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MTF Test Method for Monochrome CRT Display Systems

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MTF TEST METHOD FOR MONOCHROME CRT DISPLAY SYSTEMS

EIA JT-20 COMMITTEE ON CATHODE RAY DISPLAY DEVICES

This test method details the calculation of the Modulation Transfer Function (MTF) from resolution data such as those obtained using EIA TEPAC 105-7, "A test method for line profile measurements". A FORTRAN-language software program is provided to allow the implementation of this method with a minimum of personnel training.

Since the MTF is derived from CRT line profile data, it is recommended that line profile measurements be the preferred specification for CRTs in order to reduce the possibility of computational errors and misunderstandings between suppliers and customers on contractual requirements.

The Fourier transform algorithm included in the software package was excerpted from the computer program, "Fast Fourier Transform Algorithm" by Bergland and Dolan appearing in the IEEE Press Book - Programs for Digital Signal Processing. This algorithm is used with the permission of the Institute for Electrical and Electronics Engineers.

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MODULATION TRANSFER FUNCTION TEST PROCEDURE

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1. SCOPE: MTFs FOR MONOCHROME CRTs

Background

In most cases, the interface between humans and machines is a visual display.

The sharpness and readability of raster-scanned Cathode-Ray Tube (CRT) displays conventionally has been determined by how far the vertical raster height could be reduced while still displaying individual scan lines (Shrinking Raster Line Width Measurement). This method yields a rough "order-of-magnitude" estimate of the visible raster-line capacity of a display device.

As user demands for display readability increase, the subjectivity and over-simplification of this technique limits its practical utility for precise engineering specifications. A more definitive method of measuring the true beam spread is needed to describe the complete display performance. The measurement of line width by a scanning photometer removes a great deal of the subjectivity from this type of measurement. In this method, a measurement is made of the light distribution across the width of a single raster-line. This measurement reveals the true profile of light intensity across a raster-line in an objective manner. The line profile, in turn, usually is designated by its full-width at 50% of its peak light intensity or luminance.

Moreover, continual user demands for better image quality through increased pixel density has underscored the need for more descriptive methods of assessing the total imaging capability of a CRT display. A quantification of the accuracy achieved in reproducing the input signal on the viewer's screen is the ultimate goal. The preferred specification to describe this performance characteristic of a CRT display is the Modulation Transfer Function (MTF).

The MTF takes into account not only the raster-line width at one specific percentage of peak intensity, but also accounts for the entire line profile shape. It can be shown analytically that the shape of the raster-line profile as well as the beam width are evaluated in the MTF. Phosphor screen spreading, reflections from the phosphor and optical coatings, as well as saturation effects of the screen also affect to the MTF.

An additional advantage of the MTF measurement is that other elements of the display system may be incorporated into the evaluation, and thus, provide a composite MTF specification for the total display system. The MTF usually is presented as a curve representing modulation transfer across the spatial frequency bandpass of the display device or system.

One method to evaluate the MTF is to drive a CRT grid or cathode with a sine-wave signal. Synchronized with an appropriate raster-scan, typically 525 lines, bright-to-dark sine-wave bars are generated on the display screen. Reference conditions can be selected to assure full-on and full-off performance of the display. The bright and dark bars are scanned with a slit-aperture photometer such as that described in EIA Test Method 105-7. The modulation of the displayed sine-wave pattern is computed as:

$$\text{Modulation} = \frac{L_{\max} - L_{\min}}{L_{\max} + L_{\min}} \quad (1)$$

where $L_{\max}$ denotes the maximum (peak) luminance of the sine-wave pattern and $L_{\min}$ denotes the minimum (valley) luminance of the sine-wave pattern.

Following this modulation measurement, the sine-wave frequency is changed to other predetermined values and the modulation response is reassessed. A plot of the modulation values for each of the measured spatial frequencies defines the MTF curve (See Figure 1).

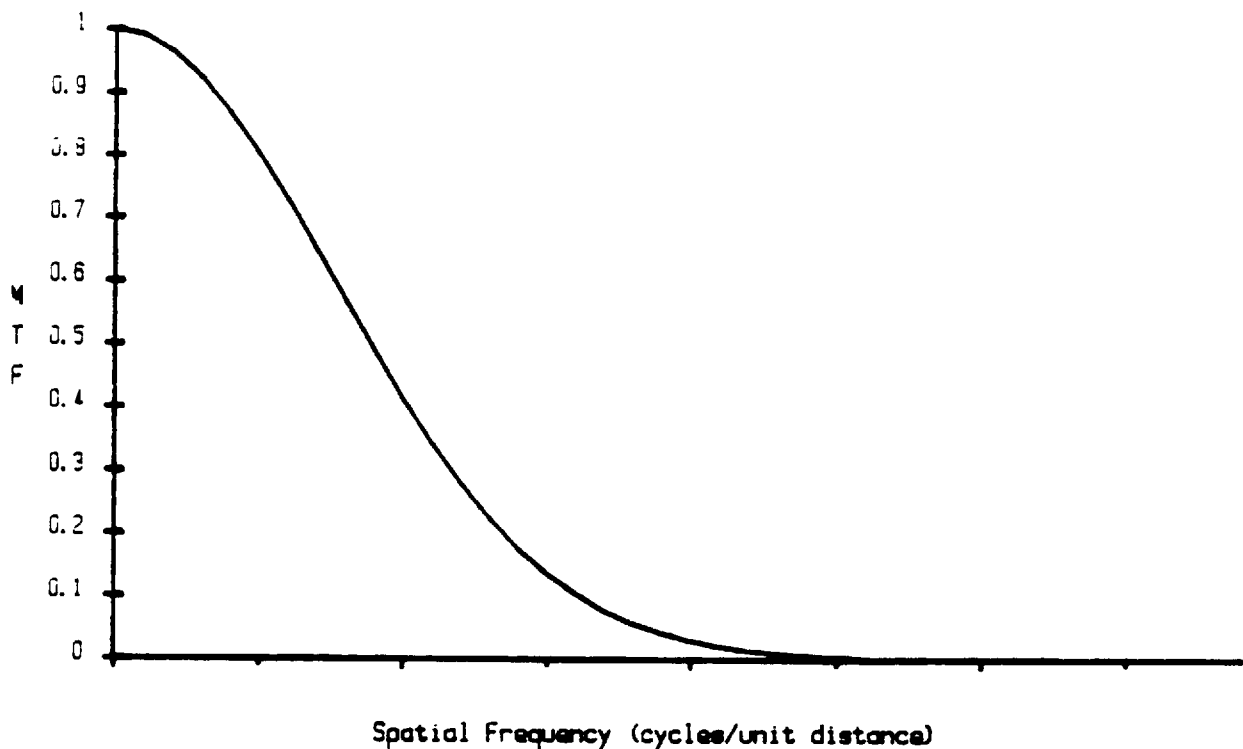


Figure 1. A hypothetical Modulation Transfer Function curve obtained by measuring the sine-wave response of a CRT at several distinct frequency points.

For example, if the active horizontal sweep time is 46.5 usec, a triggered sine-wave pulse modulating the beam could be set at 215 KHz to produce 10 vertical sine-wave bars. Scanning these vertical bars with a photometer will give the $L_{\max}$ and $L_{\min}$ necessary to calculate the modulation at one specific frequency point on the MTF curve.

As the frequency of the sine-wave signal is increased, the amplitude difference between the bright and dark bars is reduced, while the bars become closer together (See Figure 2). The reduction of amplitude produces a lower modulation (Eq. 1) and causes the MTF curve to approach zero at higher spatial frequencies.

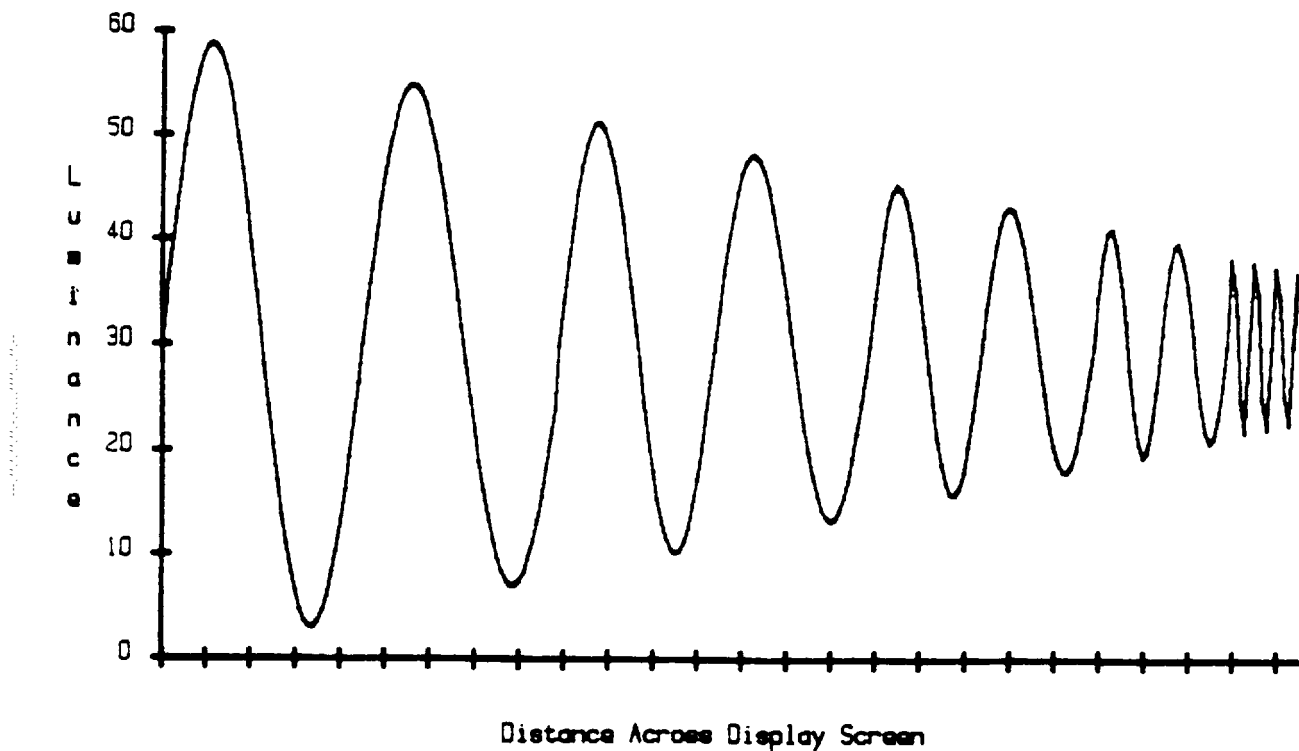


Figure 2. Hypothetical luminance profile across a series of sine-wave gratings displayed on a CRT. Note that modulation decreases as sine-wave frequency increases.

Although the measurement of individual sine-wave patterns displayed on a CRT screen can lead to a MTF plot, this procedure is time-consuming and prone to equipment drift errors. As an alternative procedure, the MTF can be computed from the Fourier transform of the raster-line profile, provided that the line profile converges to a symmetric background level.

There are several measurement techniques for assessing MTFs (See TEPAC Engineering Bulletin #25, A Survey for Data-Display CRT Resolution Measurement Techniques). All of these measurement techniques have the same purpose; that is, to assess how faithfully the CRT reproduces the input signals on the display screen.

Statement of Purpose

The purpose of this test method is to provide a procedure to compute the MTF of monochrome CRTs in order to quantify the discernability and quality of displayed information. While the mathematical concepts of the MTF are complex, this test method provides a software package which allows users to easily convert spot profile data into MTF data. There is no need for mathematical calculations by the user. The software package is designed for use on any computer system with a standard FORTRAN-77 compiler, and a second version of the software for an IBM-PC (or 100%-compatibles) personal computer provides graphical presentations of the spot profile and associated MTF data.