of a 110° VCS coil is shown in Figures 5 and 6. The spot uniformity is better than for NS at all deflection angles: it is comparable to TS [1]. As a side effect of the VCS design rules, East-West pincushion is dramatically reduced. (See Table 2: positive frame sixpole causes East-West barrel with a factor 2). A possible issue is the line coil dissipation at 120° which is larger than for NS.

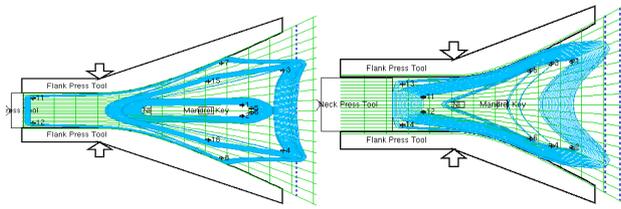
### 4. Conclusions

Vertical Colour Selection combined with vertical position tracking has been investigated as an option for slim CRTs with increased sharpness and brightness. The parts of the beam current absorbed by the shadow mask and by the aluminium mirror are detected by a capacitive signal output method. The bandwidth of this method is high enough to transfer a feedback signal of the beam position generated by a position wobbling technique.

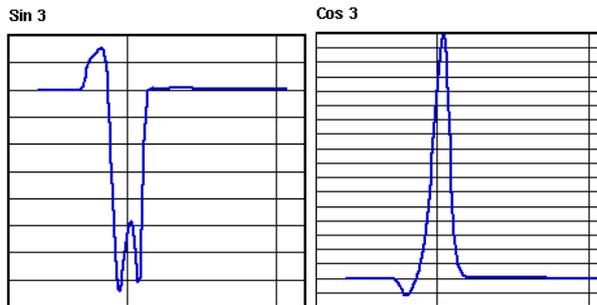
Table 1: FOS effect of a positive line sixpole	
East-West barrel	$F_x \sim -XY^2$
North-South barrel	$F_y \sim -2YX^2$
Astigmatism Y focusing	$\Delta BR Y \sim X^2$
Astigmatism X crossings	$\Delta BR X \sim XY$

Table 2: FOS effect of a positive frame sixpole	
North-South barrel	$F_y \sim -YX^2$
East-West barrel	$F_x \sim -2XY^2$
Astigmatism Y defocusing	$\Delta BR Y \sim -Y^2$
Astigmatism X crossings	$\Delta BR X \sim XY$



**Figure 5: 110° deflection VCS line and frame coils, simulated in Ducad.**



**Figure 6: Line sixpole and frame sixpole strength as a function of z for the 110° VCS design (arbitrary units).**

DY analysis using two-dimensional multipole theory shows that the twin requirements of good convergence and straight scan lines are harder to meet for VCS than for normal scan. Our simulations indicate that deflection coils for VCS can be developed, but that a corrective multipole coil will probably be needed at large deflection angles.

## 5. Acknowledgements

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## 6. References

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