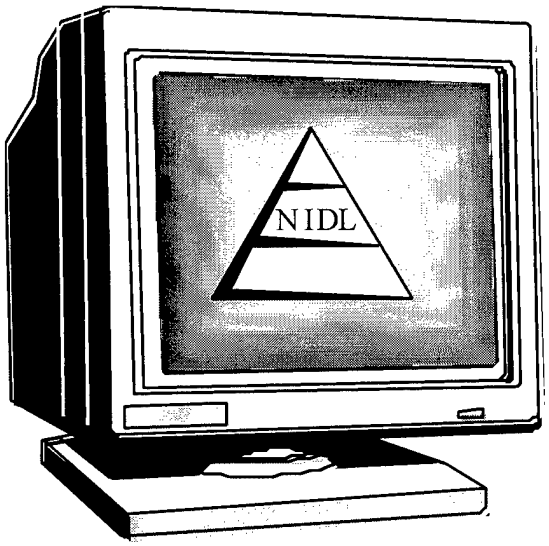
DISPLAY EVALUATION REPORT



Monitors Included:

Computer Display Solutions CDS-2111
Conrac MARS 9321
Art Media TN-2185T
Cornerstone Color 21/88fp
Daytek DT-2102M
Hyundai DeluxScan 21
IBM P201
Image Systems C21LMAX ('96 Model)
MaxTech XT-2000
Princeton Graphic Systems Ultra 20
Radius MultiView 21
Radius PrecisionView 21

A Survey of Twelve Color CRT Monitors	
• Size range:	20 to 21 inch
• Addressability:	1600 x 1280
or	1600 x 1200

National Information Display Laboratory

at the

David Sarnoff Research Center

CN 5300, Princeton, NJ 08543-5300

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ABSTRACT

Survey of performance of twelve color 1600 x 1200 pixel CRT monitors

This report presents a survey of the performance of twelve color CRT monitors. All have addressability of either 1600 x 1280 or 1600 x 1200 pixels, and CRT sizes from 20 to 21 inches in diagonal (actual image sizes are smaller). The report provides:

- Comparisons of the performance of the twelve monitors
- A two page summary of the performance of each of the twelve monitors

The results are given in a standardized graphical format.
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)
- Convergence
- Waviness (distortion)
- Moiré (only in the Comments sections of the individual monitor reports)

NIDL evaluated and compared the following monitors: Computer Display Solutions CDS-2111, Conrac MARS 9321, Art Media TN-2185T, Cornerstone Color 21/88fp, Daytek DT-2102M, Hyundai DeluxScan 21, IBM P201, Image Systems C21LMAX ('96 Model), MaxTech XT-2000, Princeton Graphic Systems Ultra 20, Radius MultiView 21, Radius PrecisionView 21.

The luminance values were measured with the monitor set to the maximum drive specified by the manufacturer. The drive is maintained for the full screen. The measured luminance of the twelve monitors ranged between about 22 and 35 fL. The background rasters were set to 0.003 fL.

If the display were perfect, the screen would show a series of full white bars with perfectly black bars between them, yielding a contrast modulation of 100%. In reality, several factors combine to spread the light out so that the pattern is one of light and dark gray bars, not black and white. We define resolution here as the number of alternate black and white lines that can be displayed with a stated minimum contrast modulation, Cm, reducing visibility. Displaying more pixels than that will lower the contrast below the minimum. Text resolution (and graphics) require crisp edge definition and clear whites and blacks. A Cm of 50% produces alternating lines that are highly visible. Image resolution typically does not require sharp changes in luminance. A pattern of alternating black and white lines with 25% contrast is still visible. Using the 25% Cm imaging criterion, a few of the monitors achieve approximately the full 1600 x 1280 or 1200 resolution one might expect from the addressability. None of them reaches that resolution if the 50% Cm criterion is used.

Monitor	Luminance (Range in fL)	Display Content	Resolution Limit (Horiz x Vert pixels)
Computer DisplaySolutions CDS-2111	34.5 to 26.9	Grayscale Imagery: Cm = 25% Text and Graphics: Cm = 50%	1520 x 1157 1000 x 881
Conrac MARS 9321	25.3 to 22.4	Grayscale Imagery: Cm = 25% Text and Graphics: Cm = 50%	1425 x 1200 1036 x 916
Art Media TN-2185T	30.0 to 24.2	Grayscale Imagery: Cm = 25% Text and Graphics: Cm = 50%	1378 x 1183 982 x 887
Cornerstone Color 21/88fp	33.5 to 27.5	Grayscale Imagery: Cm = 25% Text and Graphics: Cm = 50%	1456 x 1118 994 x 736

Daytek DT-2102M	26.9 to 21.0	Grayscale Imagery: Cm = 25% Text and Graphics: Cm = 50%	1600 x 1219 1360 x 831
Hyundai DeluxScan 21	34.0 to 25.6	Grayscale Imagery: Cm = 25% Text and Graphics: Cm = 50%	1574 x 1016 1125 x 705
IBM P201	35.9 to 31.9	Grayscale Imagery: Cm = 25% Text and Graphics: Cm = 50%	1260 x 1185 912 x 930
Image Systems C21LMAX ('96 Model)	29.5 to 20.2	Grayscale Imagery: Cm = 25% Text and Graphics: Cm = 50%	1528 x 1086 1027 x 696
MaxTech XT-2000	34.8 to 25.4	Grayscale Imagery: Cm = 25% Text and Graphics: Cm = 50%	1137 x 891 812 x 608
Princeton Graphic Systems Ultra 20	22.4 to 16.9	Grayscale Imagery: Cm = 25% Text and Graphics: Cm = 50%	1521 x 1119 1183 x 761
Radius MultiView 21	29.0 to 20.3	Grayscale Imagery: Cm = 25% Text and Graphics: Cm = 50%	1508 x 1200 970 x 918
Radius PrecisionView 21	32.5 to 24.4	Grayscale Imagery: Cm = 25% Text and Graphics: Cm = 50%	1466 x 1200 995 x 1140

DISPLAY EVALUATION REPORT

National Information Display Laboratory

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FOREWORD

On behalf of the government user community, the National Information Display Laboratory (NIDL) has prepared this report which surveys the performance of twelve color CRT monitors. All have addressability of either 1600 x 1280 or 1600 x 1200 pixels, and image sizes from 20 to 21 inches. The report presents summaries of the most important monitor parameters, plus comparisons of the twelve monitors based on those parameters.

The NIDL has also prepared a series of 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 can be obtained from the NIDL at the address listed below.

Two companion documents that describe how the measurements are made are also available from the NIDL:

- *NIDL Publication No. 313794-024*
  Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20,
  Part 1: Monochrome CRT Monitor Performance, Draft Version 1.0.
- *NIDL Publication No. 313794-025*
  Display Monitor Measurement Methods
  under Discussion by EIA (Electronic Industries Association) Committee JT-20,
  Part 2: Color CRT Monitor Performance, Draft Version 1.0.

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.

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

The NIDL can be reached at:

National Information Display Laboratory
P. O. Box 8619
Princeton, NJ 08543-8619
Tel: (609) 951-0150
Fax: (609) 734-2313
e-mail: nidl@nidl.org

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Introduction: Purpose of This Report

This report presents a survey of the performance of twelve color CRT monitors. All have addressability of either 1600 x 1280 or 1600 x 1200 pixels, and image sizes from 20 to 21 inches. The report provides:

- Comparisons of the performance of the twelve monitors
- A two page summary of the performance of each of the twelve monitors

The results are given in a standardized graphical format.

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)
- Convergence
- Waviness (distortion)

In color monitors, the desired image can beat with the phosphor dots or stripes leading to a disturbing pattern of wavy bars called Moiré. Moiré is difficult to quantify; it is very apparent to the eye in some images, but not in others. In this report we refer to Moiré only in the Comments sections of the individual monitor reports in the following section.

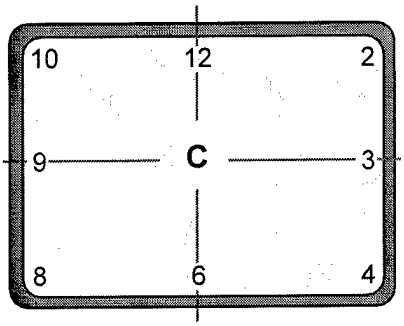
The NIDL has published a detailed description of the procedures used to make the measurements we report here, as well as many others needed for a complete characterization of a CRT monitor. [See references in Foreword, p. iii.]

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.

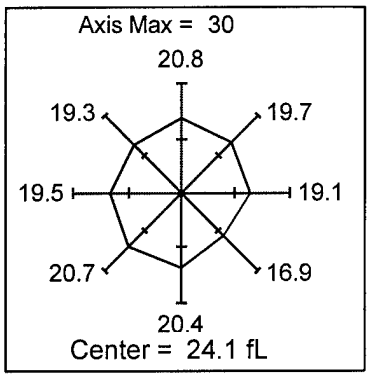


Figure 1. An example of a radar type of chart showing luminance at center and eight other positions on the screen. In this plot, luminance at screen center is 24.1 fL, at screen top it is 20.8 fL, etc. The full-scale length of each radial line is given as 30 fL.

(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.

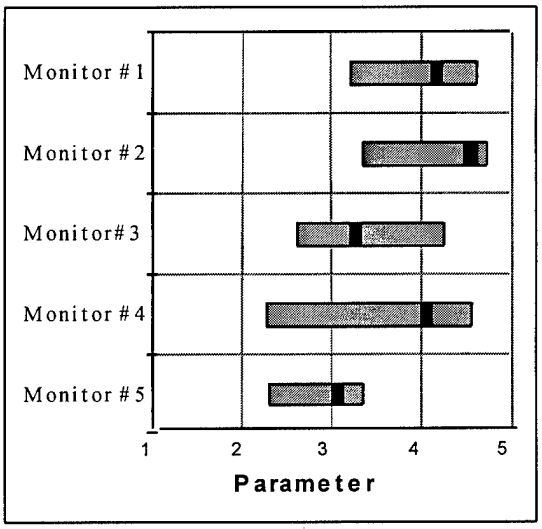


Figure 2. An example of a bar chart showing the range from the minimum to the maximum values measured, with the value at screen center indicated by the dark bar. This chart shows that the minimum and maximum values for Monitor #1 were 3.2 and 4.6 and the center screen value was 4.2.

(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.

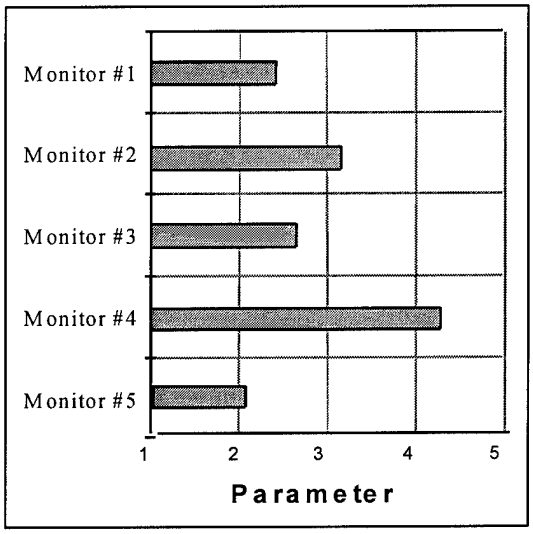


Figure 3. An example of a bar chart showing a value of 3.2 for Monitor #2.

(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.

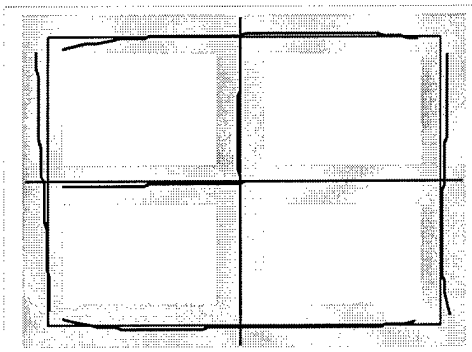


Figure 4. An example of the chart used to show waviness, or geometric distortion. The gray band indicates ±1.0% distortion.

Comparative Data on Twelve Monitors

LUMINANCE

Luminance is the technical name for the brightness of a monitor. It is measured in foot-Lamberts (fL). 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 of 25 to 30 fL. The lower luminance is related to the higher resolution of these monitors.

Higher brightness is usually accompanied by a decrease in resolution and, sometimes, in contrast as well. When comparing monitor performance one needs to consider that all these parameters can be traded off. 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.

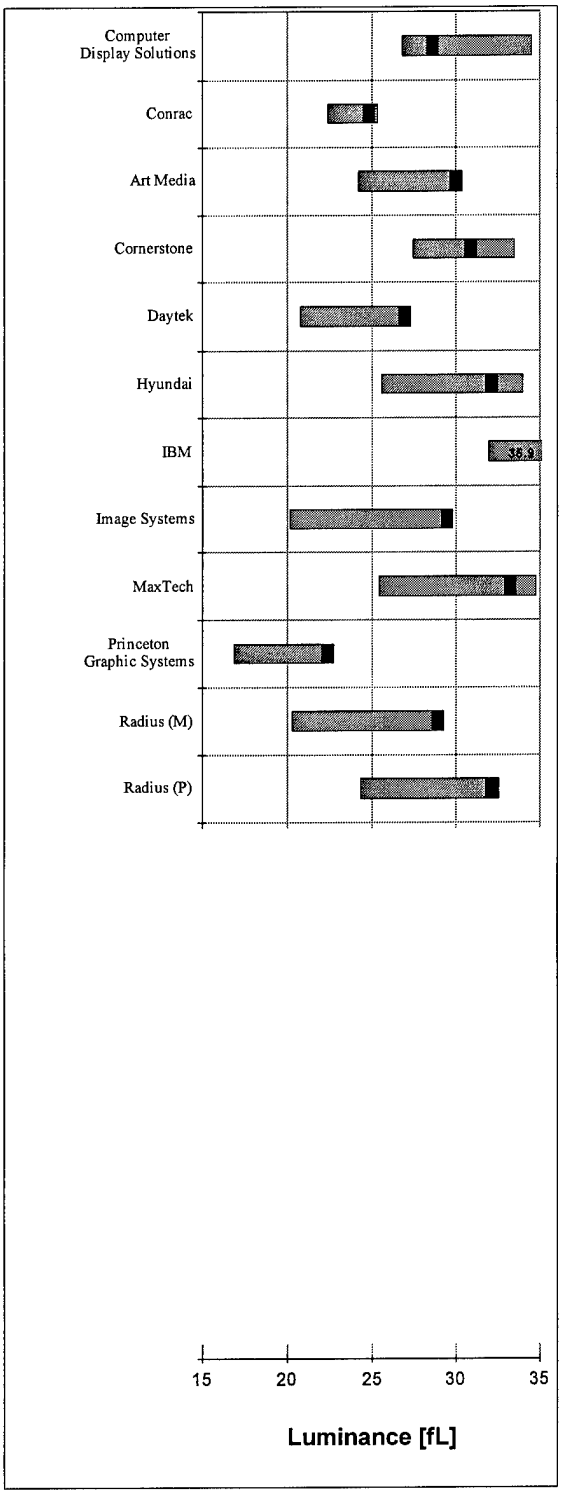


Figure 5. Measured luminance of the twelve monitors. Center screen luminance, indicated by the black bar, is usually also the maximum luminance.

RESOLUTION

Discussion of Resolution and Addressability

Resolution is often the first specification one asks about a monitor, but it is just one of the important parameters.

It is essential to distinguish between the concepts of *addressability* and *resolution*:

- *Addressability* states the number of locations at which a dot can be displayed on the screen. The displays in this report all have an addressability of 1600 positions horizontally and either 1200 or 1280 positions vertically. These are the numbers that monitor manufacturers often give in describing the display resolution. However, that does not guarantee that the spot of light is small enough to actually distinguish adjacent addressable spots.
- *Resolution* measures 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 width, causing the spot to grow. The video electronics also have finite risetime, stretching the spot along the scanning (horizontal) direction. As the spots grow and begin to overlap, the ability to discern them as individual spots decreases.

The resolution of a color CRT display is further limited by the pattern of red, green and blue dots or stripes on the screen. The spacing of the three color dots or stripes determines the minimum size that a white pixel can have. That sets the limit for the number of white pixels that can be displayed. For example a 20-inch diagonal tube with a viewable width of 14 inches (355 mm) and a phosphor stripe spacing of 0.3 mm (0.3 mm from one group of RGB stripes to the next) is limited to no more than 1183 white pixels horizontally.

The Concept of Contrast Modulation

Contrast modulation, Cm, is the best and most complete description of the ability of a monitor to display information. It directly measures the ability of the CRT to reproduce desired luminance patterns. The process is shown schematically below.

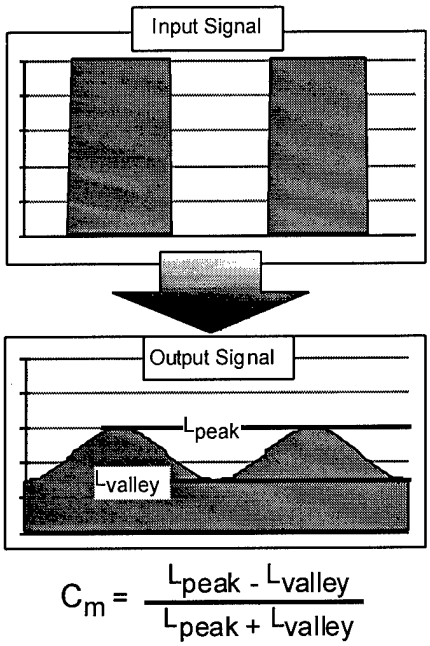


Figure 6. Contrast modulation, Cm. A fully modulated signal is input to the monitor. The contrast in the resulting screen pattern is measured.

Cm is reported here at just one frequency, although a complete characterization of a display requires Cm as a function of frequency. The frequency used in these measurements is called the 1-on/1-off frequency, and is the highest frequency that a display should produce. Adjacent pixels are turned full on and full off, in both the horizontal or vertical directions. The pattern produced is either vertical or horizontal stripes on the screen, each black or white stripe being one pixel wide. The extent to which the actual displayed light pattern changes from full white to full black is the Contrast Modulation, Cm, as indicated in Fig. 6.

Contrast Modulation Results

For this report, Cm 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.

If the display were perfect, the screen would show a series of full white bars with perfectly black bars between them, yielding a Cm of 100%. In reality, several factors combine to spread the light out so that the pattern is one of light and dark gray bars, not black and white. Among these are:

- The ability of the display to form a narrow line.
- The accuracy with which the three color beams come together, called convergence (discussed below).
- Halation - the leakage of light from bright areas of the image into the dark areas because of reflections off the glass and the phosphor surface.

The comparison of Cm for the twelve monitors is shown in Fig. 7. A perfect display would have Cm = 100%, but that is not expected in any real display. The significance of Cm in the range of 25 to 50% is discussed in the following section.

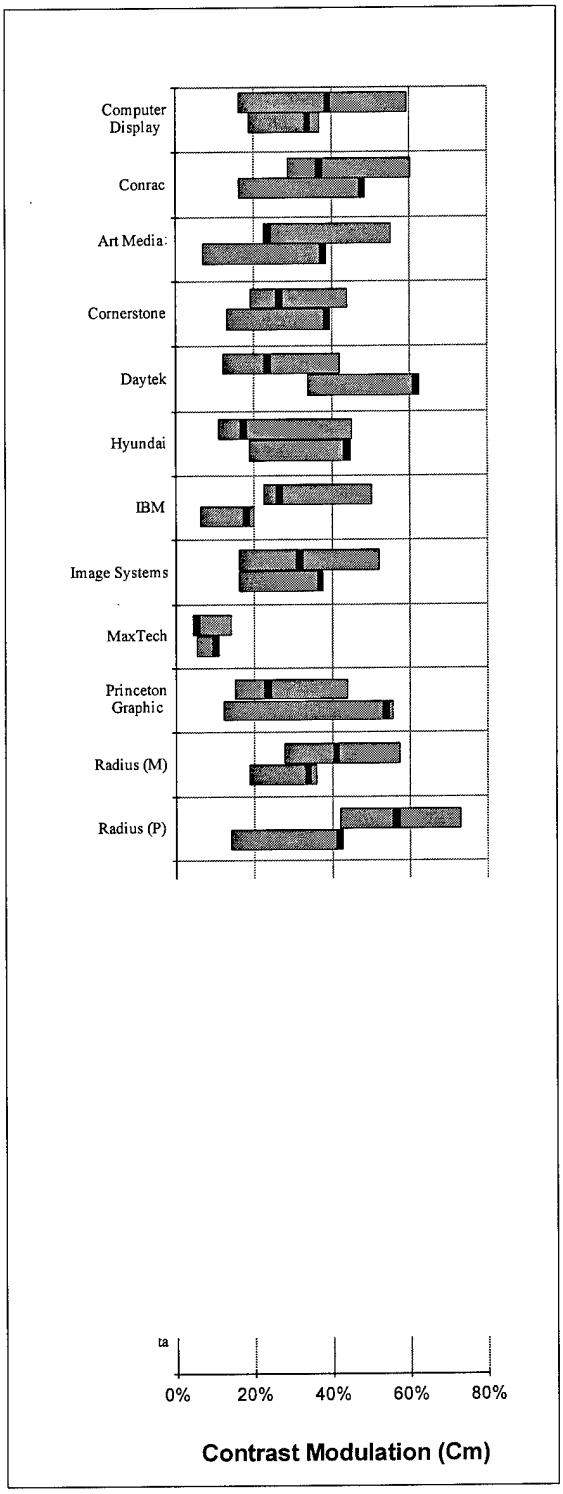


Figure 7. Measured contrast modulation Cm of the twelve monitors for the 1-on/1-off test pattern. The upper bar shows vertical modulation (horizontal stripes); the lower bar shows horizontal modulation (vertical stripes).

Realizable resolution: a simple number

Describing resolution with a simple number, such as 1600 x 1200 pixels, is an approximation to a complicated subject. To be meaningful, that number must be defined precisely. We define resolution here as the number of alternate black and white lines that can be displayed with a stated minimum contrast modulation, reducing visibility. Displaying more pixels than that will lower the contrast below the minimum.

We use two criteria to allow us to assign meaningful numbers to realizable resolution for two common applications. We state the total number of black lines plus white lines, and give the values for horizontal and vertical resolution separately.

- *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.

The comparison of realizable resolution for the twelve monitors is shown in Fig. 8.

Using the 25% Cm imaging criterion, a few of the monitors achieve approximately the full 1600 x 1280 or 1200 resolution one might expect from the addressability. None of them reaches that resolution if the 50% Cm criterion is used.

For more information see the publications on Page *iii*.

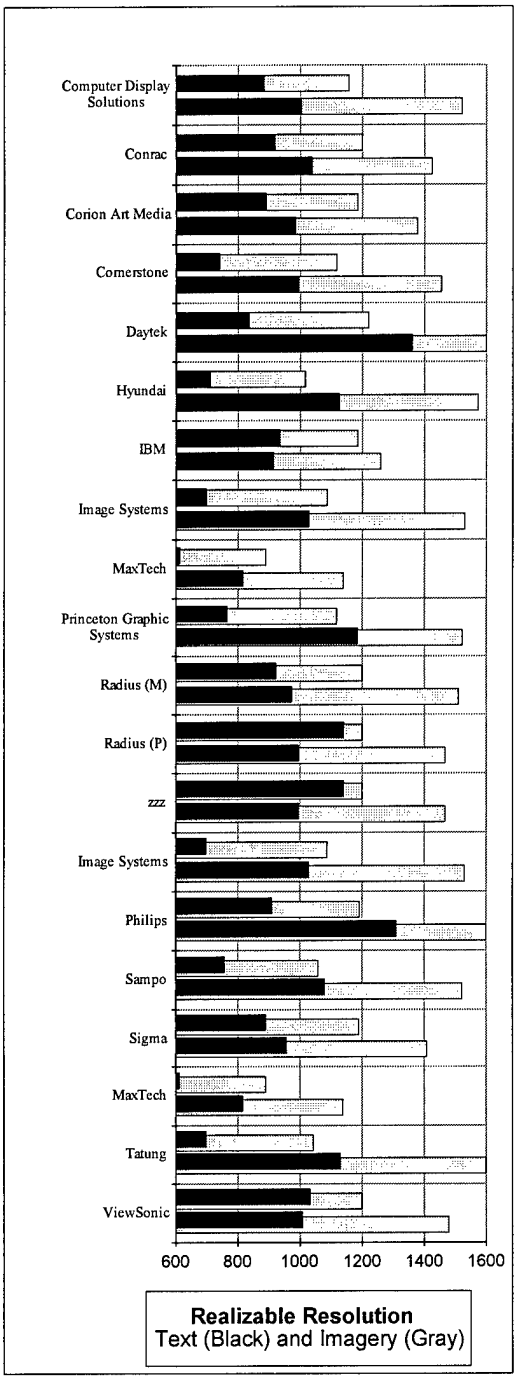


Figure 8. Realizable resolution. The upper bar shows vertical modulation (horizontal stripes), the lower bar shows horizontal modulation (vertical stripes).

Resolution-Addressability Ratio (RAR)

Another well known measure of monitor performance is called the *Resolution-Addressability Ratio* or *RAR*. It is the ratio of the size of the actual spot (or line) produced to the size of the pixel. The size of the pixel is determined by the scanned image size divided by the addressable number of pixels. RAR can also be thought of as the width of the line measured in addressable pixels. An RAR of 1.0 would mean 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 the RAR is greater than one, then the spot is too large to display each pixel separately. However, in a typical display, RAR is set to be between 1.2 and 1.3. The slightly larger spot causes adjacent spots to overlap a little, and reduces the Cm to about 50%, but reduces Moiré and the visibility of scan lines. As the RAR increases beyond 1.5, the Cm decreases markedly. Thus an RAR of 1.5 or more shows that the monitor cannot produce an image as sharp as the addressability implies.

The comparison of RAR for the twelve monitors is shown in Fig. 9. Note that the RARs for many of the monitors are between the desirable limits of 1.2 and 1.5 at screen center. Remember that 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.

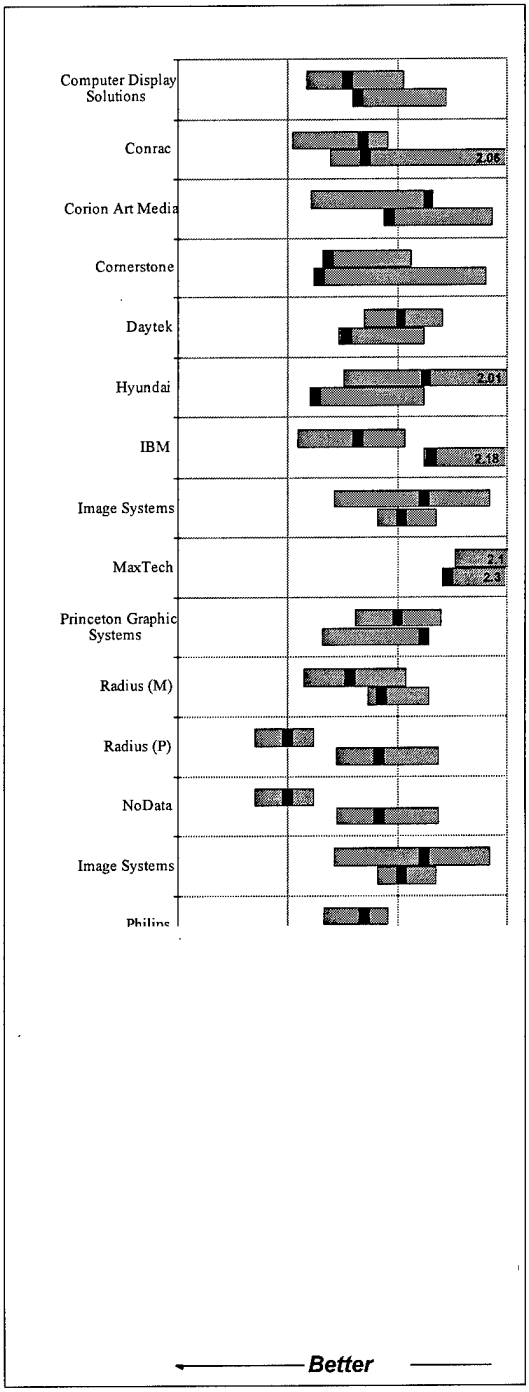


Figure 9. Resolution-Addressability Ratio or RAR. RAR of 1.2 is considered optimum. For RAR larger than 1.5, the spot is too large to display all the addressable pixels. The upper bars show vertical resolution, the lower bars horizontal.

MISCONVERGENCE

Color CRTs make a given hue by combining precise amounts of red, green, and blue light, generated by appropriate phosphors excited by three separate electron beams. For the color rendition to be correct and to minimize the effective size of the resultant white spot, the three beams must overlap completely at each addressable position on the screen. Because of the limitations in the beam deflection system, perfect registration, called *convergence* in CRTs, is not possible. The misconvergence parameter as used here describes the larger of the difference in the landing position between the red and green beams or the blue and green beams. Clearly a misconvergence of more than a pixel will result in noticeable degradation of the display.

The comparison of misconvergence for the twelve monitors is shown in Fig. 10.

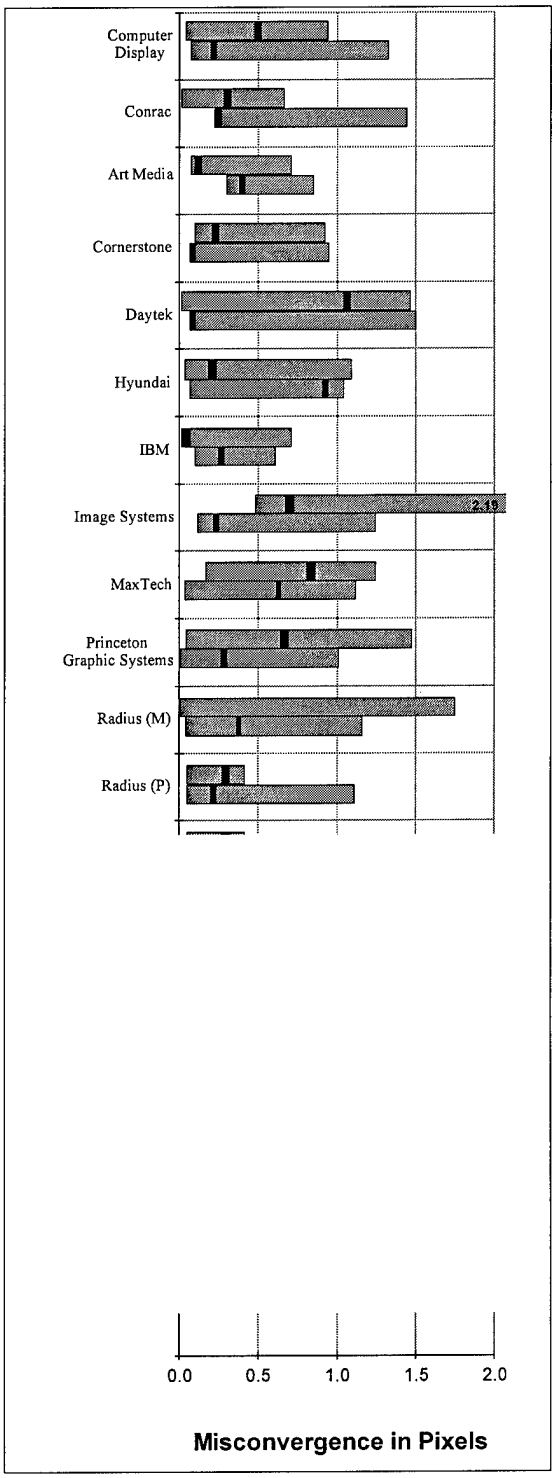


Figure 10. Comparison of misconvergence for the twelve monitors. For each monitor, the upper bar shows vertical misconvergence and the lower bar horizontal.

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.

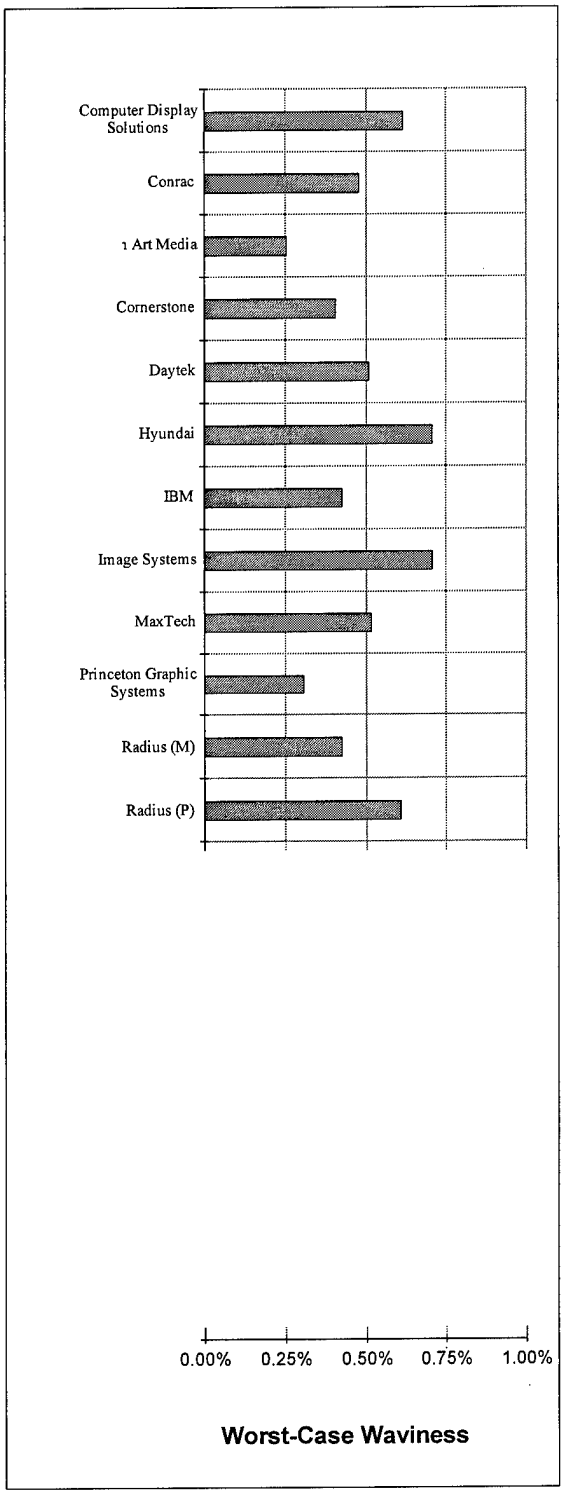


Figure 11. The length of the bar indicates worst-case waviness, or geometric distortion. Data for individual monitors in the next section show the actual form of the waviness.

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Individual Data on Each of Twelve Monitors

Computer Display Solutions CDS-2111
Conrac MARS 9321
Art Media TN-2185T
Cornerstone Color 21/88fp
Daytek DT-2102M
Hyundai DeluxScan 21
IBM P201
Image Systems C21LMAX ('96 Model)
MaxTech XT-2000
Princeton Graphic Systems Ultra 20
Radius MultiView 21
Radius PrecisionView 21

ViewSonic 21PS

COMPUTER DISPLAY SOLUTIONS CDS-2111

Manufacturer's Data

Manufacturer Name	Computer Display Solutions
Model Number	CDS-2111
Price	$2,279
Screen Diagonal	21 inches
Horizontal Scan Rate	93.75 kHz
Vertical Scan Rate	75.00 Hz
Image Size (H x V)	15.6 x 11.6 inches
Addressable Pixel Number	1600 x 1200
Pixel Size	9.72 x 9.67 mils (0.247 x 0.246 mm)
Dot Pitch	0.22 mm horizontal/0.16 mm vertical

Summary Comments:

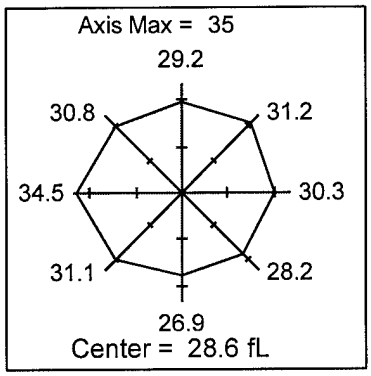
- Moiré correction circuitry available on this monitor was not evaluated and was instead set to the OFF position during testing.
- Based on a Cm = 25%, this monitor resolved 92% of the addressable pixels.

Detailed Performance Data

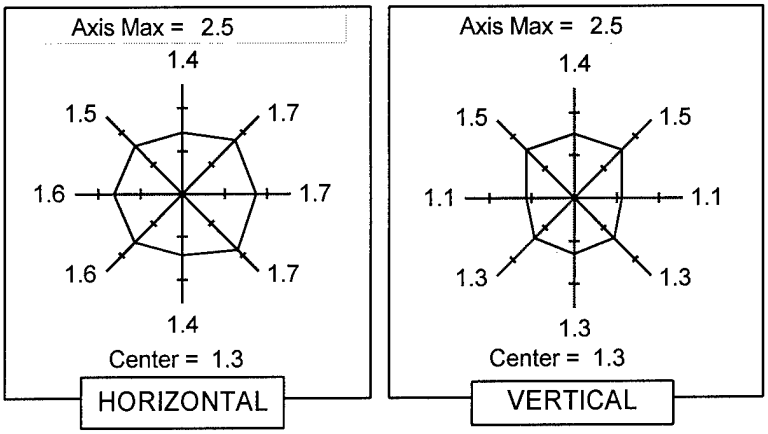
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1520 x 1157
Text and Graphics	Cm = 50%	1000 x 881

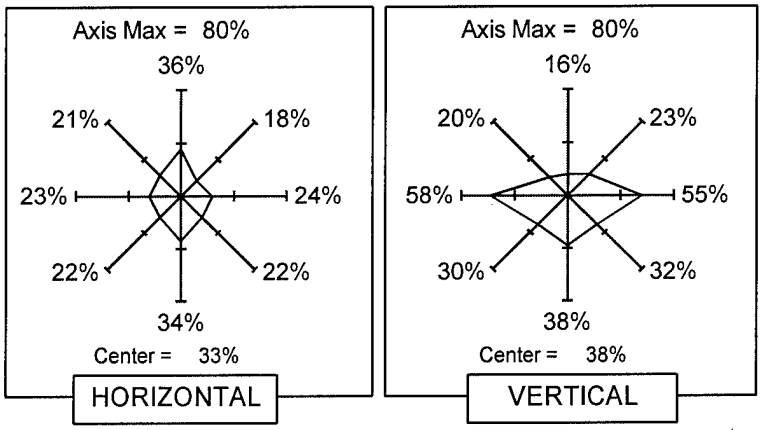
Maximum Luminance in Foot Lamberts



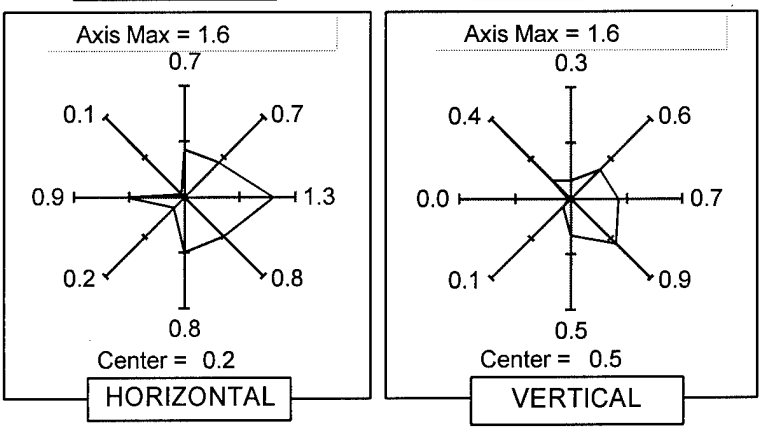
Linewidth in Pixels (RAR)



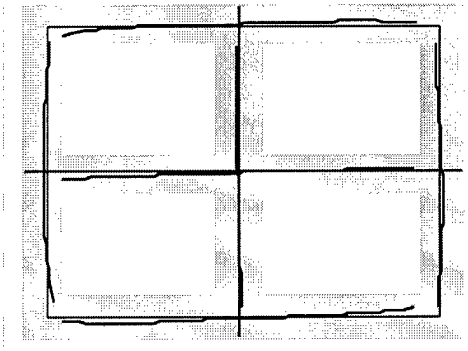
Contrast Modulation



Misconvergence in Pixels



Waviness



Gray band indicates ±1% distortion.

CONRAC MARS 9321

Manufacturer's Data

Manufacturer Name	Conrac
Model Number	MARS 9321
Price	$3,975
Screen Diagonal	21 inches
Horizontal Scan Rate	89.81 kHz
Vertical Scan Rate	72.31 Hz
Image Size (H x V)	14.9 x 11.2 inches
Addressable Pixel Number	1600 x 1200
Pixel Size	9.34 x 9.33 mils (0.237 x 0.237 mm)
Dot Pitch	11.0 mils (0.28 mm)

Summary Comments:

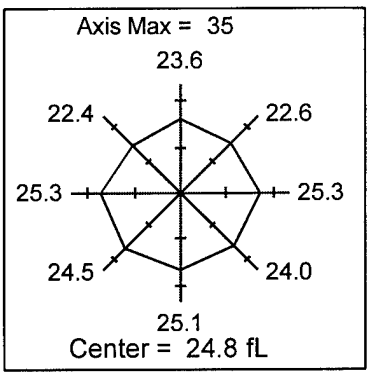
- This is the highest-cost monitor in the survey ($3,975).
- This monitor had high horizontal RAR values at some screen edges.
- Based on a Cm = 25%, this monitor resolved 89% of the addressable pixels.

Detailed Performance Data

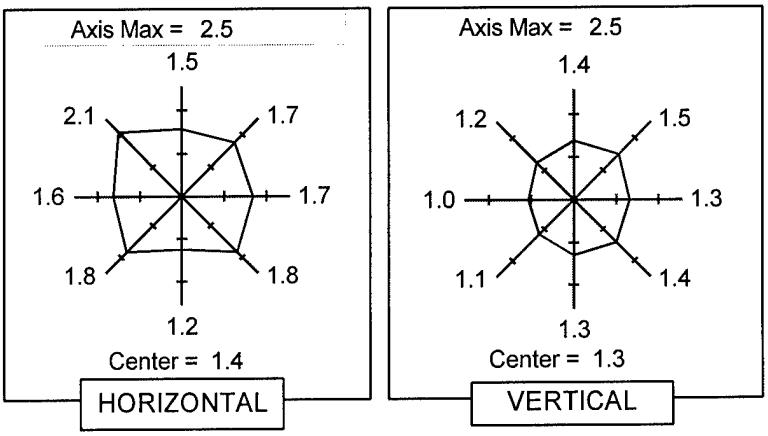
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1425 x 1200
Text and Graphics	Cm = 50%	1036 x 916

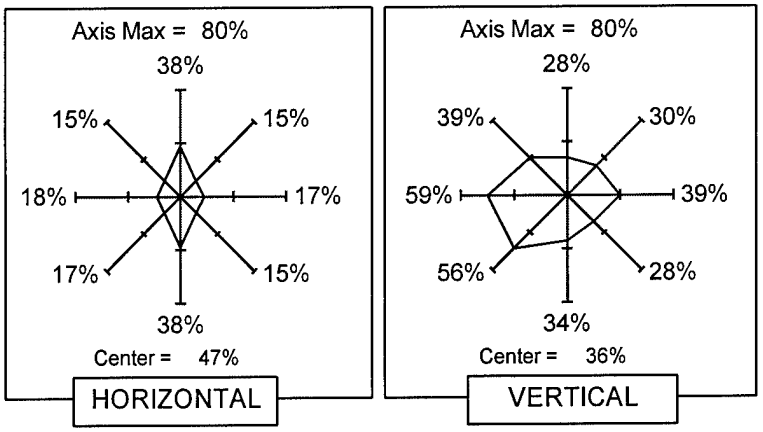
Maximum Luminance in Foot Lamberts



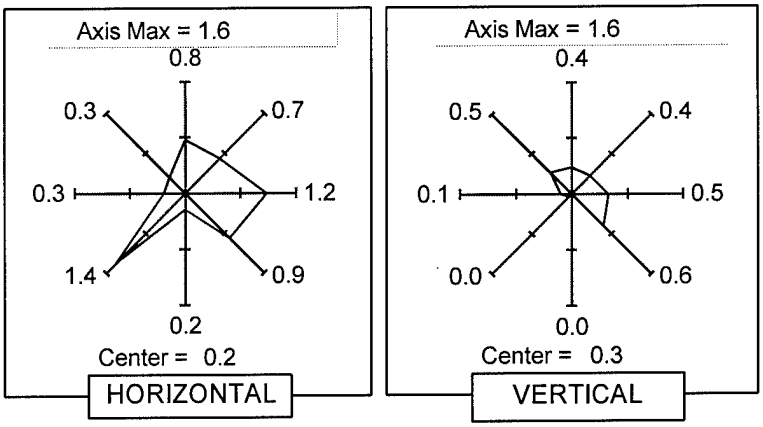
Linewidth in Pixels (RAR)



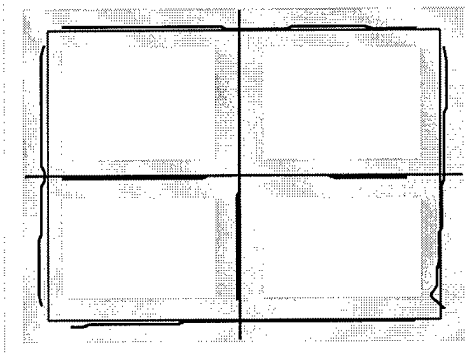
Contrast Modulation



Misconvergence in Pixels



Waviness



Gray band indicates ±1% distortion.

ART MEDIA TN-2185T

Manufacturer's Data

Manufacturer Name	Art Media
Model Number	TN-2185T
Price	$1,715 (new price: $1,449)
Screen Diagonal	20 inches
Horizontal Scan Rate	81.25 kHz (test scan rate)
Vertical Scan Rate	65.00 Hz
Image Size (H x V)	14.7 x 11.0 inches
Addressable Pixel Number	1600 x 1200
Pixel Size	9.20 x 9.20 mils (0.234 x 0.234 mm)
Stripe Pitch	11.8 mils (0.30 mm)

Summary Comments:

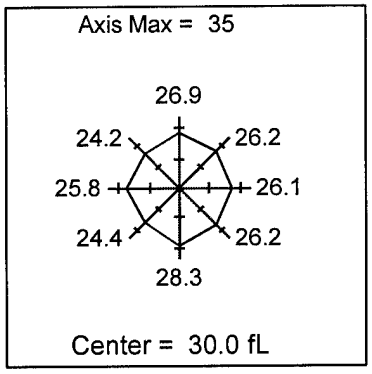
- This monitor features the Trinitron CRT aperture grille.
- The monitor exhibited low waviness; vertical pincushion was 0.25%.
- Based on a Cm = 25%, this monitor resolved 85% of the addressable pixels.

Detailed Performance Data

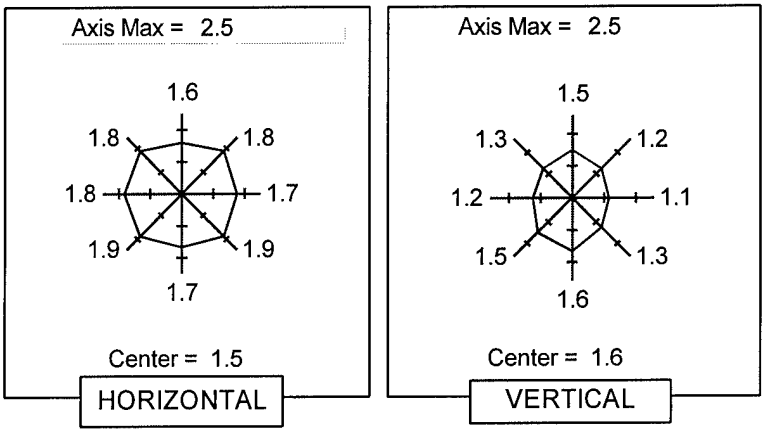
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1378 x 1183
Text and Graphics	Cm = 50%	982 x 887

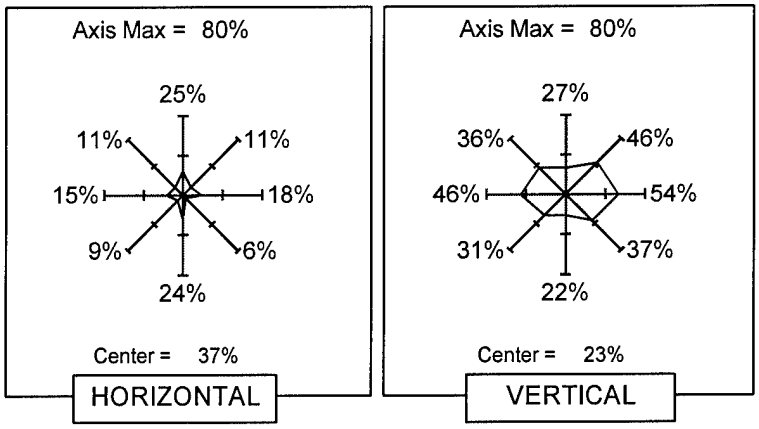
Maximum Luminance in Foot Lamberts



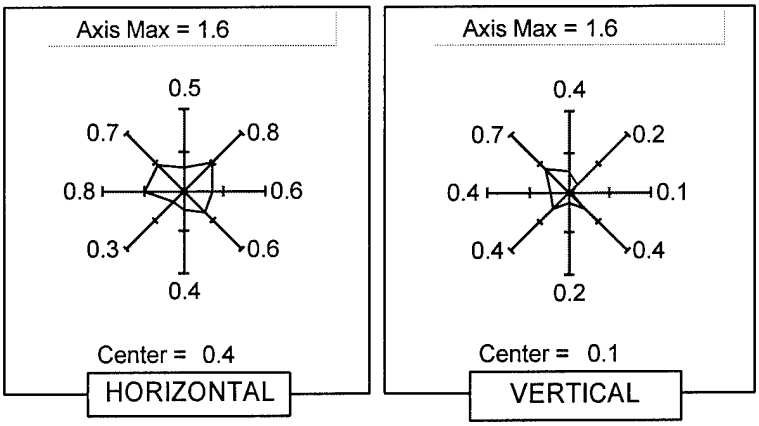
Linewidth in Pixels (RAR)



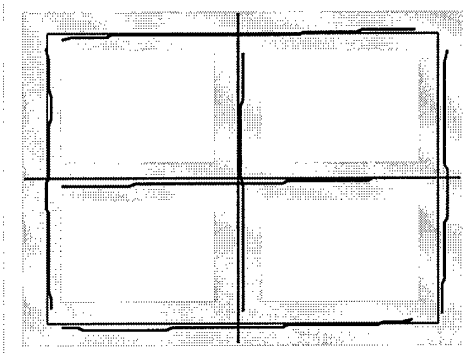
Contrast Modulation



Misconvergence in Pixels



Waviness



Gray band indicates ±1% distortion.

CORNERSTONE COLOR 21/88FP

Manufacturer's Data

Manufacturer Name	Cornerstone
Model Number	Color 21/88fp
Price	$2,365
Screen Diagonal	21 inches
Horizontal Scan Rate	109.49 kHz
Vertical Scan Rate	87.66 Hz
Image Size (H x V)	15.5 x 11.7 inches
Addressable Pixel Number	1600 x 1200
Pixel Size	9.67 x 9.72 mils (0.246 x 0.247 mm)
Dot Pitch	10.2 mils (0.26 mm)

Summary Comments:

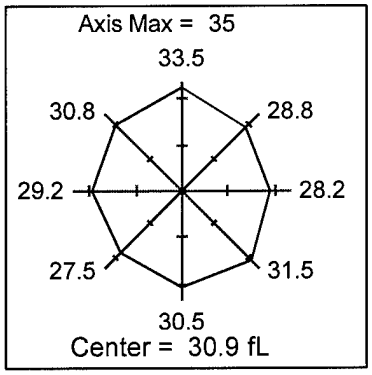
- The 88 Hz refresh rate was the highest tested.
- Based on a Cm = 25%, this monitor resolved 85% of the addressable pixels.

Detailed Performance Data

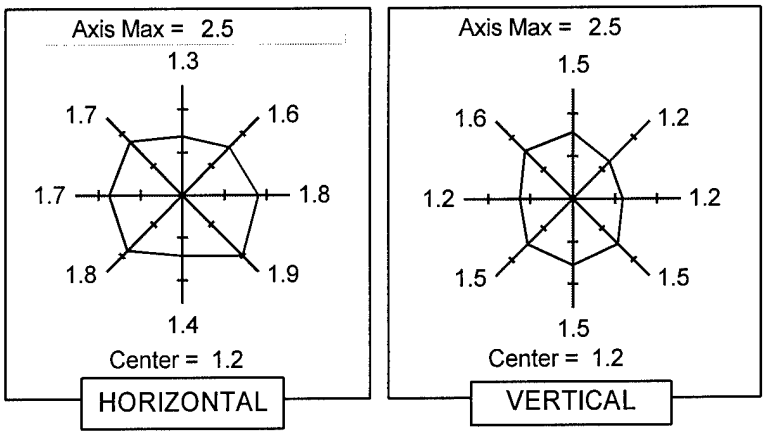
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1456 x 1118
Text and Graphics	Cm = 50%	994 x 736

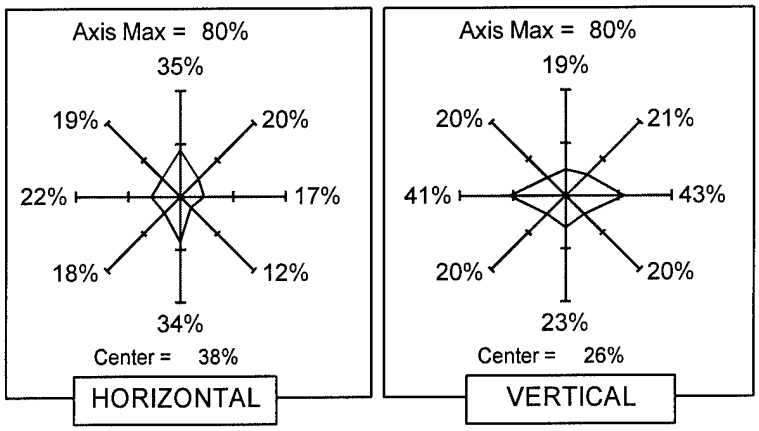
Maximum Luminance in Foot Lamberts



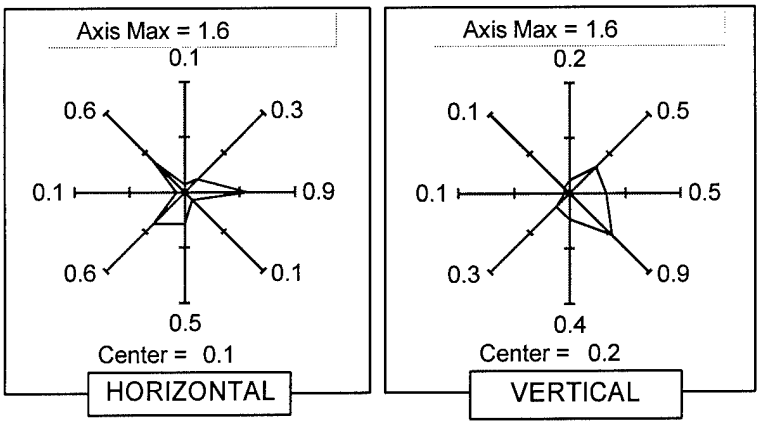
Linewidth in Pixels (RAR)



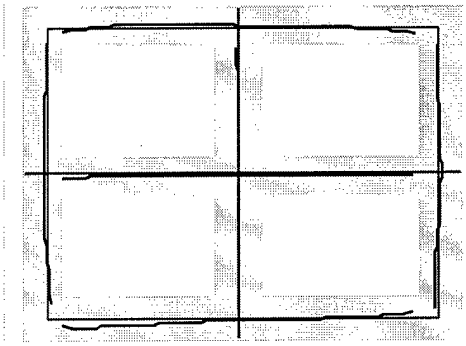
Contrast Modulation



Misconvergence in Pixels



Waviness



Gray band indicates ±1% distortion.

DAYTEK DT-2102M

Manufacturer's Data

Manufacturer Name	Daytek
Model Number	DT-2102M
Price	$1,475
Screen Diagonal	21 inches
Horizontal Scan Rate	78.42 kHz
Vertical Scan Rate	60.00 Hz
Image Size (H x V)	15.0 x 11.2 inches
Addressable Pixel Number	1600 x 1280
Pixel Size	9.35 x 8.77 mils (0.237 x 0.223 mm)
Dot Pitch	11.0 mils (0.28 mm)

Summary Comments:

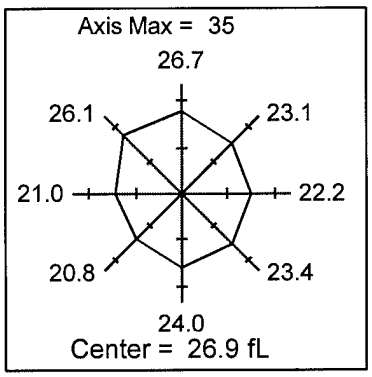
- Horizontal Cm is among the best tested.
- Based on a Cm = 25%, this monitor resolved 95% of the addressable pixels.

Detailed Performance Data

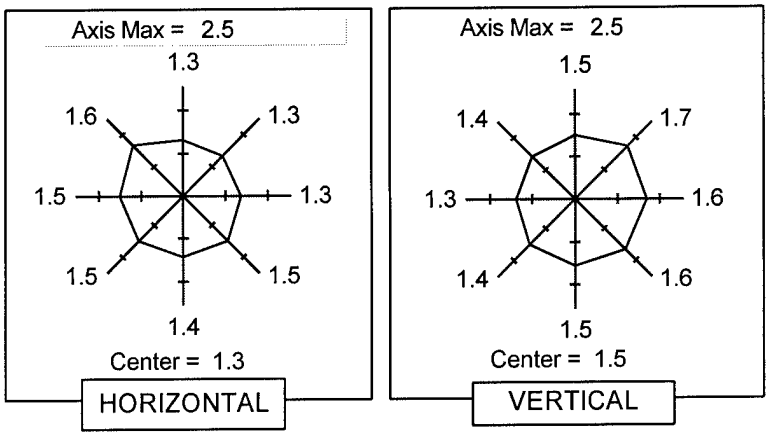
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1600 x 1219
Text and Graphics	Cm = 50%	1360 x 831

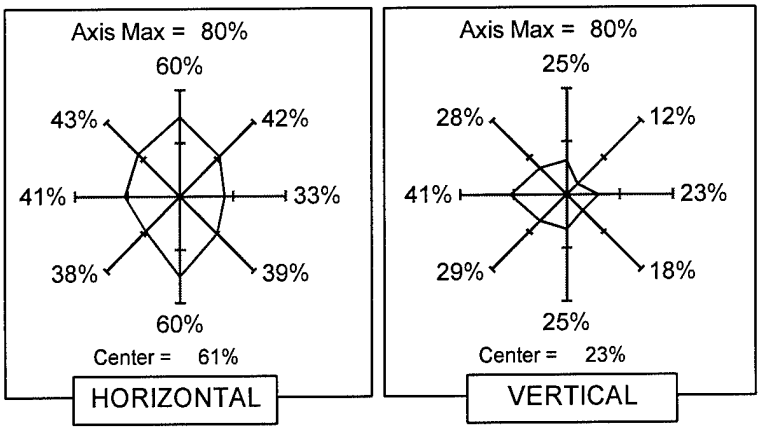
Maximum Luminance in Foot Lamberts



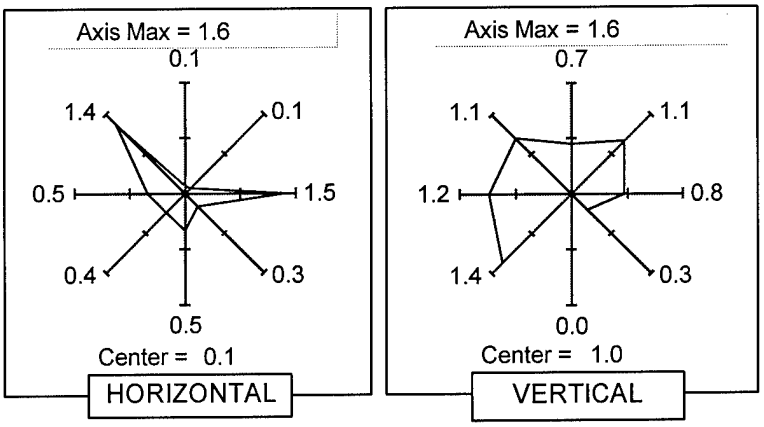
Linewidth in Pixels (RAR)



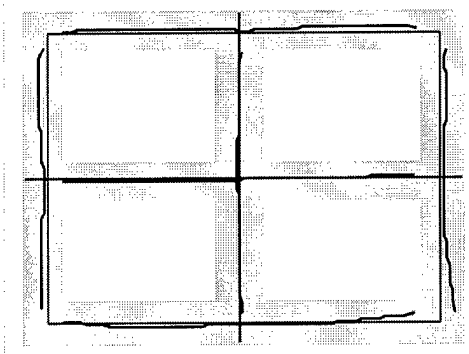
Contrast Modulation



Misconvergence in Pixels



Waviness



Gray band indicates ±1% distortion.

HYUNDAI DELUXSCAN 21

Manufacturer's Data

Manufacturer Name	Hyundai
Model Number	DeluxScan 21
Price	$1,804
Screen Diagonal	21 inches
Horizontal Scan Rate	78.72 kHz
Vertical Scan Rate	60.00 Hz
Image Size (H x V)	15.0 x 11.2 inches
Addressable Pixel Number	1600 x 1200
Pixel Size	9.35 x 8.77 mils (0.237 x 0.223 mm)
Dot Pitch	11.0 mils (0.28 mm)

Summary Comments:

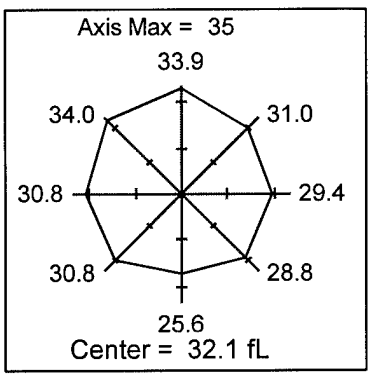
- This monitor exhibited high waviness (0.71% of vertical pincushion).
- This monitor had high vertical RAR values at several screen locations.
- Based on a Cm =25% this monitor resolved 83% of the addressable pixels.

Detailed Performance Data

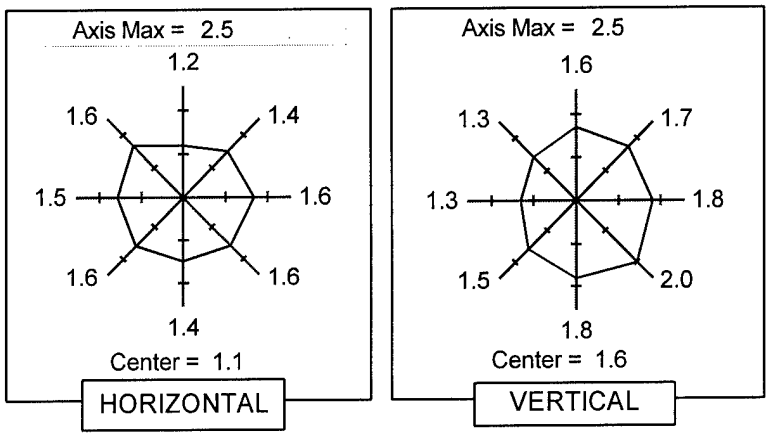
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1574 x 1016
Text and Graphics	Cm = 50%	1125 x 705

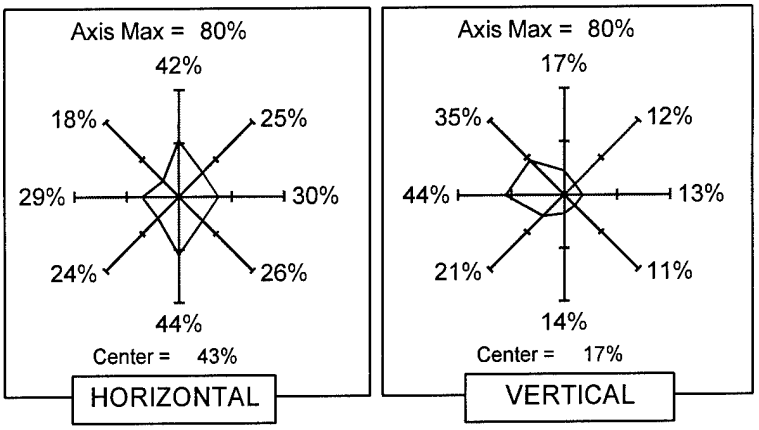
Maximum Luminance in Foot Lamberts



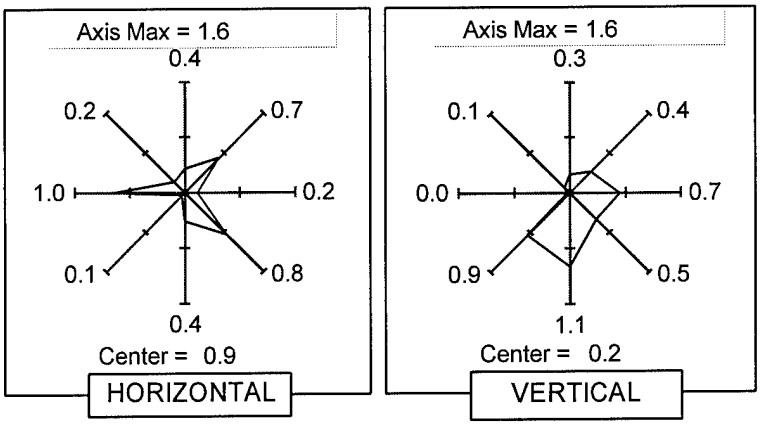
Linewidth in Pixels (RAR)



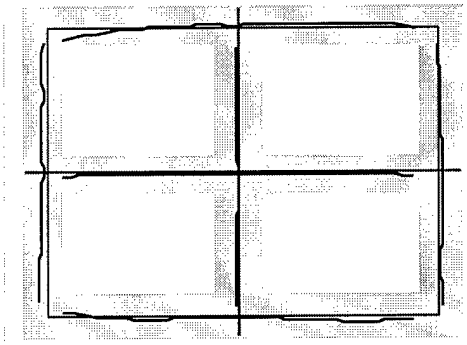
Contrast Modulation



Misconvergence in Pixels



Waviness



Gray band indicates ±1% distortion.

IBM P201

Manufacturer's Data

Manufacturer Name	IBM
Model Number	P201
Price	$2,669
Screen Diagonal	20 inches
Horizontal Scan Rate	106.96 kHz
Vertical Scan Rate	85.03 Hz
Image Size (H x V)	14.5 x 10.9 inches
Addressable Pixel Number	1600 x 1200
Pixel Size	9.04 x 9.10 mils (0.230 x 0.231 mm)
Stripe Pitch	10.2 mils (0.26 mm)

Summary Comments:

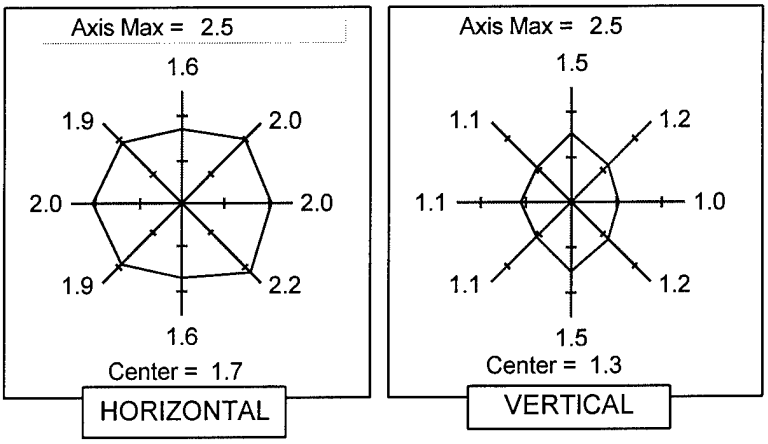
- This monitor features the Trinitron CRT aperture grille.
- The screen center luminance of 35.9 fL is one of the highest tested.
- This monitor had high horizontal RAR values at several screen locations.
- Moiré correction circuitry available on this monitor was not evaluated and was instead set to the OFF position during testing
- Based on a Cm = 25%, this monitor resolved 78% of the addressable pixels.

Detailed Performance Data

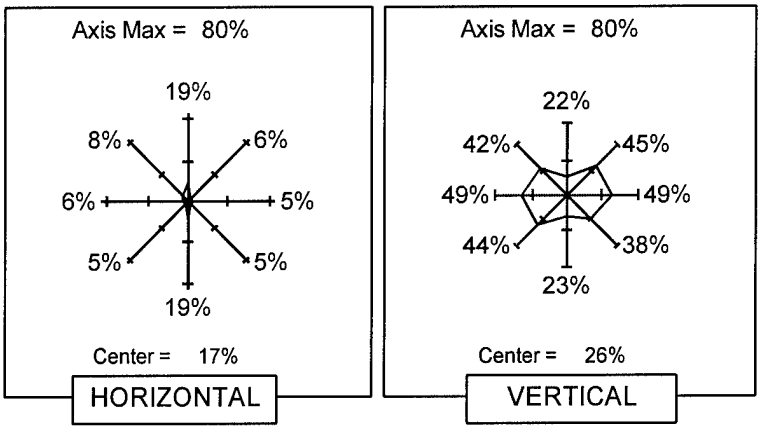
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1260 x 1185
Text and Graphics	Cm = 50%	912 x 930

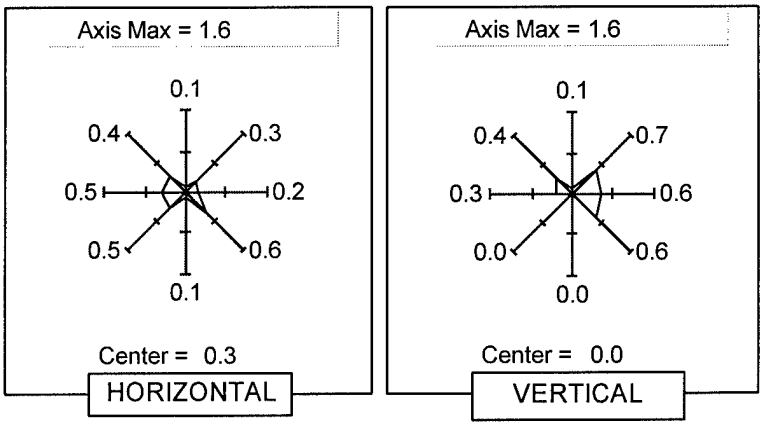
Linewidth in Pixels (RAR)



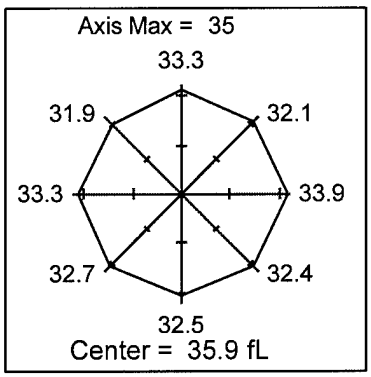
Contrast Modulation



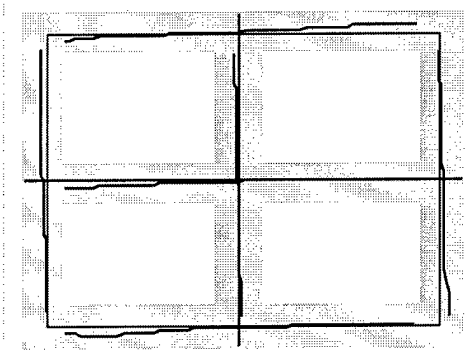
Misconvergence in Pixels



Maximum Luminance in Foot Lamberts



Waviness



Gray band indicates ±1% distortion.

IMAGE SYSTEMS C21LMAX ('96 MODEL)

Manufacturer's Data

Manufacturer Name	Image Systems
Model Number	C21LMAX ('96 Model)
Price	$2,921
Screen Diagonal	21 inches
Horizontal Scan Rate	80.66 kHz
Vertical Scan Rate	65.00 Hz
Image Size (H x V)	15.0 x 11.2 inches
Addressable Pixel Number	1600 x 1200
Pixel Size	9.38 x 9.36 mils (0.238 x 0.228 mm)
Dot Pitch	11.0 mils (0.28 mm)

Summary Comments:

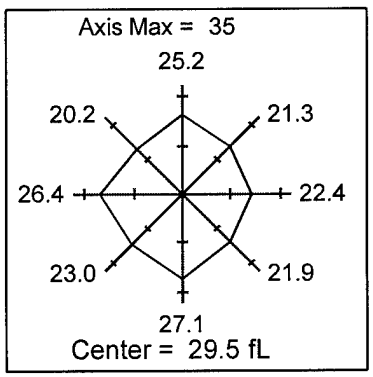
- This monitor exhibited high waviness (0.71% of vertical pincushion).
- Vertical misconvergence exceeded 1.5 pixels at several places on the screen.
- Based on a Cm = 25%, this monitor resolved 86% of the addressable pixels.

Detailed Performance Data

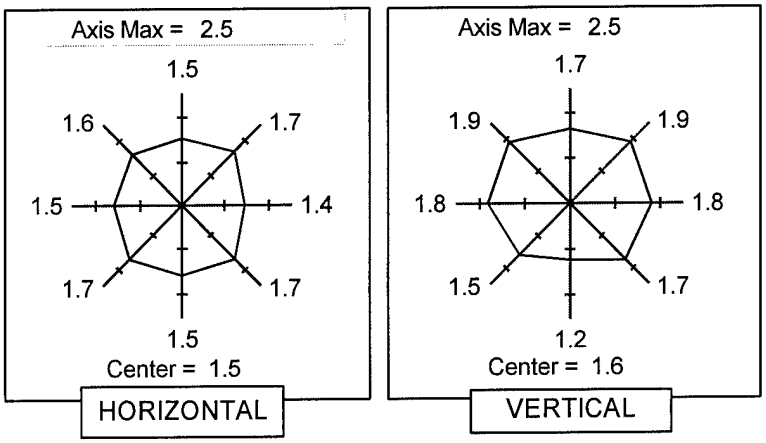
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1528 x 1086
Text and Graphics	Cm = 50%	1027 x 696

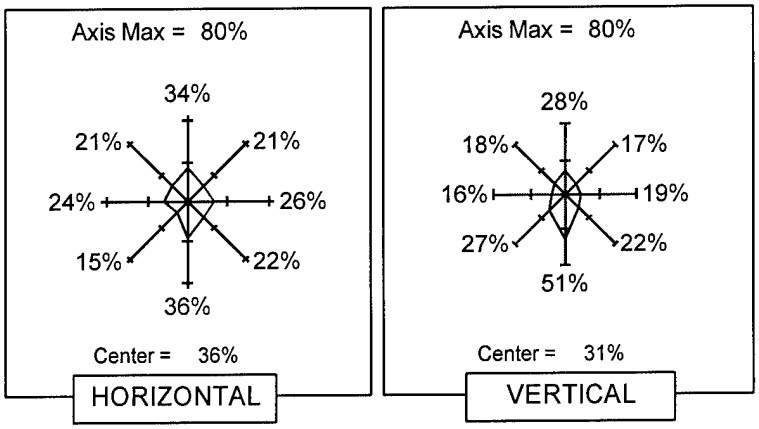
Maximum Luminance in Foot Lamberts



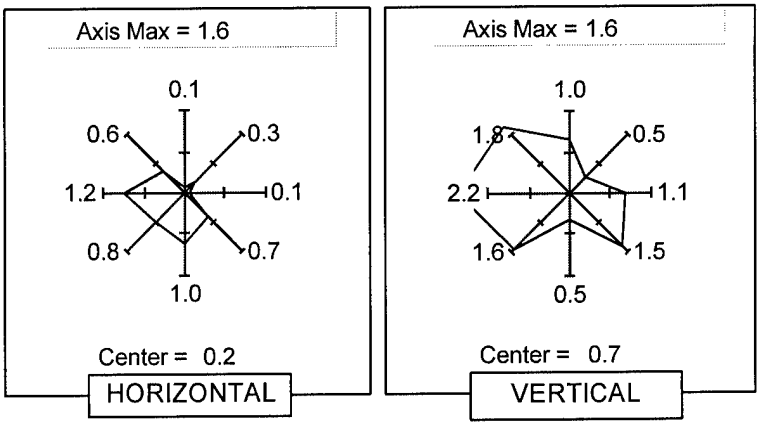
Linewidth in Pixels (RAR)



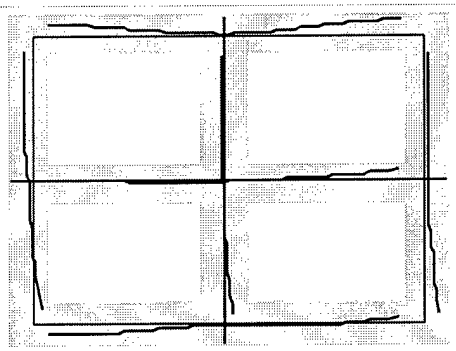
Contrast Modulation



Misconvergence in Pixels



Waviness



Gray band indicates ±1% distortion.

MAXTECH XT-2000

Manufacturer's Data

Manufacturer Name	MaxTech
Model Number	XT-2000
Price	$1,465
Screen Diagonal	20 inches
Horizontal Scan Rate	81.24 kHz
Vertical Scan Rate	60.00 Hz
Image Size (H x V)	14.2 x 10.7 inches
Addressable Pixel Number	1600 x 1280
Pixel Size	8.87 x 8.32 mils (0.225 x 0.211 mm)
Dot Pitch	11.0 mils (0.28 mm)

Summary Comments:

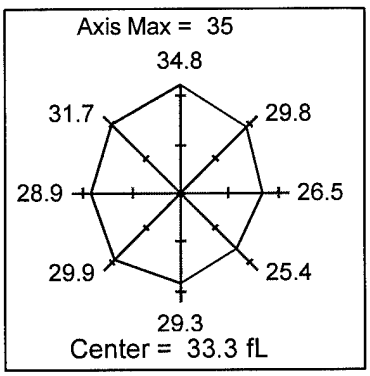
- Overall, the Cm and realizable resolution were the lowest tested.
- On the average, this monitor had high the highest RAR values
- Based on a Cm = 25%, this monitor resolved 49% of the addressable pixels.

Detailed Performance Data

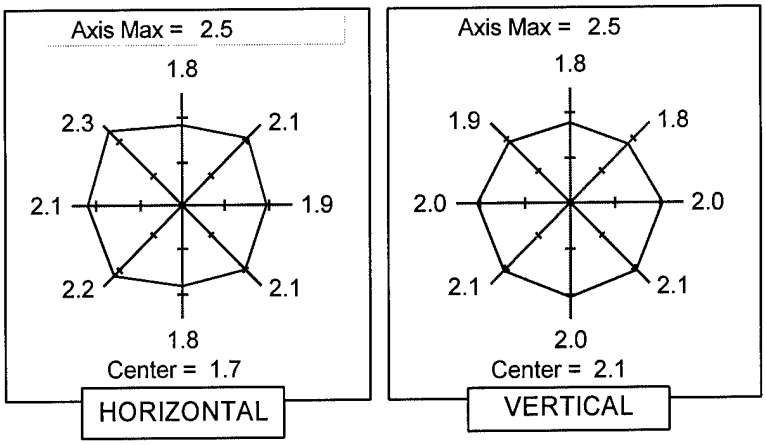
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1137 x 891
Text and Graphics	Cm = 50%	812 x 608

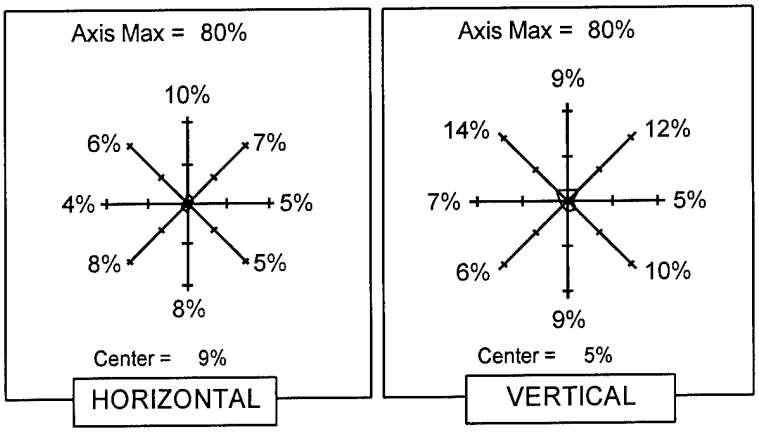
Maximum Luminance in Foot Lamberts



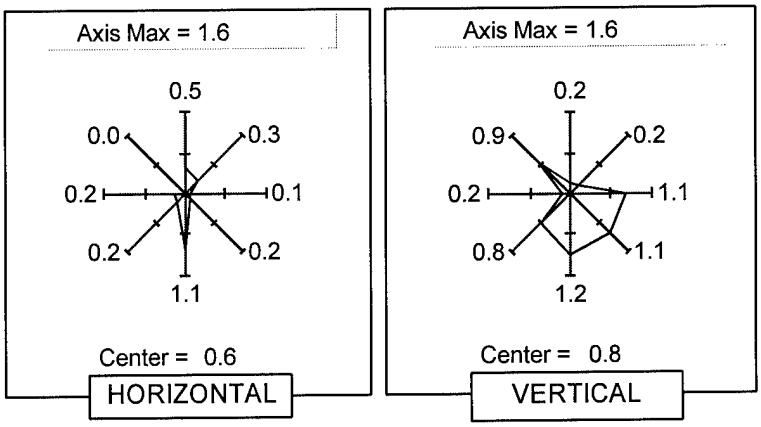
Linewidth in Pixels (RAR)



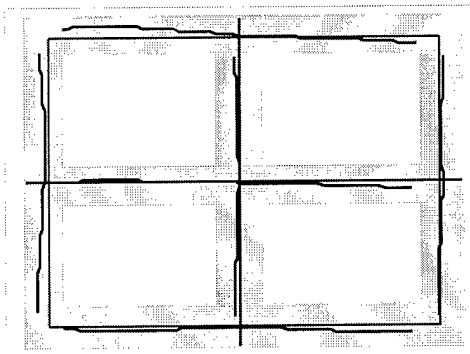
Contrast Modulation



Misconvergence in Pixels



Waviness



Gray band indicates ±1% distortion.

PRINCETON GRAPHIC SYSTEMS ULTRA 20

Manufacturer's Data

Manufacturer Name	Princeton Graphic Systems
Model Number	Ultra 20
Price	$1,329
Screen Diagonal	20 inches
Horizontal Scan Rate	81.91 kHz
Vertical Scan Rate	65.53 Hz
Image Size (H x V)	14.2 x 10.6 inches
Addressable Pixel Number	1600 x 1200
Pixel Size	8.86 x 8.86 mils (0.225 x 0.225 mm)
Dot Pitch	11.0 mils (0.28 mm)

Summary Comments:

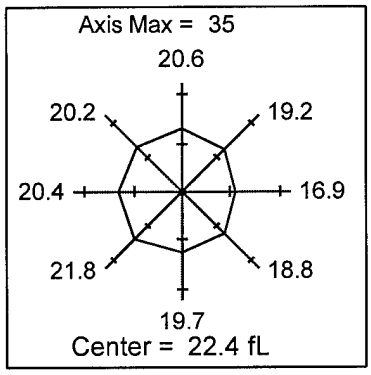
- This was the lowest-cost monitor in the survey ($1,329).
- Screen center luminance was one of the lowest in this survey (22.4 fL).
- Based on a Cm = 25%, this monitor resolved 89% of the addressable pixels.

Detailed Performance Data

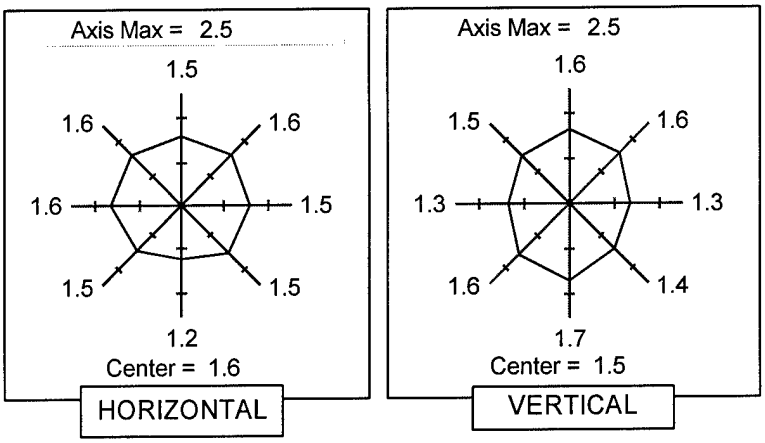
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1521 x 1119
Text and Graphics	Cm = 50%	1183 x 761

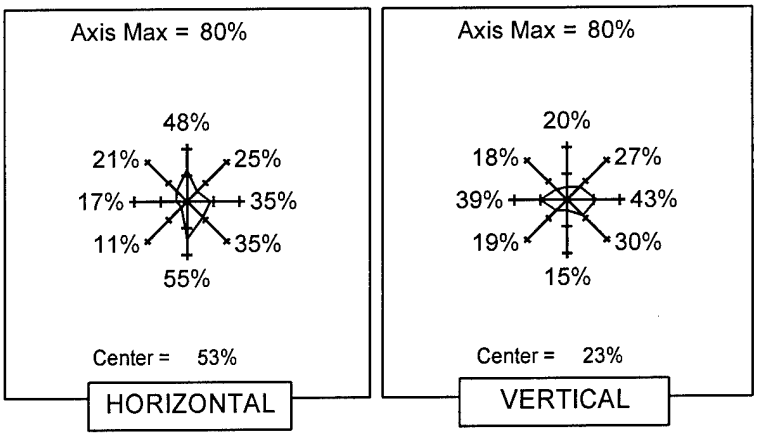
Maximum Luminance in Foot Lamberts



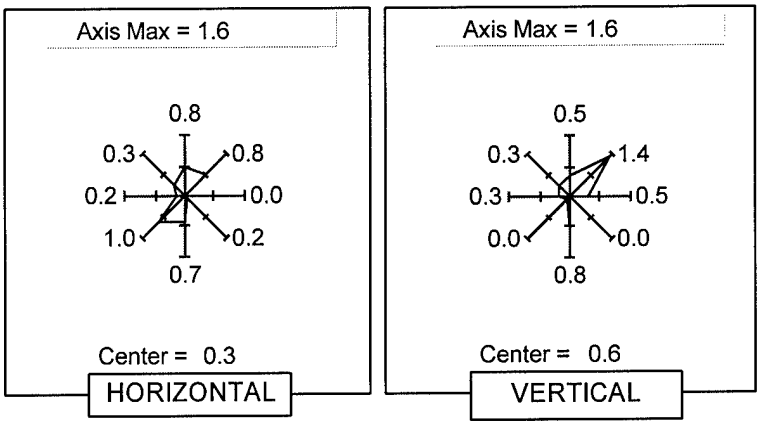
Linewidth in Pixels (RAR)



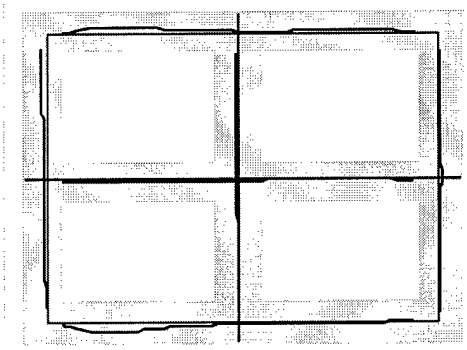
Contrast Modulation



Misconvergence in Pixels



Waviness



Gray band indicates ±1% distortion.

RADIUS MULTIVIEW 21

Manufacturer's Data

Manufacturer Name	Radius
Model Number	MultiView 21
Price	$2,279
Screen Diagonal	21 inches
Horizontal Scan Rate	85.27 kHz
Vertical Scan Rate	68.71 Hz
Image Size (H x V)	15.0 x 11.2 inches
Addressable Pixel Number	1600 x 1200
Pixel Size	9.35 x 9.35 mils (0.237 x 0.237 mm)
Dot Pitch	9.8 mils (0.25 mm)

Summary Comments:

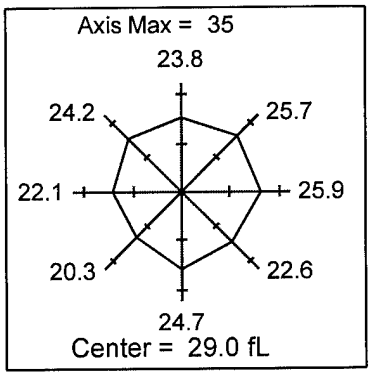
- Vertical Cm was among the best tested.
- Based on a Cm = 25%, this monitor resolved 94% of the addressable pixels.

Detailed Performance Data

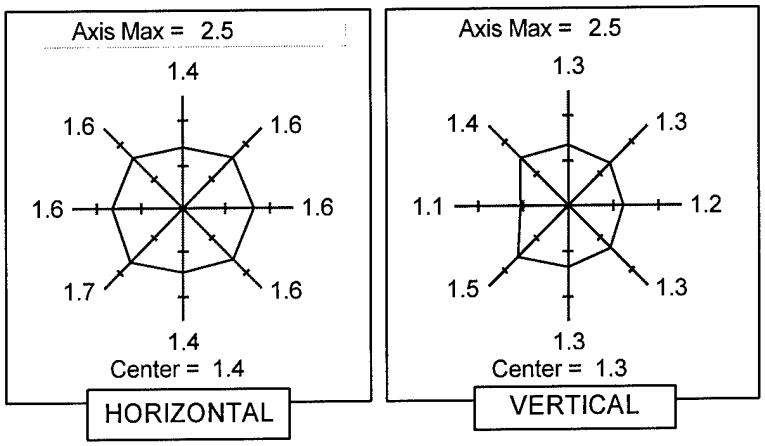
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1508 x 1200
Text and Graphics	Cm = 50%	970 x 918

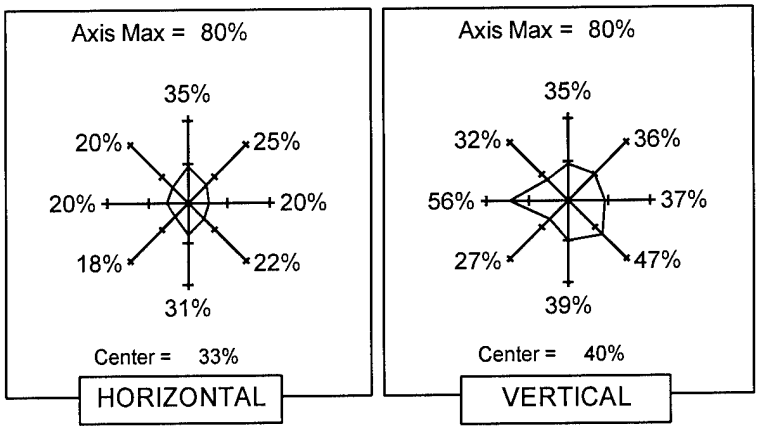
Maximum Luminance in Foot Lamberts



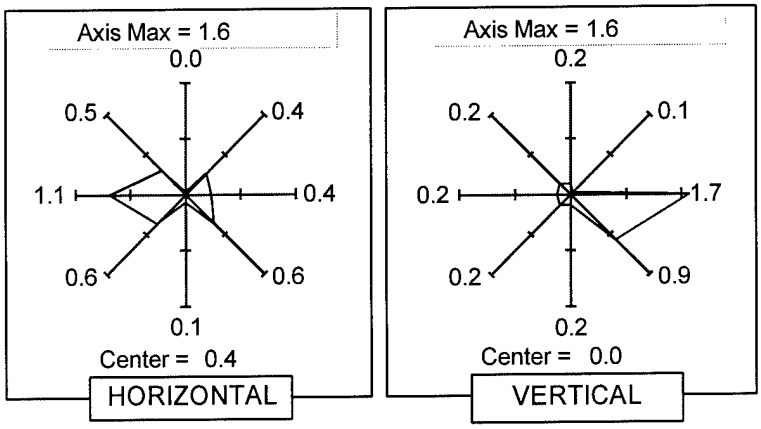
Linewidth in Pixels (RAR)



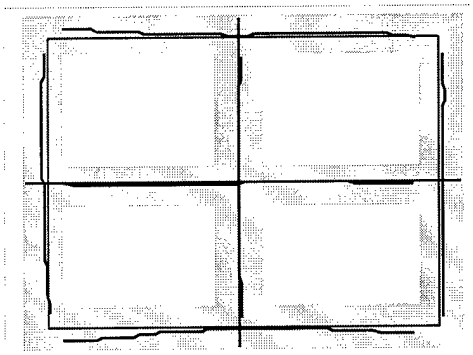
Contrast Modulation



Misconvergence in Pixels



Waviness



Gray band indicates ±1% distortion.

RADIUS PRECISIONVIEW 21

Manufacturer's Data

Manufacturer Name	Radius
Model Number	PrecisionView 21
Price	$2,611
Screen Diagonal	21 inches
Horizontal Scan Rate	85.27 kHz
Vertical Scan Rate	68.71 Hz
Image Size (H x V)	15.0 x 12.0 inches
Addressable Pixel Number	1600 x 1200
Pixel Size	9.38 x 10.00 mils (0.238 x 0.254 mm)
Stripe Pitch	11.8 mils (0.30 mm)

Summary Comments:

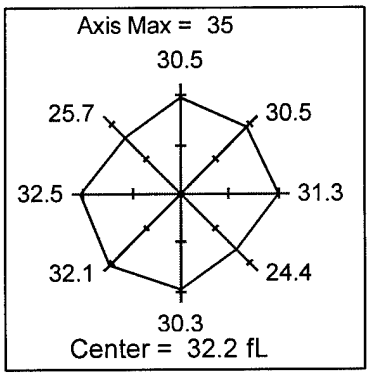
- This monitor features the DiamondTron color tube.
- Vertical Cm is among the best tested.
- Based on a Cm = 25%, this monitor resolved 92% of the addressable pixels.

Detailed Performance Data

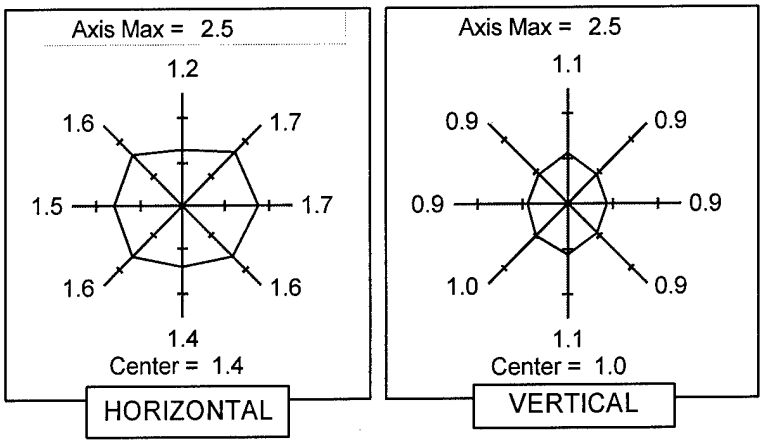
Display Resolution

Display Content	Cm Required	Resolution Limit
Grayscale Imagery:	Cm = 25%	1466 x 1200
Text and Graphics	Cm = 50%	995 x 1140

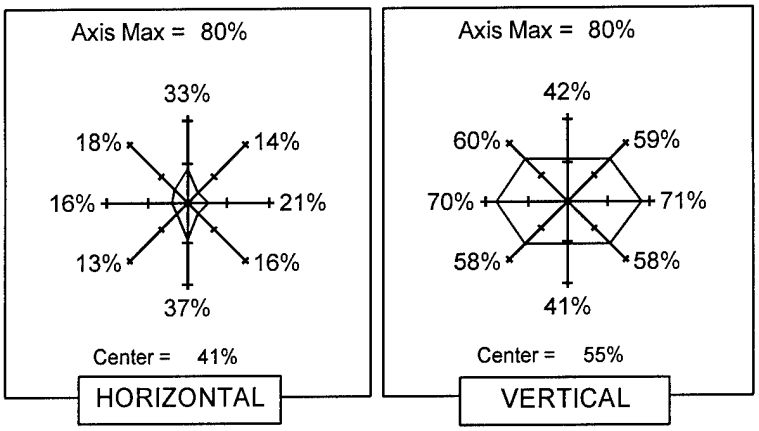
Maximum Luminance in Foot Lamberts



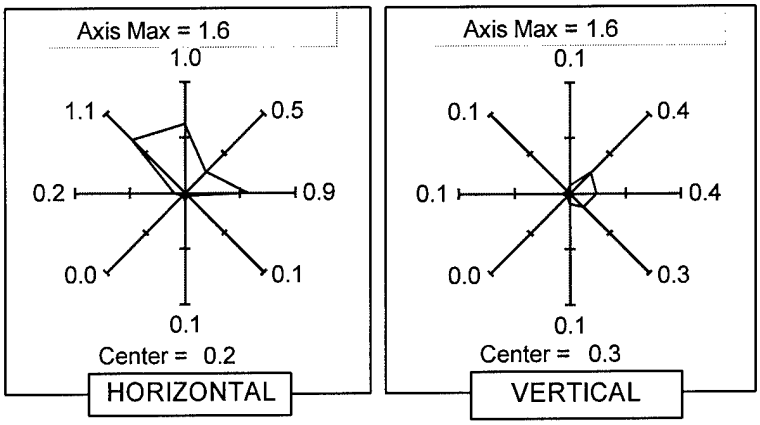
Linewidth in Pixels (RAR)



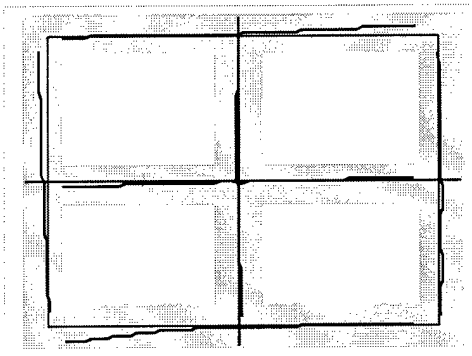
Contrast Modulation



Misconvergence in Pixels



Waviness



Gray band indicates ±1% distortion.