

Display tube with reduced spot growth

The invention relates to a method and a correction circuit for reducing spot-growth when deflecting an electron beam in a display tube which has a control electrode and a display screen, the method comprising the steps of: driving the control electrode for generating a modulated electron beam in the display tube in response to a picture signal, and
5 deflecting the modulated electron beam for displaying the picture signal on the display screen.

Such a method and correction circuit for reducing the spot-growth may be used, inter alia in picture display apparatuses having a display tube for displaying picture information.

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Such a spot-growth reduction in a display tube is known from EP-A-0,382,299. The color display tube described in this document comprises a display screen, an electron gun for generating a central electron beam and two outer electron beams which are coplanar, a deflection unit generating horizontal and vertical deflection fields for deflecting
15 the electron beams, and a correction element for reducing a horizontal spot-growth factor. The three electron beams jointly constitute a composite electron beam. The image of the composite electron beam on the display screen is referred to as spot. The horizontal spot-growth factor is the ratio between a horizontal dimension of the spot at a given position of the display screen and the horizontal dimension of the spot in the center of the display
20 screen. The correction element is arranged between the electron gun and the display screen for producing underconvergence: the outer electron beams are deflected away from the central electron beam. The deflection unit is adapted to compensate the underconvergence. The overconverging deflection unit thus obtained generates at least a horizontal deflection field having a less pronounced astigmatic character. Consequently, the outer electron beams
25 are deflected closer towards the central electron beam after they have successively traversed the underconverging and the overconverging field, and the horizontal spot-growth factor decreases. A magnetic four-pole is described as a possible correction element which can be controlled by means of currents synchronous to the line deflection and possibly also with currents related to the field deflection. The known measures yield a reduction of the

horizontal spot-growth factor. However, for a large reduction of the horizontal spot-growth factor, a large extent of under and overconvergence is necessary and side effects will also play an important role. Complicated and expensive circuits such as electronic convergence correction and/or dynamic north-south correction circuits are required for correcting the side effects.

It is inter alia an object of the invention to provide a method, a display device and a correction circuit for reducing the spot-growth when deflecting an electron beam, in which the horizontal spot-growth factor is considerably reduced without expensive correction circuits being required.

To this end, a first aspect of the invention provides a method of spot-growth reduction as defined in claim 1, and is characterized in that the method comprises the further step of generating a correction waveform which influences the modulated electron beam for obtaining a corrected modulated electron beam which, from the center towards the edges of the display screen, comprises fewer electrons per second than the modulated electron beam.

A second aspect of the invention provides a display device comprising spot-growth reduction means as defined in claim 7.

A third aspect of the invention provides a correction circuit as defined in claim 9.

Advantageous embodiments of the invention are defined in the dependent claims.

Reducing the spot-growth in this way is based on the recognition that the spot dimension is very much dependent on the number of electrons per second in an electron beam. The number of electrons per second in the electron beam is generally indicated as the value of a beam current. The picture signal influences the beam current for obtaining a modulated beam current for displaying the picture signal on the display screen. A correction waveform influences the modulated beam current for obtaining a corrected modulated beam current which, towards the edges of the display screen, comprises fewer electrons per second than the modulated beam current. By reducing the modulated beam current towards the edges of the display screen, a growth of the spot dimension (referred to as spot-growth) will be limited. The modulated beam current may be decreased, for example, by controlling the amplitude of the picture signal by means of a known contrast control, or by controlling a DC level of the picture signal by means of a known brightness control. The spot-growth

reduction according to the invention is suitable for display tubes using one electron beam or a plurality of electron beams. In a color display tube having three separate electron beams which are each related to a phosphor in one of the three primary colors, the electron beam comprises an assembly of these three separate electron beams. Reducing the spot-growth in
5 this manner is particularly interesting when there are large deflection angles.

By reducing the modulated beam current towards the edges of the display screen, the light output on the display screen will slightly decrease towards its edges. To inhibit this decrease, an embodiment of a method according to the invention, characterized as defined in claim 2, the deflection is influenced for causing the deflection rate of the electron
10 beam to decrease towards the edges of the display screen so as to compensate the decreasing light output entirely or partly. In fact, a slower electron beam will cause more electrons to land at a given position on the display screen so that the light output increases.

By influencing the deflection rate, the picture signal will reach a slightly shifted position on the display screen. An embodiment of a method according to the
15 invention, characterized as defined in claim 3, has the advantage that, by influencing an instant of occurrence of the picture signal, the shifted position as a result of the non-constant deflection rate is compensated entirely or partly. The shift in time of the position of occurrence of the picture signal can be achieved by means of known techniques such as clock modulation or interpolation. In clock modulation, the picture signal is written, for example at
20 a constant clock into a memory and read from the memory at a variable clock. In interpolation, a presented picture signal is processed by means of an interpolation algorithm into a picture signal which provides the correct information at a shifted instant.

A correction circuit for improving the impression of sharpness of a picture signal on a display screen of a display tube is known from EP-A-0,598,442. To this end, the
25 known correction circuit arrangement has a correction circuit for generating a correction signal dependent on the picture signal and dependent on display tube data. The correction signal is applied to a contrast control circuit, a velocity modulation circuit and a clock modulation circuit. In response to the correction signal, the clock modulation circuit supplies a processed picture signal which is shifted in time, and the velocity modulation circuit
30 influences the horizontal deflection rate. The contrast control circuit receives the processed picture signal and, in response to the correction signal, it supplies an amplitude-controlled control signal for display on the display screen.

The correction signal known from EP-A-0,598,442 depends, at each position of the display screen on the prevailing value of the display tube data and on the

properties of the picture signal appearing at these positions. Relevant properties of the picture signal are: a modulation frequency, an amplitude of this modulation, and a DC level on which this modulation is superimposed. Let it be assumed that, on the basis of the display tube data and the properties of the picture signal, the correction circuit computes that the picture signal occurring at that instant cannot be displayed with a sufficient resolution at these given positions of the display screen because the occurring spot size renders this impossible. Then, the amplitude of the picture signal is reduced by means of the correction signal via the contrast control circuit at that instant and at that given position, and the spot dimension decreases. Consequently, the light output on the display screen decreases which can be compensated by a decrease of the horizontal deflection rate via the velocity modulation circuit. Before the deflection rate decreases, the position error of the picture signal on the display screen is first precompensated by the deflection velocity modulation by stretching the picture signal in time. This known complex correction circuit generates a correction signal which depends on display tube properties and on the picture signal. The dimension of the spot is thus controlled by the correction circuit at each position of the display tube, dependent on the picture signal. The known correction circuit therefore does not yield a uniform horizontal spot dimension throughout the display screen, but allows, for example a large spot size where there is little resolution in the picture signal and reduces the spot where there is a high resolution in the picture signal.

An embodiment of a method according to the invention, characterized as defined in claim 4, has the advantage that a maximum dimension of the spot in a given chosen direction is constant throughout the display screen. The maximum spot dimension occurs at a maximum amplitude of the picture signal. Consequently, the spot dimensions on the display screen will become more uniform upon modulation of the beam current by the picture signal, and there is no or a less hazy impression of picture information at the edges of the display screen. The correction waveform may be generated, for example by means of a waveform generator which is synchronized with the line and/or field deflection, or the correction waveform may be derived from line and field deflection currents.

An embodiment of a method according to the invention, characterized as defined in claim 5, has the advantage that the decrease of the brightness towards the edges of the display screen is eliminated as a result of reducing the modulated beam current towards the edges of the display screen.

An embodiment of a method according to the invention, characterized as defined in claim 6, has the advantage that not only the decrease of brightness towards the

edges of the display screen as a result of reducing the modulated beam current towards the edges of the display screen is eliminated, but also a decrease of light on the display screen upon control by means of a constant beam current. Upon control by means of a constant beam current, there is a decrease of light on the display screen which is caused, inter alia by the thickness of the display screen glass increasing from the center of the display screen. This decrease of light becomes more and more manifest now that a transmission of the glass becomes increasingly smaller for improving the black level on the display screen.

An embodiment of a display device according to the invention, characterized as defined in claim 8, is based on the recognition that an improvement of the spot uniformity is possible in many display tubes by means of a parabolic correction of the modulated beam current. To compensate for the decrease of light, this correction of the modulated beam current requires a parabolic decrease of the horizontal deflection rate towards the edges of the display screen. Such a decrease of the horizontal deflection rate can be realised in a simple manner by giving the S-correction capacitor in series with the relevant deflection coil a suitable, too small value.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

In the drawings:

Fig. 1 shows an embodiment of a display device according to the invention;

Fig. 2 shows a simple embodiment of a display device according to the invention, and

Fig. 3 shows some waveforms to explain the operation of the display device of Fig. 2.

Fig. 1 shows a display device according to the invention. A color display tube 1 comprises control electrodes 11, 12, 13 and a display screen 10. The display screen 10 is provided with phosphors (not shown) in the three primary colors. The control signals V_{c1} , V_{c2} , V_{c3} , which are derived from a picture signal P_i , drive the control electrodes 11, 12, 13 for modulating the number of electrons in separate electron beams. Each modulated electron beam is related to one of the phosphors. The separate modulated electron beams constitute a modulated composite electron beam. The number of electrons per second in this modulated composite electron beam determines a light output on the display screen 10. A

deflection circuit 5 comprises field and a line deflection coils L_v , L_h , and a deflection control circuit 50 for driving the field and line deflection coils L_v , L_h . The deflection control circuit 50 receives vertical V_s and horizontal H_s synchronizing information which is derived from the picture signal P_i by a synchronizing circuit 6 for generating sawtooth-shaped field and line deflection currents I_v , I_h in the field and line deflection coils L_v , L_h , in synchronism with the picture signal P_i .

A waveform-generating circuit 4 receives the horizontal and vertical synchronizing information H_s , H_v and applies a first correction waveform C_1 to a beam current correction circuit 2, and a second correction waveform C_2 to a time correction circuit 3 and the deflection drive circuit 50. The time correction circuit 3 further receives the picture signal P_i and supplies a time-shifted picture signal P_d . The quantity of time shift is determined by the second correction waveform C_2 . The beam current correction circuit 2 further receives the time-shifted picture signal P_d and supplies the control voltages V_{c1} , V_{c2} , V_{c3} . The number of electrons per second in the modulated composite electron beam (further referred to as a value of the beam current) is also determined by the first correction signal C_1 . In the embodiment described, the line deflection current I_h is influenced by the second correction signal C_2 for causing a horizontal deflection rate to decrease towards the edges of the display screen 10.

In this embodiment, the shape of the first correction waveform C_1 is chosen to be such that the beam current is decreased towards the edges of the display screen 10 (the number of electrons per second in the modulated composite electron beam is reduced towards the edges of the display screen 10) for reducing or preventing horizontal spot-growth towards the edges of the display screen 10. The shape of the second correction waveform C_2 is chosen for delaying the horizontal deflection rate towards the edges of the display screen 10 so as to reduce or compensate the decreasing light output on the display screen. The position error of the picture signal P_i , caused by the influence of the horizontal deflection rate, on the display screen 10 is compensated by means of the second correction waveform C_2 via the time correction circuit 3.

The value of the beam current may be influenced, for example by means of an adapted contrast control: the time-shifted picture signal P_d is multiplied by the first correction signal C_1 . The contrast control may be combined with an existing contrast control in a picture display device, or may be included as an extra feature. As already previously stated, the time correction may be realised by means of, for example clock modulation or interpolation.

Fig. 2 shows a simple embodiment of a display device according to the invention. In principle, this correction circuit shown in Fig. 2 is identical to the correction circuit shown in Fig. 1. However, a first difference is that the deflection circuit 5 has an S-correction capacitor C_s which is arranged in series with the line deflection coil L_h . In known circuits, the value of the S-correction capacitor C_s is chosen to be such that a decrease of the voltage across the horizontal deflection coil L_h is produced towards the vertical edges of the display screen 10 so as to compensate a too high deflection rate towards the edges of the display screen 10 as much as possible. This too high deflection rate occurs as a result of the substantial planeness of the display screen 10. In the invention, the value of the S-correction capacitor C_s is chosen to be too small, thereby causing the horizontal deflection rate to decrease towards the edges of the display screen 10. A further difference is that the waveform-generating circuit 4 now does not apply any correction waveform to the deflection control circuit 50; the second correction waveform C_2 is only presented to the time correction circuit 3. The value of the too small S-correction capacitor C_s is chosen to be such that the extent of the decrease of the deflection rate towards the edges of the display screen 10 results in an increase of the light output which can be entirely or partly compensated by means of a first correction waveform C_1 having a variation for causing the beam current to decrease towards the edges of the display screen 10 so as to reduce the horizontal spot-growth. The position error of the picture signal P_i , caused by the too small S-correction capacitor, on the display screen 10 can be compensated by means of the second correction waveform C_2 via the time correction circuit 3. If the correction waveform C_2 for causing the beam current to decrease towards the edges of the display screen 10 corresponds reasonably well with the shape of the correction of the horizontal deflection rate, it will be possible to present the same correction waveform to both the time correction circuit 3 and the beam current correction circuit 2. However, this applies exclusively if the time correction is achieved by clock modulation and the influence of a gamma of the display tube is not compensated. The gamma of the display tube can be compensated by dividing in the second correction waveform C_2 by this gamma.

The correction waveforms may be chosen to be equal for each line throughout the height of the display screen 10. The correction waveforms may also be dependent on the vertical position on the display screen 10 so as to reduce or prevent possible extra horizontal spot-growth towards the corners of the display screen 10.

Possible unwanted effects on a vertical spot dimension due to influencing the horizontal spot dimension in accordance with the aspect of the invention described

hereinbefore can be compensated by means of known dynamically controlled focusing (dynamic astigmatism focusing).

Fig. 3 shows some waveforms to illustrate the operation of the display device of Fig. 2. Each time, a period t_0 , t_1 is shown which corresponds to a horizontal time interval in which a horizontal line is written on the display screen 10. Fig. 3a shows in a broken line a horizontal deflection current I_{ho} in accordance with the prior art, having an amount of S-correction for writing on the display screen 10 at a (substantially) constant horizontal deflection rate. A corrected horizontal deflection current I_{hc} having a too large S-correction due to an S-correction capacitor C_s chosen, in accordance with the invention, to be deliberately too small, is shown as a solid-line curve. In Fig. 3b the horizontal deflection rate v_h is shown, the broken line shows the constant horizontal deflection rate v_{ho} associated with the horizontal deflection current I_{ho} in accordance with the prior art. The solid-line curve shows that the corrected horizontal deflection rate v_{hc} according to the invention slightly increases in a center of the display screen 10 and decreases towards the edges of the display screen 10. Fig. 3c shows the maximum horizontal spot dimension d_s . The broken-line curve d_{so} shows, on a given vertical position of the display screen 10, the spot-growth towards the edges of the display screen 10 occurring at a constant horizontal deflection rate v_{ho} in accordance with the prior art. Solid line d_{sc} shows the constant maximum horizontal spot dimension occurring at the (fully) corrected horizontal deflection rate v_{hc} . The waveforms shown in Fig. 3 are only given by way of example, and simple waveforms, for example consisting of a combination of line sections is suitable for spot-growth reduction.

It is to be noted that the embodiments mentioned above elucidate rather than limit the invention and that those skilled in the art will be able to conceive many alternative embodiments without departing from the scope of the appendant claims. Reference signs between brackets in the claims should not be construed as limiting the claims. The invention, and notably the waveform-generating circuit 4, the time correction circuit 3 and the beam current correction circuit 2 may be implemented in hardware with various elements or in an integrated circuit and/or by means of a suitably programmed processor, both implementations being within the scope of the invention. The invention may be used for maintaining the horizontal dimensions of the spot upon horizontal deflection as constant as possible, or for maintaining the vertical dimension of the spot upon vertical deflection as constant as possible. The invention is applicable to the conventional deflection, in which lines obtained by a horizontal deflection succeed each other vertically, and in transposed scanning, in which vertical columns obtained by vertical deflection succeed each other horizontally.

CLAIMS:

1. A method of reducing spot-growth when deflecting an electron beam in a display tube (1), which display tube (1) has a control electrode (11, 12, 13) and a display screen (10), the method comprising the steps of: driving (2, 3) the control electrode (11, 12, 13) for generating a modulated electron beam in the display tube (1) in response to a picture signal (Pi), and deflecting (5) the modulated electron beam for displaying the picture signal (Pi) on the display screen (10), characterized in that the method comprises the further step of generating (4) a correction waveform (C1) which influences the modulated electron beam (2) for obtaining a corrected modulated electron beam which, from the center towards the edges of the display screen (10), comprises fewer electrons per second than the modulated electron beam.
10 beam.
2. A method of reducing spot-growth as claimed in Claim 1, characterized in that the method comprises the further step of influencing (C2; Cs) the deflection (5) for causing a deflection rate of the electron beam to decrease from the center towards the edges of the display screen (10).
- 15 3. A method of reducing spot-growth as claimed in Claim 2, characterized in that the method comprises the further step of influencing (3) an instant of occurrence of the picture signal (Pi) for compensating a position error on the display screen (10).
4. A method of reducing spot-growth as claimed in Claim 1, characterized in that the correction waveform (C1) is suitable for rendering a maximum dimension, occurring
20 in a chosen direction, of an image of the electron beam on the display screen (10) substantially uniform throughout the display screen (10).
5. A method of reducing spot-growth as claimed in Claim 2, characterized in that the deflection rate from the center towards the edges of the display screen (10) is decreased in such a manner that a decrease of a maximum light output on the display screen
25 (10) towards the edges as a result of the reduced number of electrons per second in the corrected modulated electron beam from the center towards the edges of the display screen (10), is substantially compensated.
6. A method of reducing spot-growth as claimed in Claim 2, characterized in that the deflection rate is decreased in such a manner that a maximum light output throughout



the display screen (10) is rendered constant.

7. A display device provided with means for reducing spot-growth when deflecting an electron beam, said display device comprising:

5 a display tube (1) provided with a control electrode (11, 12, 13) and a display screen (10),

control means (2, 3) for driving the control electrode (11, 12, 13) for generating a modulated electron beam in the display tube (1) in response to a picture signal (Pi), and

10 means (5) for deflecting the modulated electron beam for displaying the picture signal (Pi) on the display screen (10), characterized in that the display device further comprises correction means (4) which are coupled to the control means (2, 3) for supplying a correction waveform (C1) which influences the modulated electron beam for obtaining a corrected modulated electron beam which, from the center towards the edges of the display screen (10), comprises fewer electrons per second than the modulated electron beam.

15 8. A display device as claimed in Claim 7, characterized in that the deflection means (5) include an S- correction capacitor (Cs) which is arranged in series with a deflection coil (Lh), the S-correction capacitor (Cs) having a smaller value than a nominal value for causing the deflection rate of the electron beam to decrease from the center towards the edges of the display screen (10), said nominal value being associated with a substantially
20 constant deflection rate.

9. A correction circuit for reducing spot-growth when deflecting an electron beam, which correction circuit comprises means (2, 3) for driving a control electrode (11, 12, 13) of a display tube (1) having a display screen (10), characterized in that the correction circuit further comprises correction means (4) for applying a correction signal (C1) to the
25 control means (2, 3) for obtaining a corrected modulated electron beam which, from the center towards the edges of the display screen (10), comprises fewer electrons per second than the modulated electron beam.