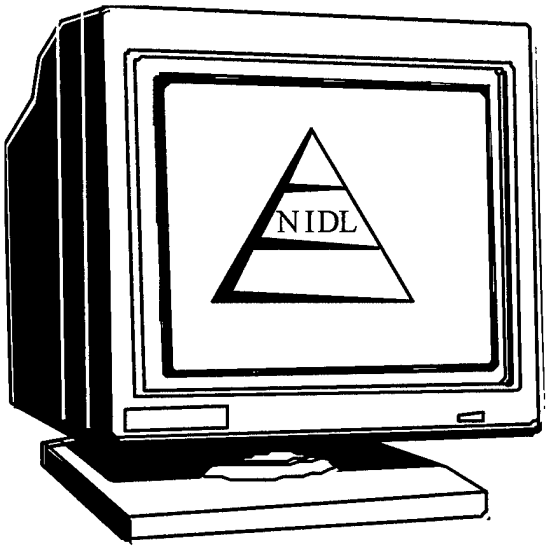
DISPLAY EVALUATION REPORT



Monitors Included:
Data Ray DR110
Image Systems M21P2KHBMAX Turbo
MegaScan MD5-4820PD
Nortech Systems UHR21P
Orwin Model 2000

A Survey of Five 5-MegaPixel Monochrome CRT Monitors for Medical and Government Imaging Applications

- Size: 21 inches, portrait
- Addressability: 2,048 x 2,560 pixels

National Information Display Laboratory

at the

Sarnoff Corporation

CN 5300, Princeton, NJ 08543-5300

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DISPLAY EVALUATION REPORT

National Information Display Laboratory

FOREWORD

On behalf of the government user community, the National Information Display Laboratory (NIDL) has prepared this report which surveys the performance of five 5-MegaPixel monochrome CRT monitors. All have addressability of 2048 x 2560 and screen diagonals of 21 inches. The report presents summaries of the most important monitor parameters, plus comparisons of the five 5-MegaPixel monitors based on those parameters.

Many of these monitors are currently under consideration for use at various Government facilities. In addition, because most of these monitors are capable of high brightness and high contrast, they are also under consideration for or in use at various medical imaging facilities.

Since 1990, the NIDL has prepared surveys and individual evaluations of high-resolution display monitors. These detailed reports help government users to obtain, at reasonable cost, display monitors with the required performance. The reports are available and can be obtained from the NIDL at the address listed below or on the worldwide web at: http://www.nta.org/SoftcopyQualityControl/MonitorReports

A companion document that describes how the measurements are made is also available from the NIDL:

- *NIDL Publication No. 171795-036*
  Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20, Part 1: Monochrome CRT Monitor Performance, Draft Version 2.0, July 12, 1995.

The above measurement procedures were developed by the NIDL in collaboration with the display industry and are currently under review in EIA and ANSI Committees and with the National Institute of Standards and Technology (NIST). Standards for the measurement of flat panel displays are under development by VESA (Video Electronics Standards Association) with participation and leadership from NIDL and NIST.

Comments, suggestions, and questions about this report are welcome and encouraged.

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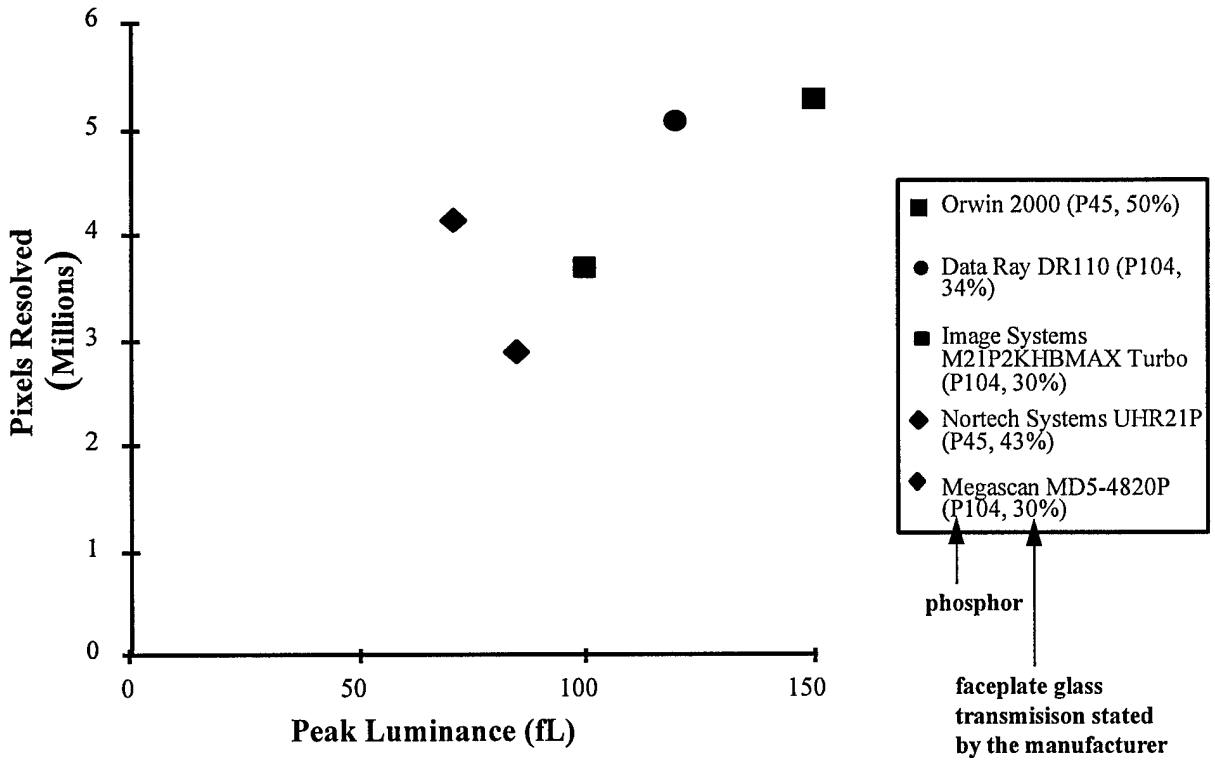
EXECUTIVE SUMMARY

Measurements of the performance of five, high-brightness, monochrome, 21-inch viewing diagonal, portrait, CRT monitors with addressability of 2,048 x 2,560 pixels have been conducted, analyzed, and reported in accordance with consistent metrological practices developed by the NIDL. In terms of two performance metrics, the number of "resolvable pixels on grayscale imagery" (see page 6) and peak luminance, the monitors range in performance from 2.9 to 5.2 million pixels and from 240 candelas per square meter (70 footLamberts) to 514 cd/m^2 (150fL). Although each monitor can address 2,048 x 2,560 pixels, each monitor achieves a different number of resolvable pixels because of differences in the size of the scanned electron beam spot at the phosphor screen. Measurements of the spot shape and size were conducted and plotted on the same scale to facilitate comparison. The range in peak luminance arises from the range in transmission of the CRT faceplate glass (30% to 50%), the efficiency of the phosphor screen, and the peak beam current the CRT and monitor circuitry were specified to operate at.

Given a number of monitors all matched in peak brightness, those with low faceplate glass transmission are expected to provide visibly-higher contrast in brightly-lit viewing environments and, therefore, to better enable people to detect low-brightness, low-contrast detail in images. Given a number of monitors of the same peak brightness and transmission and under the same ambient lighting, those with a larger number of resolved pixels will provide a sharper looking image that better enables detection of detail. Given a number of monitors with the same transmission and resolvable number of pixels and under the same ambient lighting conditions, those with higher peak luminance and, therefore, higher dynamic range, are expected to better enable the detection of low-brightness, low-contrast pixels or small clusters of pixels in an image, e.g., microcalcifications in mammograms or bolts in an airplane wing in surveillance imagery.


Pixels Resolved (Millions)
6
5
4
3
2
1
0
0
50
100
150
Peak Luminance (fL)
Orwin 2000 (P45, 50%)
Data Ray DR110 (P104, 34%)
Image Systems M21P2KHBMAX Turbo (P104, 30%)
Nortech Systems UHR21P (P45, 43%)
Megascan MD5-4820P (P104, 30%)
phosphor
faceplate glass transmisison stated by the manufacturer

SECTION I

Introduction: Purpose of This Report

This report presents a survey of the performance of five 5-MegaPixel monochrome CRT monitors. All have addressability of 2048 x 2560 pixels, and an image size of 21 inches. The report provides:

- Comparisons of the performance of the five 5-MegaPixel monitors (Section II)
- A two page summary of the performance of each of the five 5-MegaPixel monitors (Section III)

The results are given in a standardized graphical format.

In addition, to facilitate comparisons of the monitors' performance for applications in medical and Government imaging, two Appendices present measured spot contours and contrast modulations at specific screen locations at luminance settings appropriate for some Government imaging applications (Appendix A) and for medical imaging applications (Appendix B).

The purpose of the report is to provide an overview of the performance of these monitors. To do that, we have concentrated on the most important monitor parameters, providing the reader with information that will allow a rapid and timely review.

These parameters are:

- Luminance (brightness)
- Resolution (measured and interpreted in several ways)
- Waviness (distortion)

The NIDL has published a detailed description of the procedures used to make the measurements we report here, as well as many others needed for a complete characterization of a CRT monitor. [See reference in Foreword, p. iii.]

One additional performance parameter of importance is:

- "Reflectance"

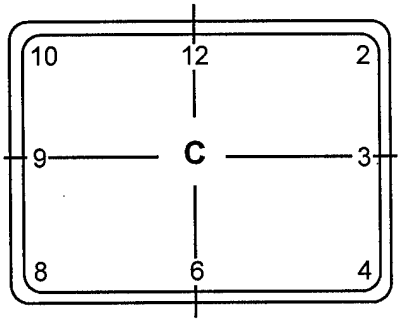
Reflectance is a measure of how much the ambient illumination will be reflected back to the viewer. Reflectance indicates how the monitor will perform in a bright viewing environment.

UNDERSTANDING THE MEASUREMENTS AND CHARTS

We provide a brief explanation of each measured parameter just before we present the measurements of that parameter. With the exception of waviness (geometric distortion), all measurements were made at nine positions on the monitor screens:

- the center of the screen,
- top and bottom (12 and 6 o'clock),
- right and left (3 and 9 o'clock),
- four corners (2, 4, 8, and 10 o'clock).

This allows us to assess both the behavior at the center of the screen and the variation as one moves around the screen.



For simplicity, measurements are reported using only four kinds of charts.

(1) A radar chart is used to show measurements at the nine positions across the screen for each monitor. The example in Fig. 1 shows luminance data for one monitor. (Luminance in foot-Lamberts, described later.) The radius of the shaded region indicates the magnitude of the parameter.

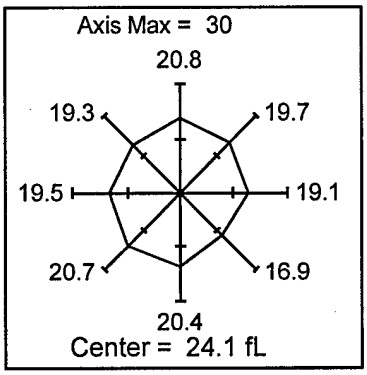


Figure 1. An example of a radar type of chart showing luminance at center and eight other positions on the screen. In this plot, luminance at screen center is 24.1 fL, at screen top it is 20.8 fL, etc. The full-scale length of each radial line is given as 30 fL.

(2) Horizontal high-low-center bar charts are used to compare monitors as in Fig. 2. Minimum and maximum values plus the value at center screen are shown in charts of the type illustrated in Fig. 2.

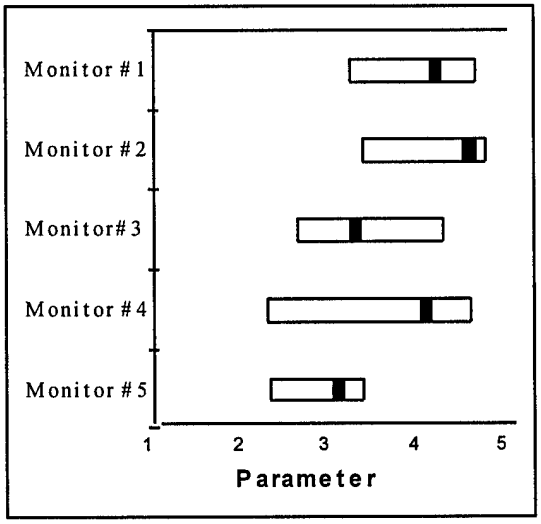


Figure 2. An example of a bar chart showing the range from the minimum to the maximum values measured, with the value at screen center indicated by the dark bar. This chart shows that the minimum and maximum values for Monitor #1 were 3.2 and 4.6 and the center screen value was 4.2.

(3) A conventional bar chart is illustrated in Fig. 3, in which the length of the bar indicates the value of the measured parameter. The left edge of the bar has no significance.

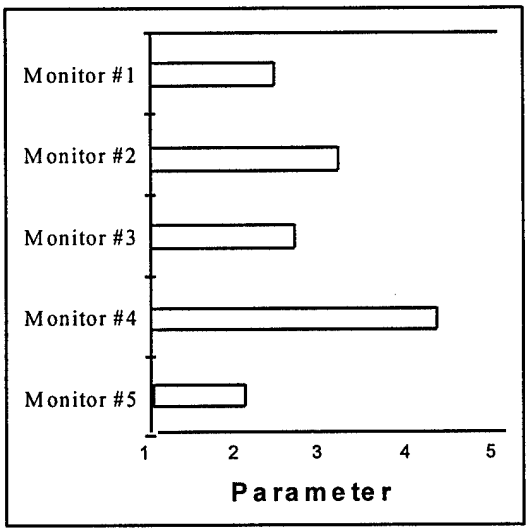


Figure 3. An example of a bar chart showing a value of 3.2 for Monitor #2.

(4) The final type of chart is used to show waviness, or geometric distortion. The irregular lines are exaggerations of the shape of perfect straight lines as displayed across the center and along the edges of the monitor.

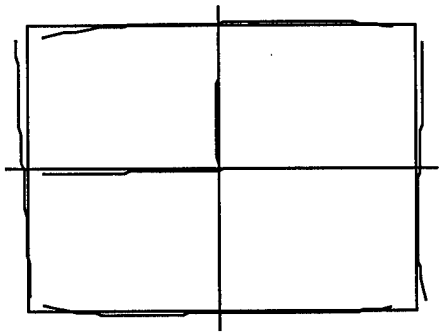


Figure 4. An example of the chart used to show waviness, or geometric distortion. The gray band indicates ±1.0% distortion.

SECTION II

Comparative Data on Five Monitors

LUMINANCE

Luminance is the technical name for the brightness of a monitor. It is measured in foot-Lamberts (fL) or millifoot-Lamberts (mfL). The typical home television receiver provides about 100 fL brightness. Most good quality color CRT monitors used with computers or other technical display applications have average luminances no greater than 25 to 35 fL. Typically, color CRT monitors cannot achieve higher luminance without a significant, noticeable loss in resolution. Several of the monochrome monitors measured in this report used cathode ray tubes (CRTs) specially designed to achieve much higher resolution than standard monochrome tubes and at considerably higher luminances.

When comparing monitor performance one needs to consider that brightness, contrast, and resolution can be traded off. To improve contrast in bright office environments, "dark" or low transmission (≤30%) faceplate glass can be used. The attendant loss in luminance is often judged to be acceptable. An ideal monitor achieves high resolution, brightness, and contrast simultaneously.

The values shown in Fig. 5 were measured using a PhotoResearch SpectraScan PR-704 spectroradiometer with the monitor set to the maximum drive specified by the manufacturer. The drive is maintained for the full screen. For various applications, the minimum luminance setting may also be of interest. The minimum and maximum luminance settings of the monitors are indicated by (Lmin, Lmax).

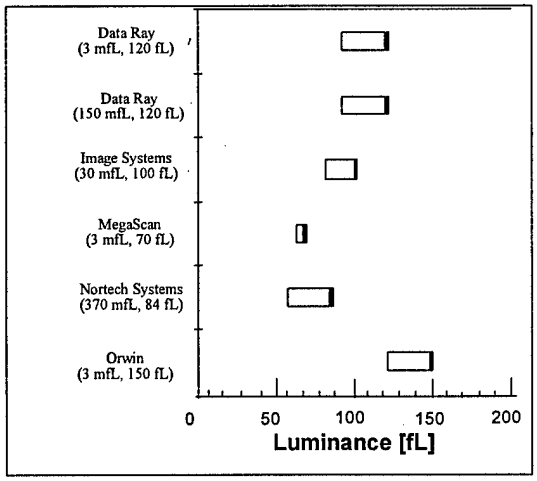


Figure 5. Measured luminance of the five monitors at manufacturers' recommended settings (@ 100% Lmax). Center screen luminance, indicated by the black bar, is usually also the maximum luminance. The length of the gray bar indicates the range of luminances measured on the screen and is an indication, therefore, of luminance nonuniformity.

Luminance [fL]

RESOLUTION

Discussion of Resolution and Addressability

It is essential to distinguish between *addressability* and *resolution*:

- *Addressability* states the number of locations at which a spot can be displayed on the screen. The displays in this report all have an addressability of 2048 positions horizontally and 2560 positions vertically. However, that does not guarantee that the spot of light is small enough and bright enough to display spatially-distinguishable spots.
- *Resolution* describes the actual number of spots or lines that can be distinguished across the screen. The electron beam that forms the spot on the screen has a finite size that may vary with beam current, or brightness. In addition, the spot's width is stretched in the direction of the horizontal scan by the finite risetimes of the video amplifier. Deflection of a spot across the CRT screen also changes its size and shape. As neighboring spots grow and overlap, one's ability to discern them as individual spots decreases, and the "resolution" of the display is degraded.

The "Resolution" of a monitor is a complex characteristic and it can be described and quantified in a number of ways. It can be described by:

- the contrast modulation measured on the screen that results from a 1-pixel-on, 1-pixel-off grille video input signal
- the contrast modulation at all signal frequencies, e.g. 1-pixel-on, 1-pixel-off; 2-pixel-on, 2-pixel-off, etc.
- the ratio of linewidth to pixel size, i.e., the Resolution-to-Addressability Ratio or RAR
- measurements of spot size
- MTF measurements
- others

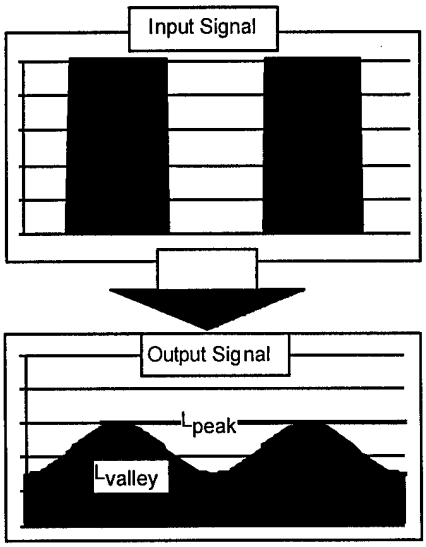
Resolution is very complex for CRTs also because contrast modulation, linewidth, and spot size all vary with beam current and screen location. Given this complexity, we propose a simpler definition that puts resolution on a level that can be compared easily with addressability:

- the maximum number of white and black lines that can be addressed with a specific minimum contrast modulation, averaged over the screen.

We call this last metric "realizable resolution."

Contrast Modulation

Contrast modulation, Cm, measures the ability of the CRT to reproduce modulation patterns. The process is shown schematically below.



$$C_m = \frac{L_{peak} - L_{valley}}{L_{peak} + L_{valley}}$$

Figure 6. Contrast modulation, Cm. A fully modulated signal is input to the monitor. Cm is calculated from measurements of the luminance of the peaks and valleys of the resulting pattern on the screen.

An input signal with a horizontal or vertical 1-pixel-on, 1-pixel-off grille pattern provides a stringent test of monitor resolution (Figure 6). Monitors with spots that are too large for the addressability will have low contrast modulations. The performance of the monitor can be completely characterized by measuring Lpeak and Lvalley for n-pixel-on, n-pixel-off horizontal and vertical grille patterns where n=1,2,....., and where the modulation of the input signal is varied between all possible levels. Such a broad program of measurements would enable the Modulation Transfer Function or MTF of the monitor to be fully-characterized. Unfortunately, it is difficult and very time-consuming to conduct such an extensive program of measurements. In this report, we measured contrast modulation at grille pattern frequencies of 1-pixel-on, 1-pixel-off, 2-pixel-on, 2-pixel-off and 3-pixel-on, 3-pixel-off used the results to compute realizable resolution.

Contrast Modulation Results

For this report, Cm for 1-pixel-on, 1-pixel-off test patterns was measured using a Microvision Display Characterization system, a line-scan camera that scans the tube face and maps out the intensity of the pattern. The measurements were conducted at nine screen locations and for both horizontal and vertical grille patterns.

Figure 7a shows a comparison of Cm for the five monitors when operated at the manufacturers' recommended settings.

Figure 7b shows a comparison of Cm for four of the monitors operated at a peak luminance of 36 fL, as appropriate for a number of Government display applications.

a.

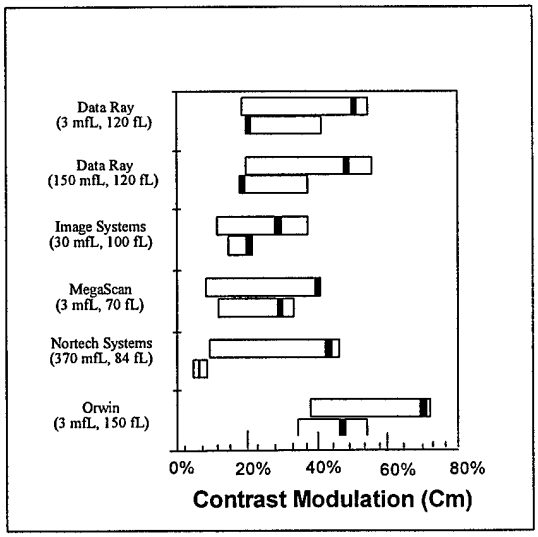
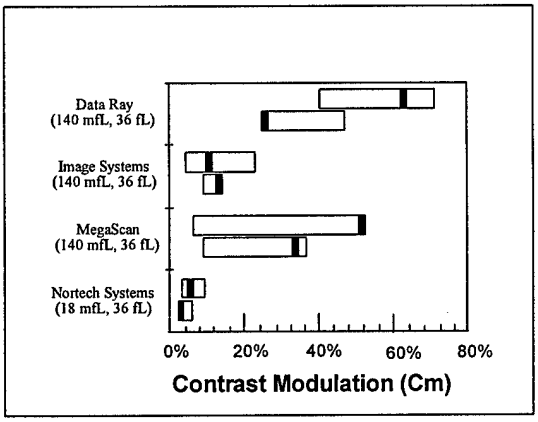


Figure 7a and b. Measured contrast modulation Cm of the five monitors for the 1-on/1-off test pattern at 50% Lmax, where Lmax is set to (a) manufacturer's recommended settings or (b) ~36fL. The upper bar shows vertical modulation (horizontal stripes); the lower bar shows horizontal modulation (vertical stripes).

b.


Data Ray
(140 mfL, 36 fL)
Image Systems
(140 mfL, 36 fL)
MegaScan
(140 mfL, 36 fL)
Nortech Systems
(18 mfL, 36 fL)
0%
20%
40%
60%
80%
Contrast Modulation (Cm)

Realizable resolution: a simple number

Realizable resolution is a simple way of describing the resolution of a CRT monitor in a manner that is easily compared with the stated addressability. We define resolution here as the maximum number of alternate black and white lines that can be displayed with a stated minimum contrast modulation.

We use different conditions to determine realizable resolution for two common applications.

- *Text resolution* (and graphics) require crisp edge definition and clear whites and blacks. We define the resolution for this use as the maximum number of alternating black and white lines that can be displayed with a Cm of 50% or more. A Cm of 50% produces alternating lines that are highly visible.
- *Image resolution* typically does not require sharp changes in luminance. For monitors displaying images rather than text, we define the resolution using a minimum Cm of only 25%. A pattern of alternating black and white lines with 25% contrast is still visible.

Since these definitions demand a higher Cm for text than for images, the stated resolution is always lower for text.

Figure 8a shows a comparison of realizable resolution for five monitors when operated at the manufacturers' recommended settings.

Figure 8b shows a comparison of realizable resolution for four monitors operated at a peak luminance of ~ 36 fL.

For more information on how realizable resolution is determined see the publication on Page *iii*.

a.

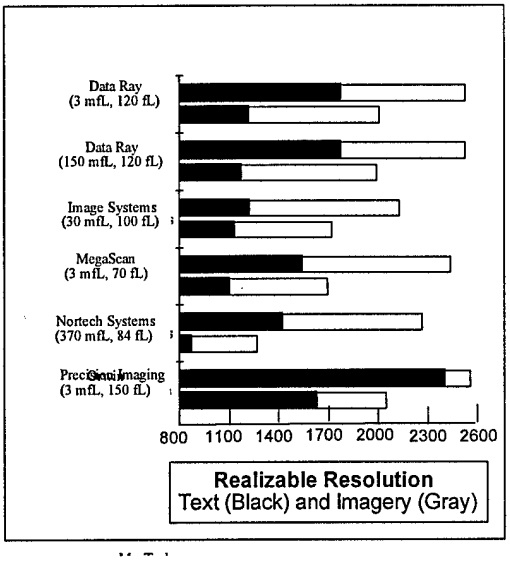
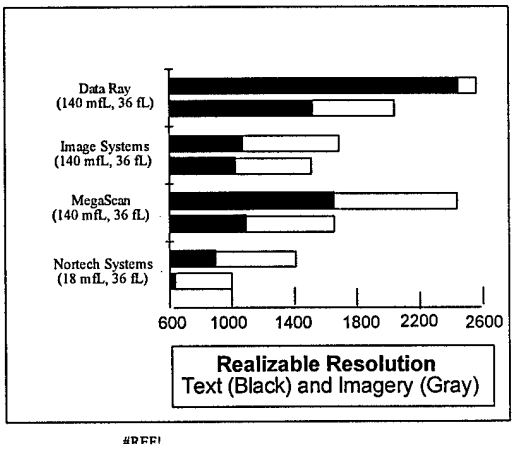


Figure 8a and 8b. Realizable resolution at 50% Lmax, where Lmax is set to (a) manufacturers' recommended settings or (b) ~36fL. The upper bar shows vertical modulation (horizontal stripes), the lower bar shows horizontal modulation (vertical stripes).

b.



Resolution-Addressability Ratio (RAR)

Another well-known measure of resolution is the *Resolution-Addressability Ratio* or *RAR*. It is the ratio of the width of a vertical or horizontal line on the display to the size of the pixel. Line width is defined to be the full width of the spot's luminance profile at 50% of its peak value. Pixel size is determined by the scanned image size divided by the number of addressable pixels. RAR can be thought of as the width of the line measured in addressable pixels.

An RAR of 1.0 means that the addressability and resolution are equal, i.e. that the spot is just small enough to display the addressable number of pixels as separated, individual dots. If RAR < 1 the display will have noticeable structure in solid fields because the spot size does not adequately fill the inter-pixel space when all pixels are on. This noticeable structure is often called "raster visibility" and is a fixed-spatial-noise pattern that degrades image quality. If, on the other hand, the RAR is greater than 1.5, image quality will also be degraded since the large spots will degrade contrast modulation. For RAR between 1.2 and 1.3, raster visibility is typically undetectable and the spot size is not so large as to significantly degrade contrast modulation. As a result, an RAR between 1.2 and 1.3 is frequently stated to provide the best image quality.

For a given CRT monitor, RAR will vary across the screen depending on how the spot is distorted and enlarged during deflection.

The comparison of RAR for the five monitors is shown in Fig. 9. As noted earlier, in this style of chart, the ends of the indicated bar are the minimum and maximum values, which may occur at only a small portion of the screen, and the dark bar is the value at screen center.

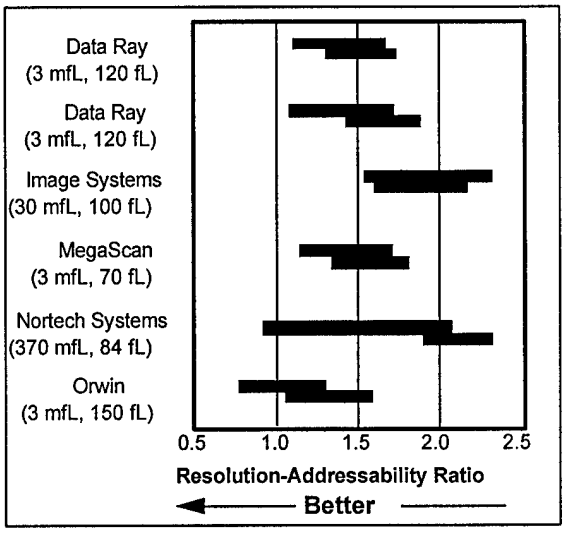


Figure 9. Resolution-Addressability Ratio or RAR at manufacturer's recommended settings. RAR between 1.2 and 1.3 is considered optimum. For RAR larger than 1.5, the spot is too large to display all the addressable pixels. The upper bars show vertical resolution, the lower bars horizontal.

Spotsize

Figure 10a shows a comparison of spot size for the five monitors operated at a peak luminance recommended by the manufacturers. Figure 10b shows a comparison of spot size for three of the monitors operated at a peak luminance of 36 fL. In the Figures the length of the gray bar indicates the magnitude of the variation in spot size across the screen, while the black bar indicated the spot size at screen center.

a.

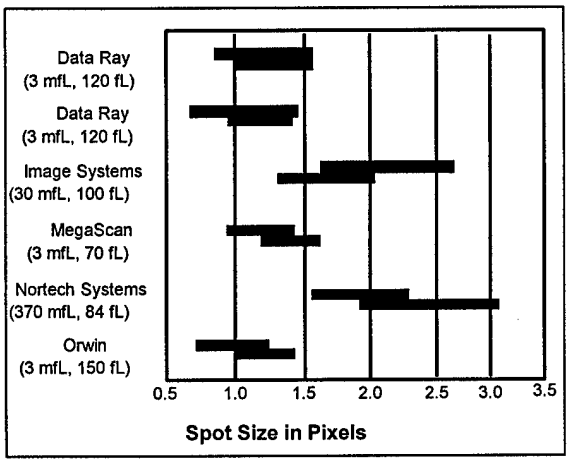
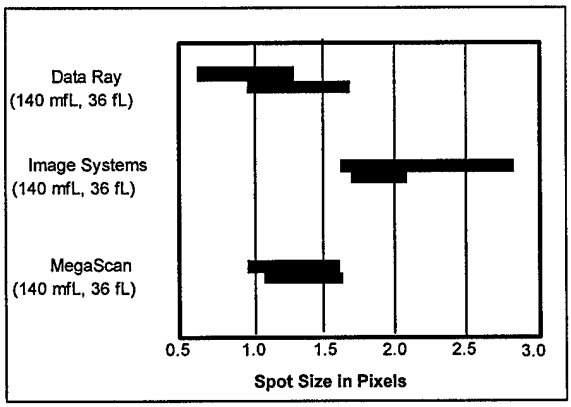


Figure 10a and b. Comparison of spot size for the five monitors at 50% Lmax, where Lmax is set to (a) manufacturers' recommended settings or (b) ~36fL. For each monitor, the upper bar shows the vertical spot size and the lower bar, the horizontal spot size.

b.



WAVINESS

The magnetic deflection system that moves the electron beam across the face of the tube does not produce perfectly straight lines. *Waviness* measures how much the display of a straight line varies from true straightness. This is sometimes called *geometric distortion*.

In the individual reports that follow we show the waviness of horizontally scanned lines at the top, center, and bottom of the display and for vertically scanned lines at the right side, center, and left side of the screen. In the comparison chart in Fig. 11, we show only the worst case waviness. A good display deviates from a straight line by less than 0.5% of the screen height.

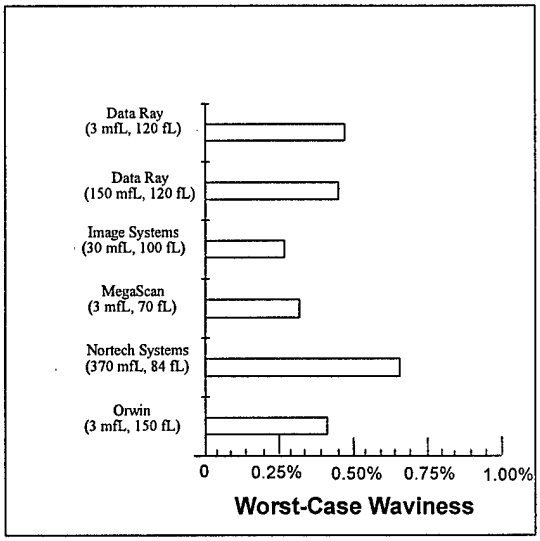


Figure 11. The length of the bar indicates worst-case waviness at manufacturers' recommended settings, or geometric distortion. Data for individual monitors in the next section show the actual form of the waviness.

Worst-Case Waviness

REFLECTANCE

The reflectance of a display screen is a measure of the fraction of light incident on the screen that is reflected into the viewer's eyes. The incident light comprises all light that comes from outside the screen (e.g., from lighting sources in the room and from illuminated objects such as walls and white shirts). However, it does not include any light from the phosphors except the light that escapes the screen, reflects off objects in the environment, and returns to the screen.

When more incident light is reflected from a display screen due to higher screen reflectance, the contrast achievable on the screen is reduced, as is the dynamic range of screen luminances. The contrast modulation capability will also be reduced, with the consequence that information once visible in an image may not be visible anymore. One very effective way to mitigate these effects is to decrease the screen reflectance by using an absorptive faceplate. In this case, the light from the phosphor screen is absorbed only once by the faceplate on the way to the viewer, but light from the outside is absorbed twice: once on the way in, and again on the way out of the glass faceplate. Therefore, a monitor with 30% transmission will reflect only $(30/50)^2$ or 36% of the ambient illumination reflected by a monitor with 50% transmission.

Another approach to increase contrast and contrast modulation involves the use of an AR or Anti-Reflective coating on the display. Such coatings reduce the specular or mirror-like reflection of ambient light.

Diffuse Reflectance

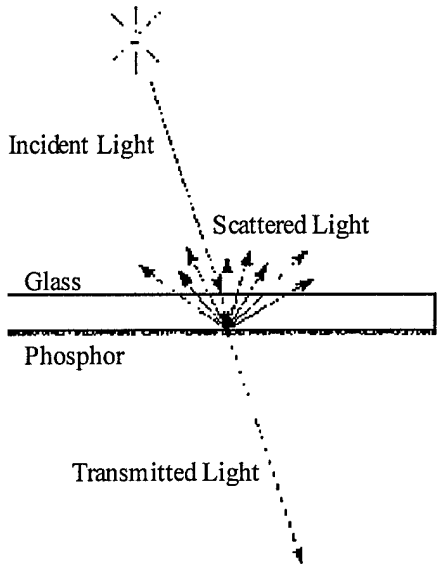


Figure 12. Diffuse reflectance of ambient light from the aluminized phosphor screen of a CRT

When used in a room with significant ambient illumination, a monitor with low reflectance will have higher contrast and higher contrast modulation in comparison to a monitor that has higher reflectance. Even in a dark viewing environment, a low-reflectance monitor will perform better than a high-reflectance one, since it will reduce the reflection of light that impinges on the screen from objects in the dark room illuminated by the display, objects such as white shirts, walls, etc.

Faceplate transmittances provided by the manufacturers for the monitors measured in this report are:

- Orwin Model 2000, 50% *
- Data Ray DR110, 34%
- Image Systems M21P2KHBMAX Turbo, 30%
- Nortech Systems UHR21P, 43%
- Megascan MD5-4820P, 30%

* Orwin also makes 30% transmission model 2000 monitors.

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SECTION III

Individual Data on 5 MegaPixel Monochrome Monitors at Manufacturer's Recommended Settings

Data Ray DR110

Image Systems M21P2KHBMAX Turbo

MegaScan MD5-4820PD

Nortech Systems UHR21P

Orwin Model 2000

DATA RAY DR110

Manufacturer's Data

Manufacturer Name	Data Ray
Model Number	DR110
Price	$7,925
Screen Diagonal	21 inches
Faceplate Transmission	34%
Horizontal Scan Rate	186.07 kHz
Vertical Scan Rate	71.02 Hz
Image Size (H x V)	11.5 x 14.7 inches
Addressable Pixel Number	2048 x 2560
Pixel Size	5.61 x 5.74 mils (0.142 x 0.146 mm)

Summary Comments:

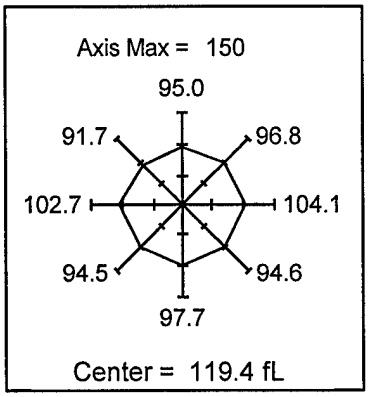
- This monitor was driven by a DOME Md5/PCI video board.
- Based on Cm = 25%, this monitor resolved 100%, 97% and 96% of the addressable pixels when operated with min/max luminance settings of (140 mfL, 36 fL), (3 mfL, 120 fL) and (150 mfL, 120 fL) respectively.

Detailed Performance Data (3 mfL, 120 fL)

Display Resolution

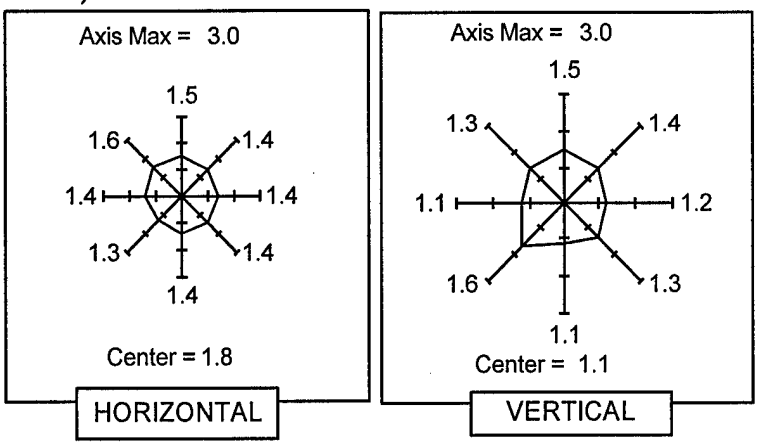
Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	2005 x 2524
Text and Graphics:	Cm = 50%	1230 x 1798

Maximum Luminance in Foot Lamberts

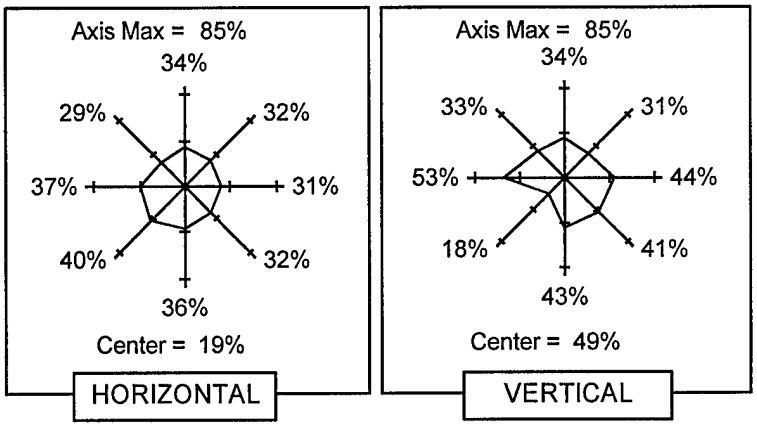


Data Ray DR110 (3 mfL, 120 fL)

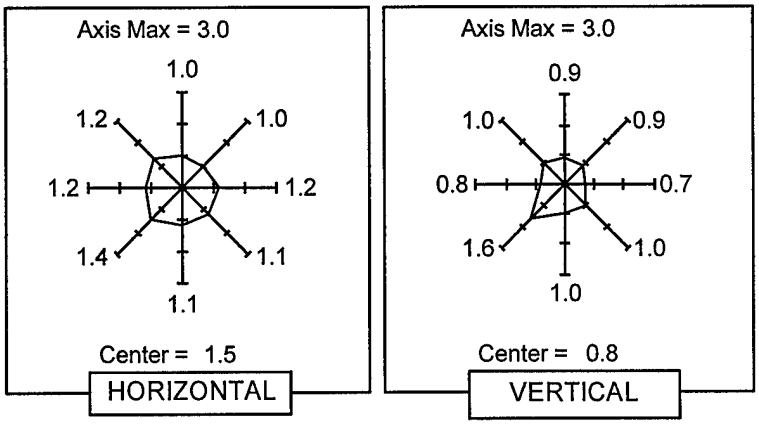
Linewidth in Pixels (RAR)



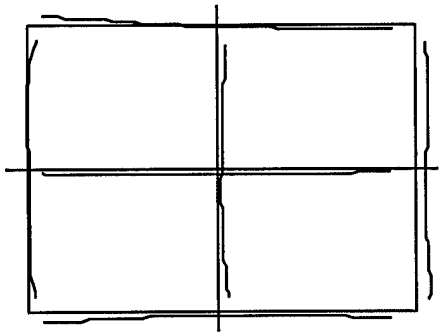
Contrast Modulation



Spot Size in Pixels at 50% Lmax



Waviness



Gray band indicates ±1% distortion.

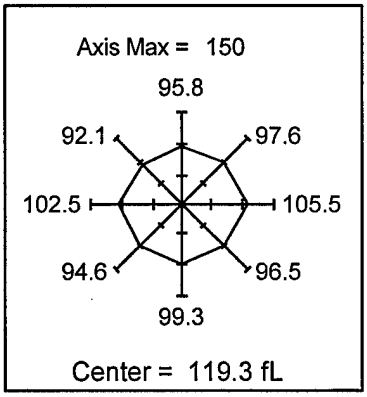
Data Ray DR110

Detailed Performance Data (150 mfL, 120 fL)

Display Resolution

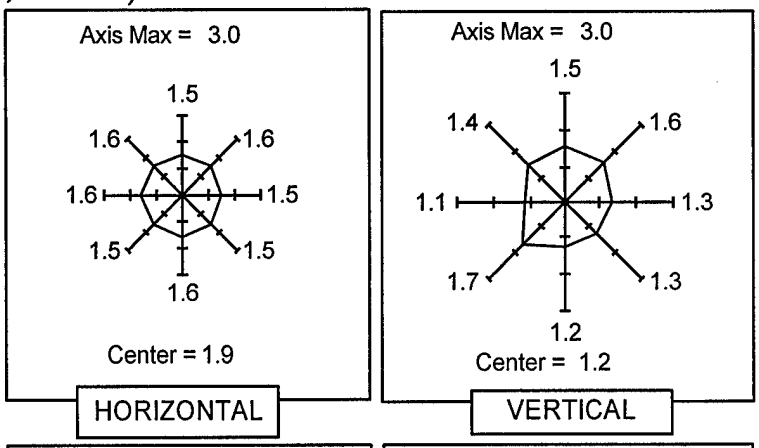
Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1994 x 2528
Text and Graphics:	Cm = 50%	1187 x 1797

Maximum Luminance in Foot Lamberts

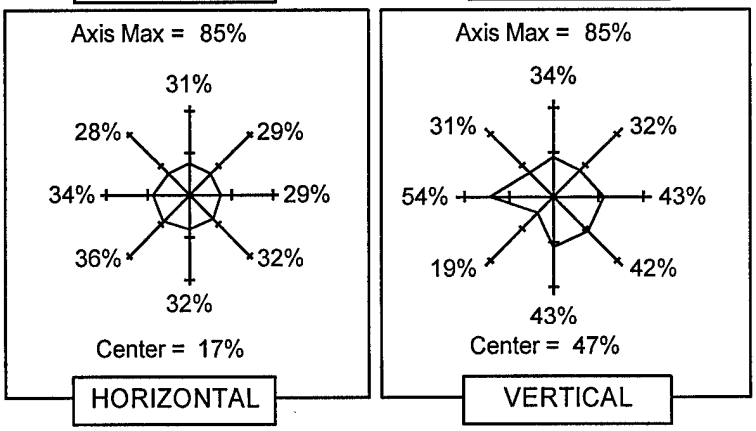


Data Ray DR110 (150 mfL, 120 fL)

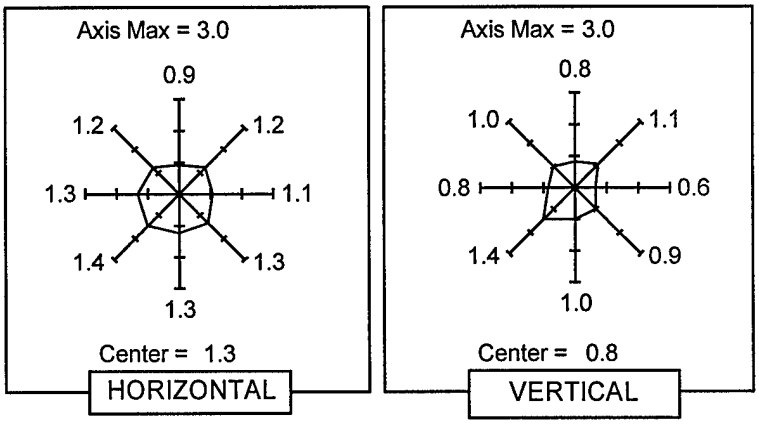
Linewidth in Pixels (RAR)



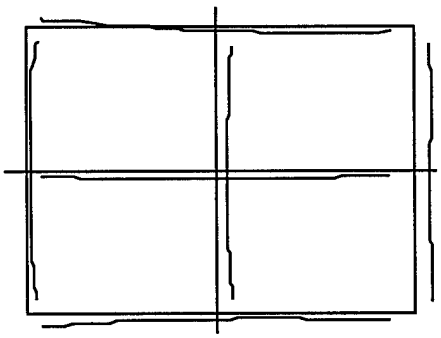
Contrast Modulation



Spot Size in Pixels at 50% Lmax



Waviness



Gray band indicates ±1% distortion.

IMAGE SYSTEMS M21P2KHBMAX TURBO

Manufacturer's Data

Manufacturer Name	Image Systems
Model Number	M21P2KHBMAX Turbo
Price	$6,120
Screen Diagonal	21 inches
Faceplate Transmission	60%
Horizontal Scan Rate	186.07 kHz
Vertical Scan Rate	71.02 Hz
Image Size (H x V)	11.0 x 14.6 inches
Addressable Pixel Number	2048 x 2560
Pixel Size	5.38 x 5.72 mils (0.137 x 0.145 mm)

Summary Comments:

- This monitor was driven by a DOME Md5/PCI video board.
- Based on Cm = 25%, this monitor resolved 48% and 70% of the addressable pixels when operated with min/max luminance settings of (140 mfL, 36 fL) and (30 mfL, 100 fL) respectively.

Detailed Performance Data (30 mfL, 100 fL)

Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1723 x 2128
Text and Graphics:	Cm = 50%	1140 x 1235

Maximum Luminance in Foot Lamberts

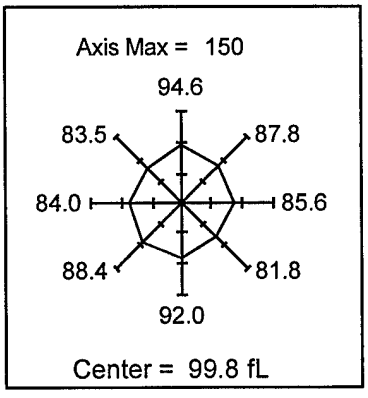
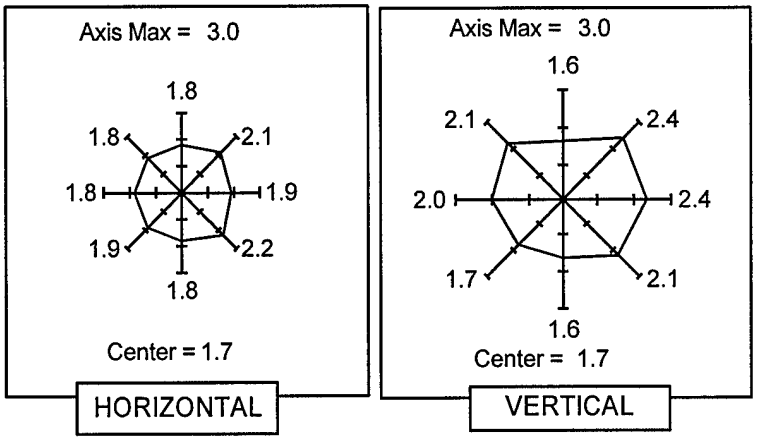
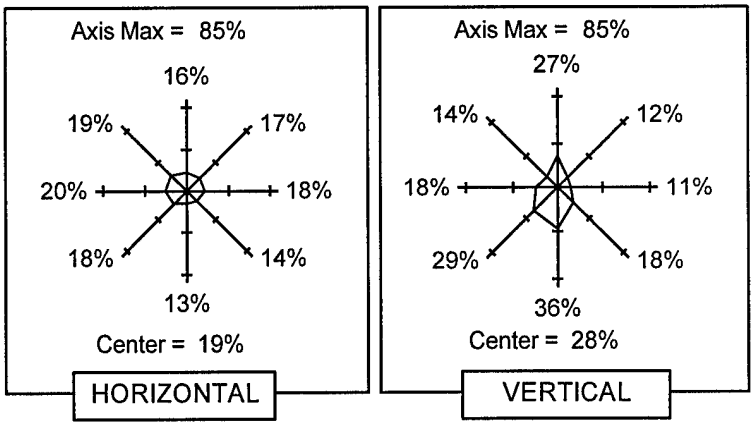


Image Systems M21P2KHBMAX Turbo (30 mfL, 100 fL)

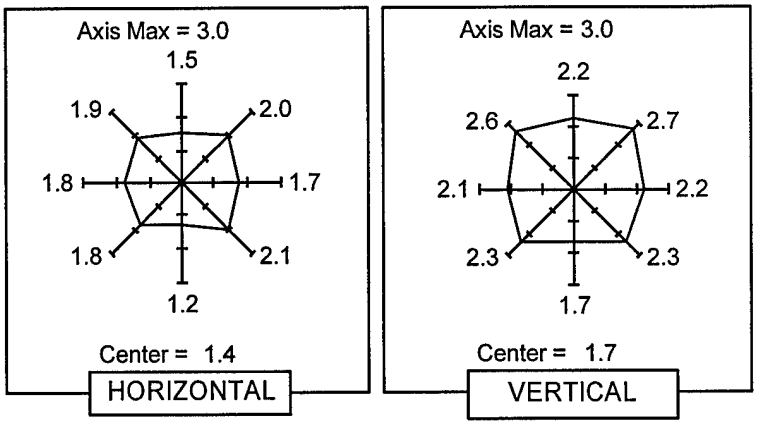
Linewidth in Pixels (RAR)



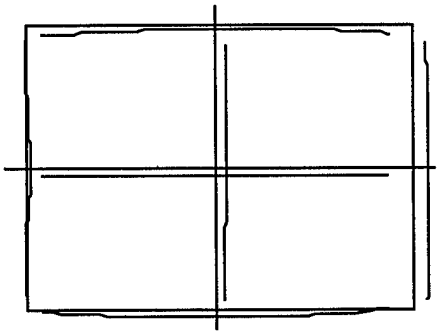
Contrast Modulation



Spot Size in Pixels at 50% Lmax



Waviness



Gray band indicates ±1% distortion.

MEGASCAN MD5-4820PD

Manufacturer's Data

Manufacturer Name	MegaScan
Model Number	MD5-4820PD
Price	$7,690
Screen Diagonal	21 inches
Faceplate Transmission	30%
Horizontal Scan Rate	186.07 kHz
Vertical Scan Rate	71.02 Hz
Image Size (H x V)	10.9 x 13.9 inches
Addressable Pixel Number	2048 x 2560
Pixel Size	5.33 x 5.43 mils (0.135 x 0.138 mm)

Summary Comments:

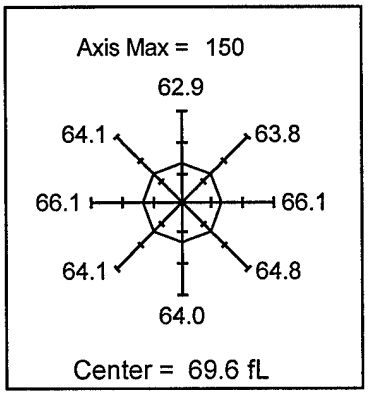
- This monitor was driven by a DOME Md5/PCI video board.
- Based on Cm = 25%, this monitor resolved 77% and 79% of the addressable pixels when operated with min/max luminance settings of (140 mfL, 36 fL) and (3 mfL, 70 fL) respectively.

Detailed Performance Data (3 mfL, 70 fL)

Display Resolution

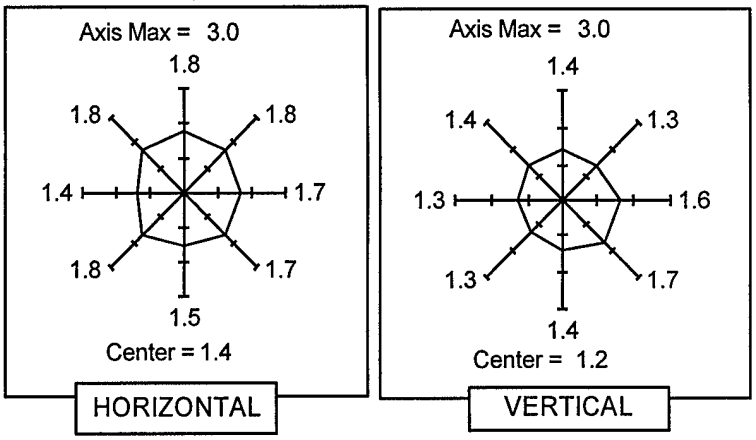
Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1698 x 2441
Text and Graphics:	Cm = 50%	1113 x 1563

Maximum Luminance in Foot Lamberts

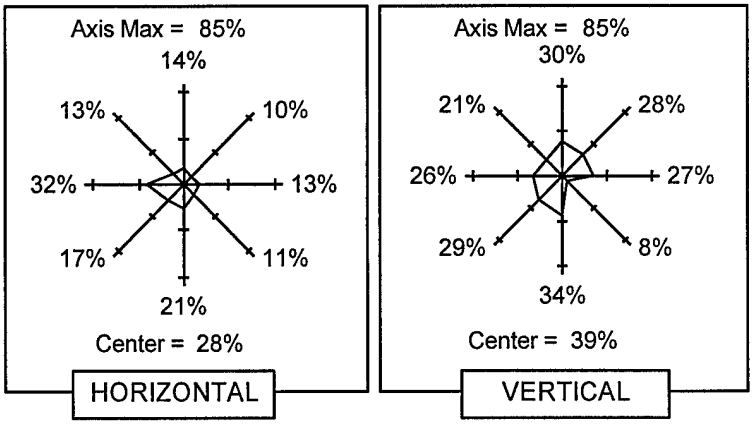


MegaScan MD5-4820PD (3 mfL, 70 fL)

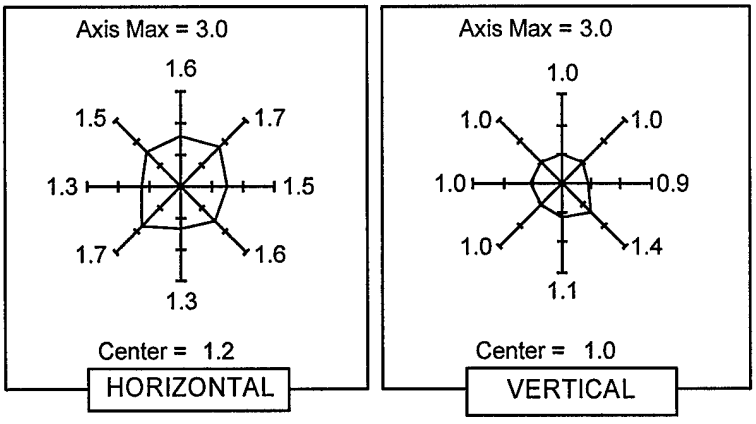
Linewidth in Pixels (RAR)



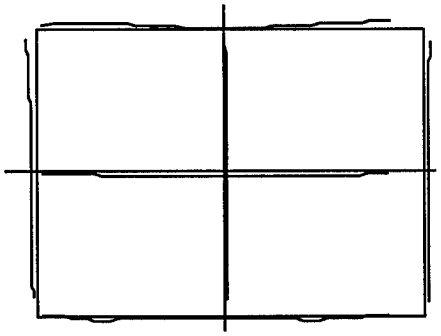
Contrast Modulation



Spot Size in Pixels at 50% Lmax



Waviness



Gray band indicates ±1% distortion.

NORTECH SYSTEMS UHR21P

Manufacturer's Data

Manufacturer Name	Nortech Systems
Model Number	UHR21P
Price	$6,295
Screen Diagonal	21 inches
Faceplate Transmission	43%
Horizontal Scan Rate	186.01 kHz
Vertical Scan Rate	71.00 Hz
Image Size (H x V)	12.0 x 16.0 inches
Addressable Pixel Number	2048 x 2560
Pixel Size	5.86 x 6.25 mils (0.149 x 0.159 mm)

Summary Comments:

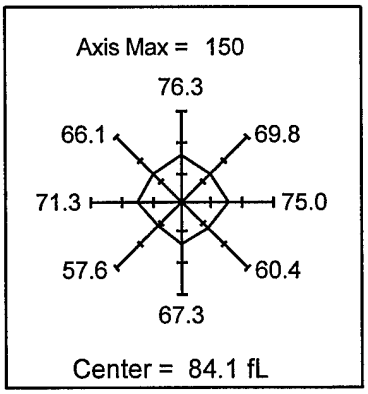
- This monitor was driven by a Metheus P1540 video board.
- Based on Cm = 25%, this monitor resolved 55% of the addressable pixels when operated with min/max luminance settings of (370 mfL, 84 fL).

Detailed Performance Data (370 mfL, 84 fL)

Display Resolution

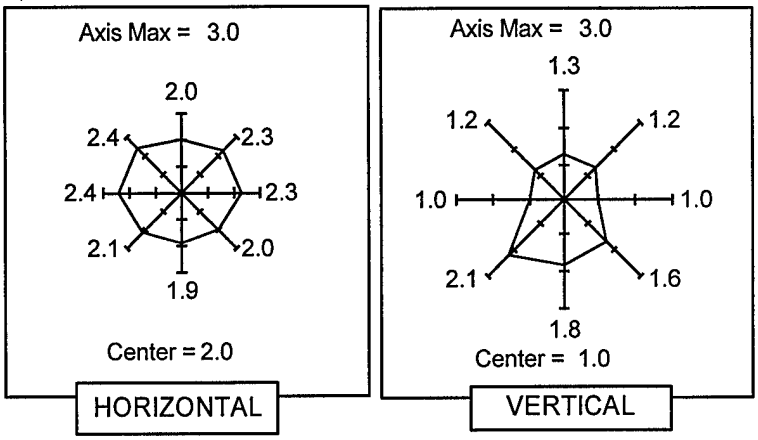
Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1273 x 2265
Text and Graphics:	Cm = 50%	871 x 1437

Maximum Luminance in Foot Lamberts

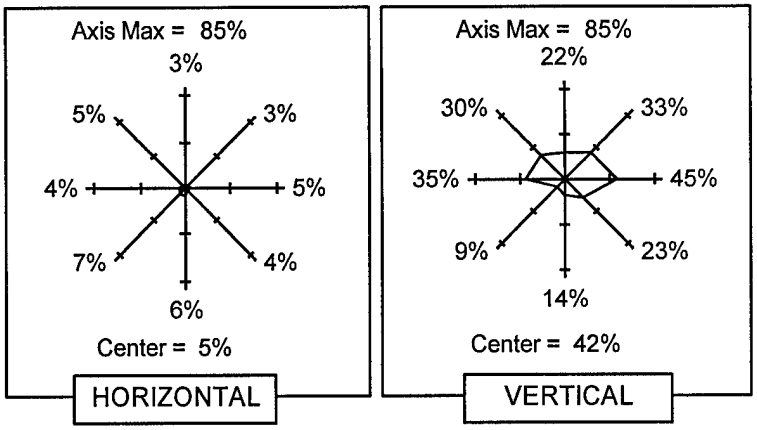


Nortech Systems UHR21P (370 mfL, 84 fL)

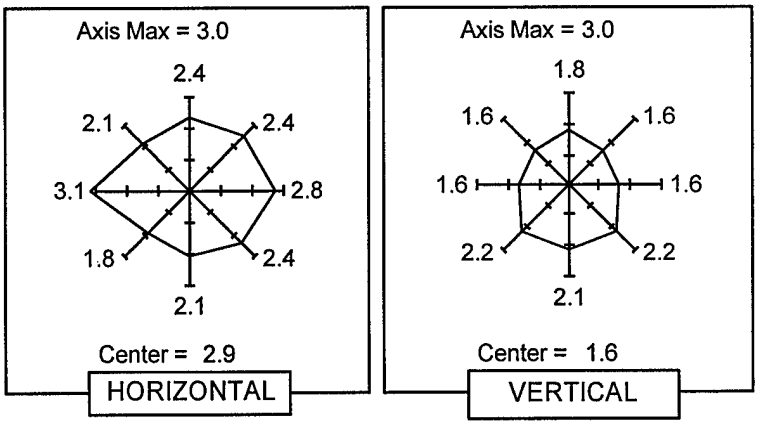
Linewidth in Pixels (RAR)



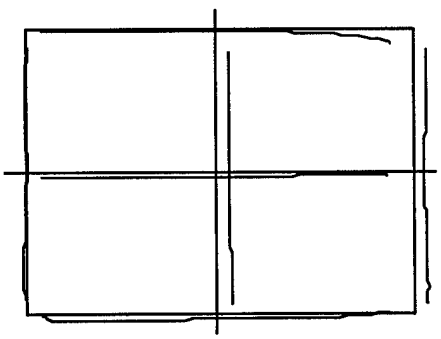
Contrast Modulation



Spot Size in Pixels at 50% Lmax



Waviness



Gray band indicates ±1% distortion.

ORWIN MODEL 2000

Manufacturer's Data

Manufacturer Name	Orwin
Model Number	2000
Price	$7,800
Screen Diagonal	21 inches
Faceplate Transmission	50%
Horizontal Scan Rate	186.07 kHz
Vertical Scan Rate	71.02 Hz
Image Size (H x V)	16.0 x 12.0 inches
Addressable Pixel Number	2048 x 2560
Pixel Size	5.86 x 6.25 mils (0.149 x 0.159 mm)

Summary Comments:

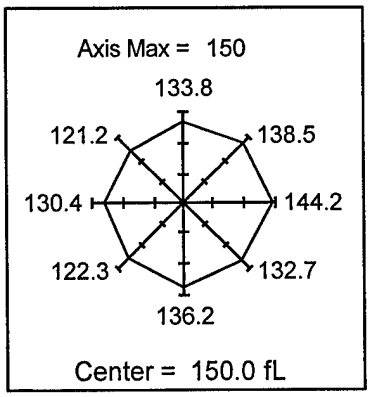
- This monitor was driven by a DOME Md5/PCI video board.
- Based on Cm = 25%, this monitor resolved 100% of the addressable pixels when operated with min/max luminance settings of (3 mfL, 150 fL).

Detailed Performance Data (3 mfL, 150 fL)

Display Resolution

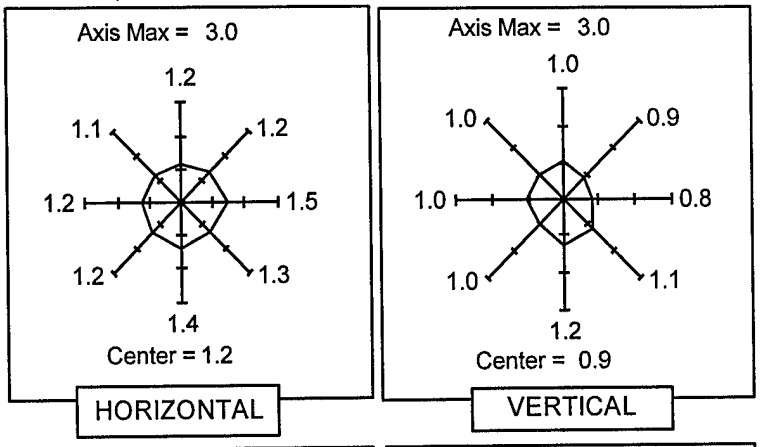
Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	2048 x 2560
Text and Graphics:	Cm = 50%	1652 x 2447

Maximum Luminance in Foot Lamberts

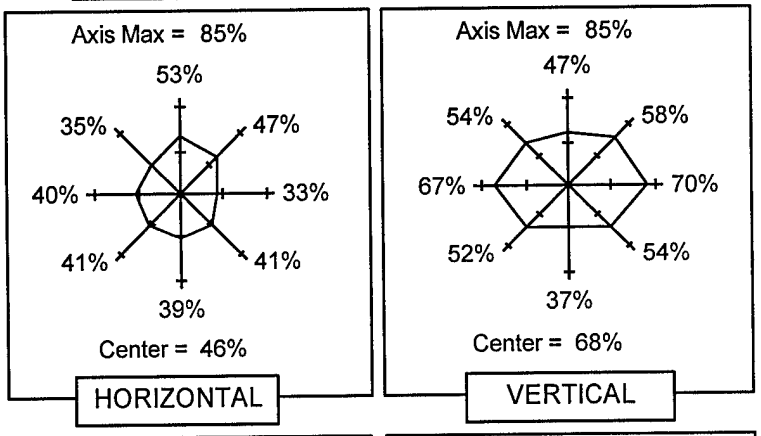


Orwin Model 2000 (3 mfL, 150 fL)

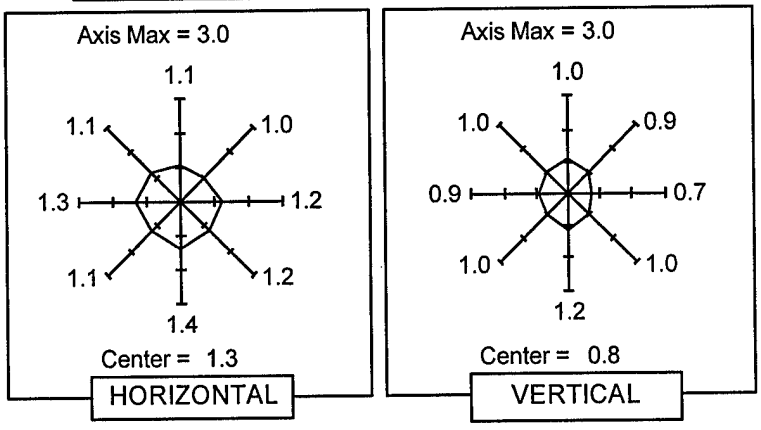
Linewidth in Pixels (RAR)



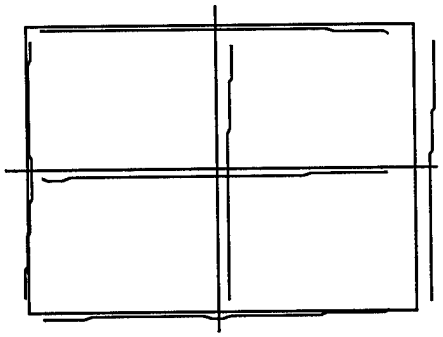
Contrast Modulation



Spot Size in Pixels at 50% Lmax



Waviness



Gray band indicates ±1% distortion.

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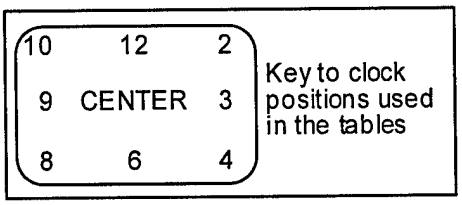
APPENDIX A: CONTRAST MODULATION AND SPOT CONTOUR MEASUREMENTS AT 50% Lmax, WITH Lmax SET ~ 36 fL

MONITOR	MINIMUM/MAXIMUM LUMINANCE SETTING
Data Ray DR110	(140 mfL, 36 fL)
Image Systems M21P2KHBMAX Turbo	(140 mfL, 36 fL)
MegaScan MD5-4820PD	(140 mfL, 36 fL)
Nortech Systems UHR21P	(18 mfL, 36 fL)

It should be noted that all images of spot contours were scaled to the same size to facilitate comparison by overlay. The spot contour images were acquired at the following screen locations as shown in the diagram below. The 2:00 o'clock, 3:00, 4:00, 6:00, 8:00, 9:00, 10:00, and 12:00 o'clock locations are 20 millimeters inside the addressable screen edges *(see NIDL Publication No. 171795-036 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20, Part 1: Monochrome CRT Monitor Performance, Draft Version 2.0, July 12, 1995).* It should also be noted that moire' artifacts appear on some of the spot contour images as a result of interactions between the imaging and reprographic processes. Spot growth across monitor screens and the comparisons of spots between monitors are not significantly impacted by these artifacts.

On Lmin settings Nortech adjustability made it impossible to increase brightness to 140mfL Lmin setting with Lmax = 36fL.

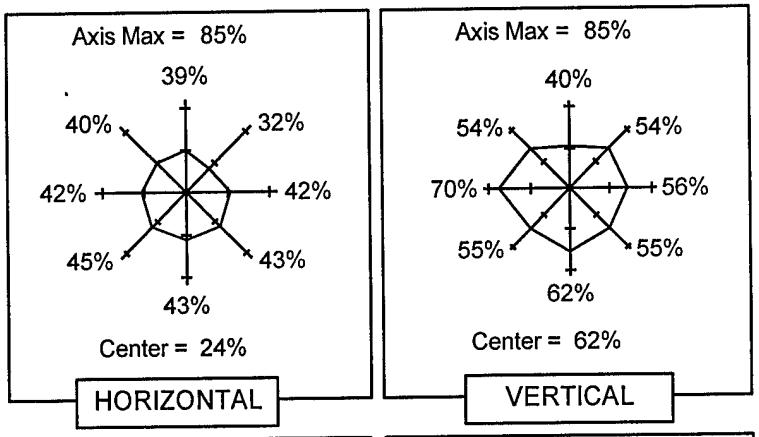


Data Ray DR110 (140 mfL, 36 fL)

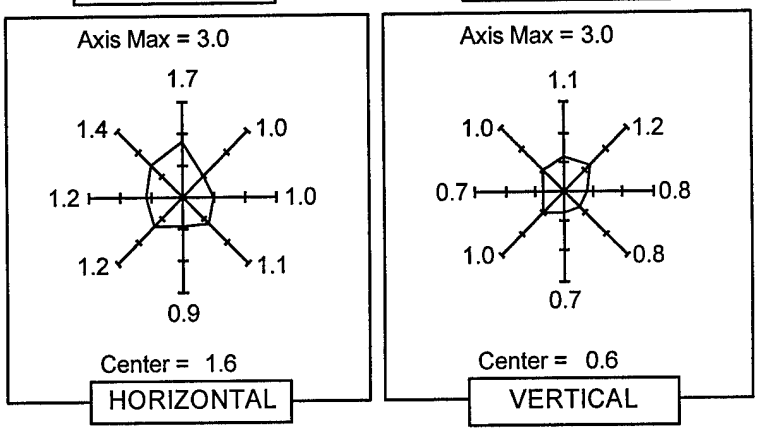
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	2042 x 2560
Text and Graphics:	Cm = 50%	1536 x 2481

Contrast Modulation



Spot Size in Pixels at 50% Lmax



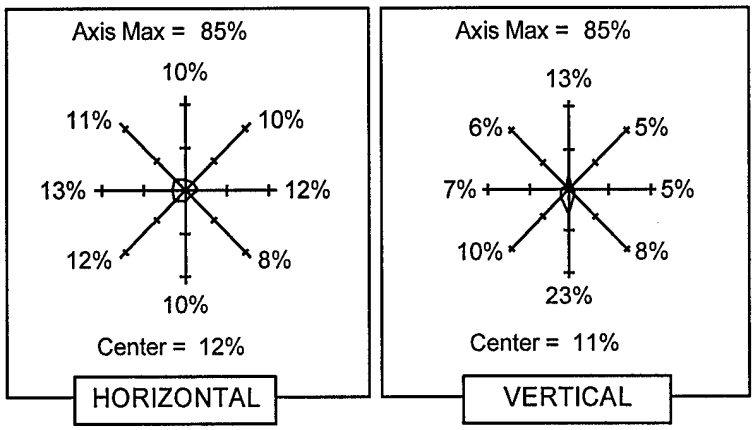
INSERT Data Ray DR110 (140 mfL, 36 fL) SPOT PROFILE PAGE

Image Systems M21P2KHBMAX Turbo (140 mfL, 36 fL)

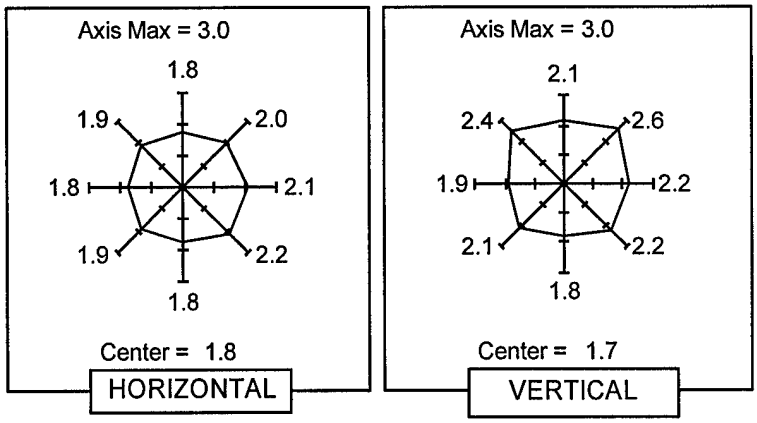
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1509 x 1685
Text and Graphics:	Cm = 50%	1029 x 1079

Contrast Modulation



Spot Size in Pixels at 50% Lmax



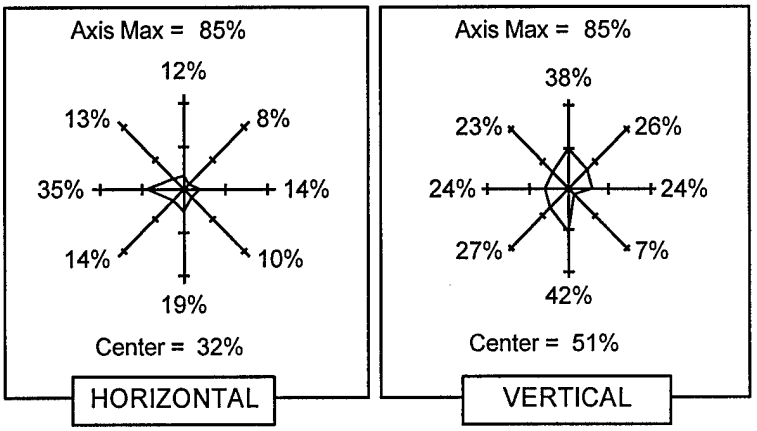
INSERT Image Systems M21P2KHBMAX Turbo (140 mfL, 36 fL) SPOT PROFILE PAGE

MegaScan MD5-4820PD (140 mfL, 36 fL)

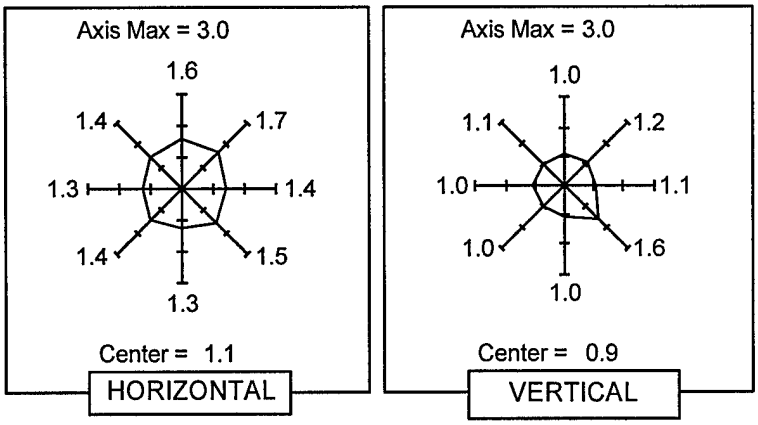
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1657 x 2437
Text and Graphics:	Cm = 50%	1102 x 1673

Contrast Modulation



Spot Size in Pixels at 50% Lmax



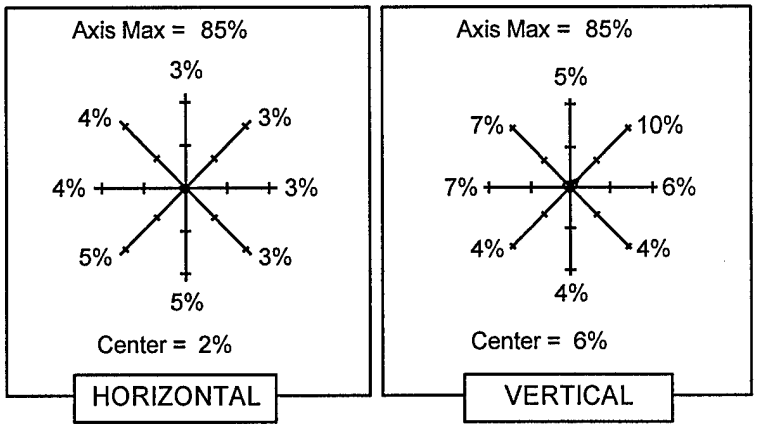
INSERT MegaScan MD5-4820PD (140 mfL, 36 fL) SPOT PROFILE PAGE

Nortech Systems UHR21P (18 mfL, 36 fL)

Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	997 x 1407
Text and Graphics:	Cm = 50%	643 x 900

Contrast Modulation



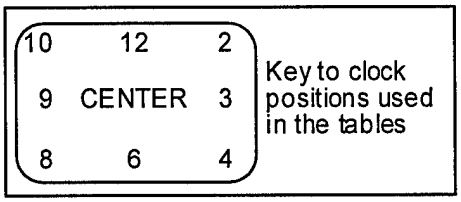
Spot Size Measurements/Spot Profiles Could Not Be Obtained

APPENDIX B: SPOT CONTOUR MEASUREMENTS AT 50% OF MANUFACTURER'S NOMINAL PEAK LUMINANCE SETTING (Lmax)

MONITOR	MINIMUM/MAXIMUM LUMINANCE SETTING
Data Ray DR110	(3 mfL, 120 fL)
Data Ray DR110	(150 mfL, 120 fL)
Image Systems M21P2KHBMAX Turbo	(30 mfL, 100 fL)
MegaScan MD5-4820PD	(3 mfL, 70 fL)
Nortech Systems UHR21P	(370 mfL, 84 fL)
Orwin Model 2000	(3 mfL, 150 fL)

It should be noted that all images of spot contours were scaled to the same size to facilitate overlay comparison. The spot contour images were acquired at the following screen locations as shown in the diagram below. The 2:00 o'clock, 3:00, 4:00, 6:00, 8:00, 9:00, 10:00, and 12:00 o'clock locations are 20 millimeters inside the addressable screen edges *(see NIDL Publication No. 171795-036 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20, Part 1: Monochrome CRT Monitor Performance, Draft Version 2.0, July 12, 1995).* It should also be noted that moire' artifacts appear on some of the spot contour images as a result of interactions between the imaging and reprographic processes. Spot growth across monitor screens and the comparisons of spots between monitors are not significantly impacted by these artifacts.

On Lmin settings Nortech and Image Systems adjustability made it impossible to decrease brightness to 3mfL, 140mfL Lmin setting with Lmax set to the manufacturers' recommended levels.



Data Ray DR110

Linewidth, Contrast Modulation, 50% spot size and other data for this monitor are on pages 14 and 15.

INSERT Data Ray DR110 (3 mfL, 120 fL) SPOT PROFILE PAGE

INSERT Data Ray DR110 (150 mfL, 120 fL) SPOT PROFILE PAGE

Image Systems M21P2KHBMAX Turbo

Linewidth, Contrast Modulation, 50% spot size and other data for this monitor are on pages 16 and 17.

INSERT Image Systems M21P2KHBMAX Turbo (30 mfL, 100 fL) SPOT PROFILE PAGE

MegaScan MD5-4820PD

Linewidth, Contrast Modulation, 50% spot size and other data for this monitor are on pages 18, 19, 20 and 21.

INSERT MegaScan MD5-4820PD (3 mfL, 70 fL) SPOT PROFILE PAGE

Nortech Systems UHR21P

Linewidth, Contrast Modulation, 50% spot size and other data for this monitor are on pages 18, 19, 20 and 21.

INSERT Nortech Systems UHR21P (370 mfL, 84 fL) SPOT PROFILE PAGE

Orwin Model 2000

Linewidth, Contrast Modulation, 50% spot size and other data for this monitor are on pages 12 and 13.

INSERT Orwin Model 2000 (3 mfL, 150 fL) SPOT PROFILE PAGE

INTERNET DOCUMENT INFORMATION FORM

A . Report Title: Display Evaluation Report - A Survey of Five 5-MegaPixel Monochrone CRT Monitors for Medical and Government Imaging Applications

B. DATE Report Downloaded From the Internet: 21 Sep 98

C. Report's Point of Contact: (Name, Organization, Address, Office Symbol, & Ph #:) **Sarnoff Corporation**
National Information Display Laboratory
Princeton, NJ

D. Currently Applicable Classification Level: Unclassified

E. Distribution Statement A: Approved for Public Release

F. The foregoing information was compiled and provided by:
DTIC-OCA, Initials: __JR__ **Preparation Date:** 21 Sep 98

The foregoing information should exactly correspond to the Title, Report Number, and the Date on the accompanying report document. If there are mismatches, or other questions, contact the above OCA Representative for resolution.