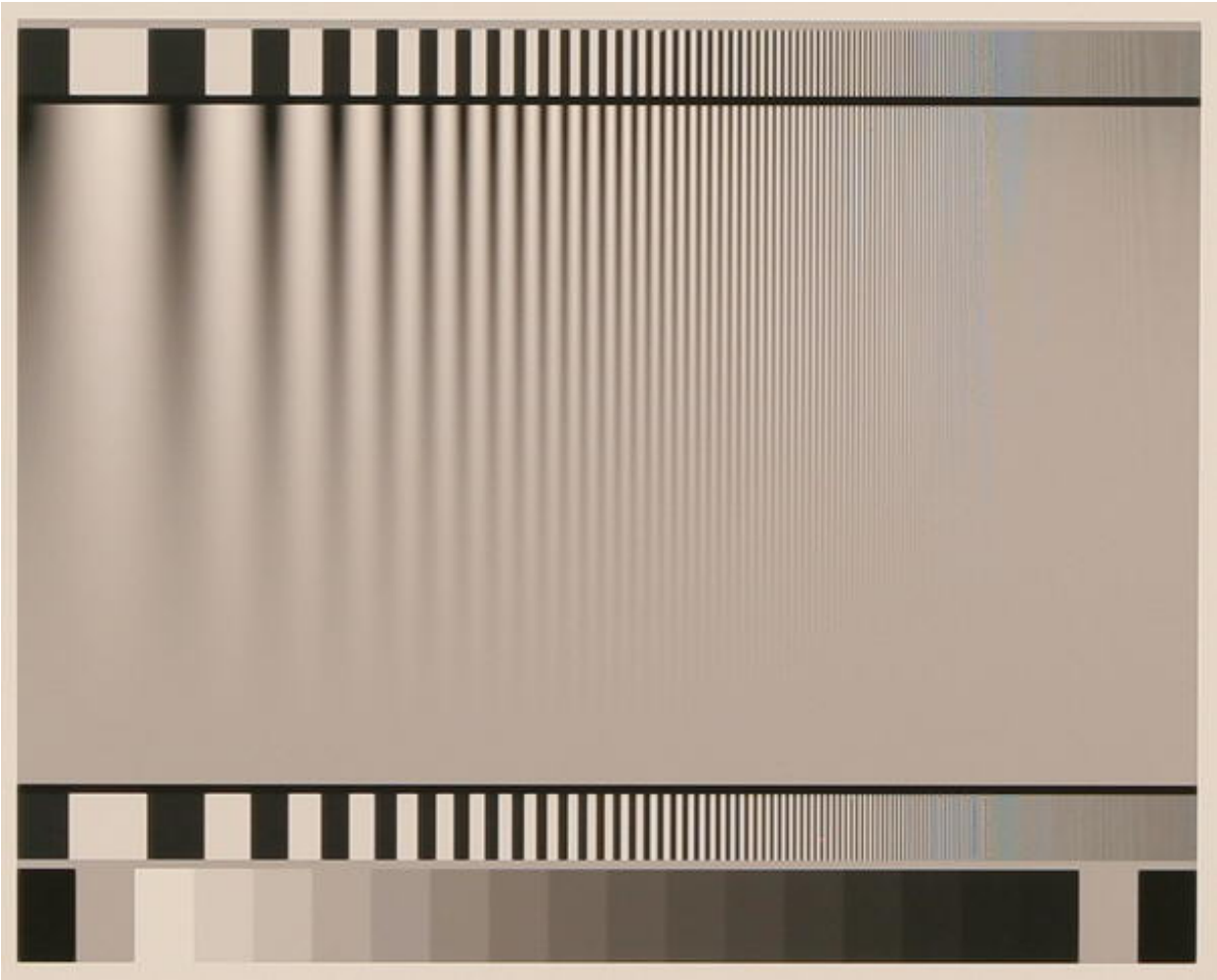
Imatest - Log F-Contrast

Analysis of Log Frequency-Contrast charts

Introduction

Log F-Contrast (short for ***Log Frequency-Contrast***; Imatest Master only), which uses the Rescharts interface, measures the image contrast of charts that vary in spatial frequency on the horizontal axis (log frequency increases with x) and in contrast on the vertical axis (contrast is proportional to $(y/h)^2$ for image height h). When the image pattern is sinusoidal (rather than a bar pattern) the contrast is equivalent to SFR or MTF.

This module can be used to measure fine, low-contrast detail lost to software noise reduction, which can result in a “plastic” appearance in areas where fine texture is missing. This type of ***nonlinear signal processing*** is especially common in cameras with tiny pixels (< 2 microns), such as camera phones. The chart can be purchased at the Imatest store or created by Test Charts and printed on a high quality inkjet printer. An image of a Log Frequency-Contrast chart, acquired with a Canon EOS-20D camera, is shown below, slightly reduced.



Log F-Contrast Image, Canon EOS-20D camera, 24-70mm f/2.8L lens set at 42mm, f/5.6, ISO 100. Click on image to load full-size image.

The chart is divided into twenty-five zones (numbered from top to bottom) for analyzing contrast (MTF), which can be displayed in several ways. Second-order interpolation and smoothing are used to increase the accuracy of the MTF calculations. Spatial frequency is derived from the pattern.

Creating and printing the chart

The Log Frequency-contrast can be purchased from the Imatest Store, downloaded, or printed on a high quality photographic printer from a file created with Imatest Test Charts.

Downloadable charts

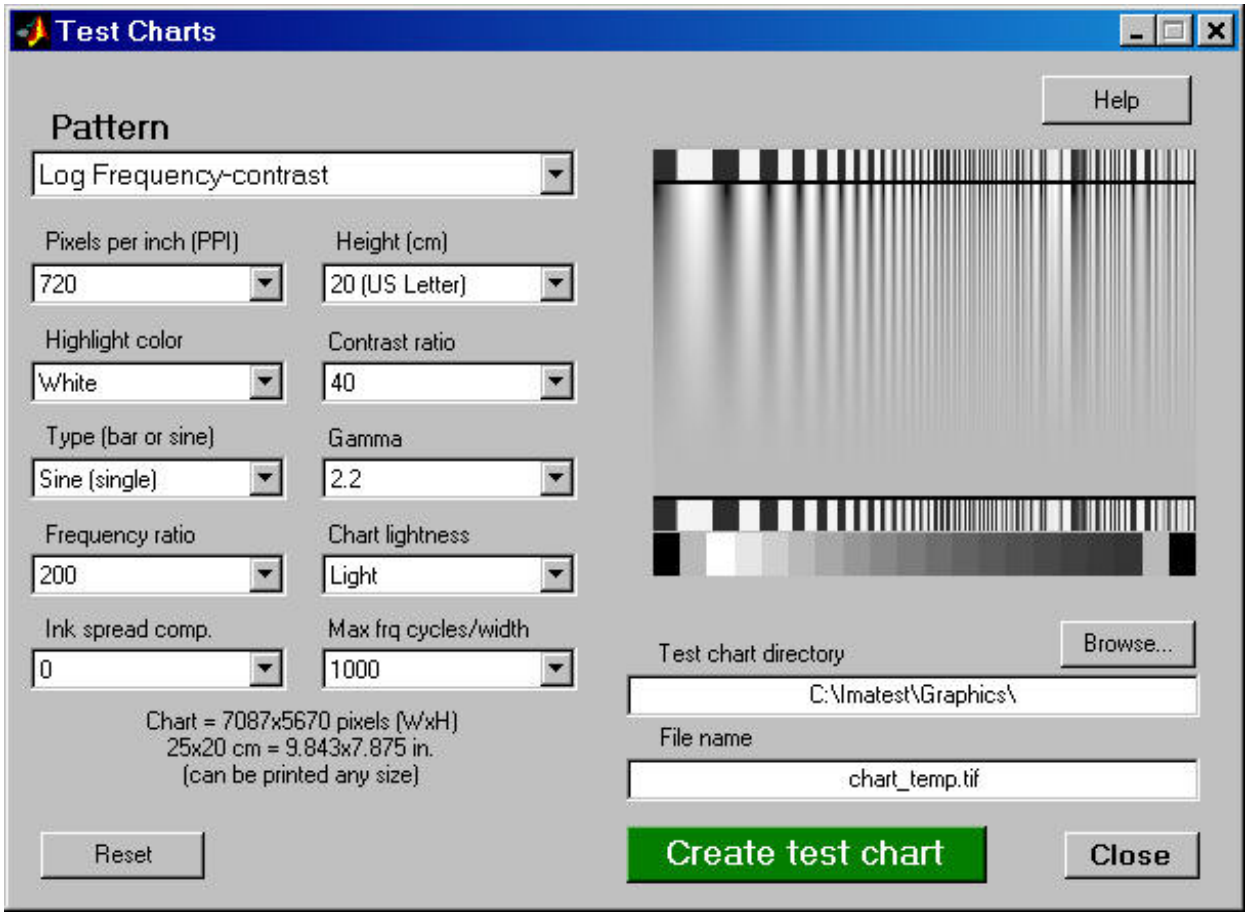
Two Log F-Contrast sine charts are available as PNG files (around 0.8 MB) for download and printing on high quality inkjet printers. One is optimized for printing at 600 dpi on HP and Canon printers; the other is for 720 dpi on Epson printers. Both are designed to be printed 20 cm (7.874 inches) wide (20 cm high if printed in landscape mode) on letter size or A4 paper using high quality print settings.

600 dpi 20 cm chart | 720 dpi 20 cm chart (Right-click to download.)

Both charts have a frequency ratio of 200:1 and a maximum frequency of 800 cycles/width. They should work well covering roughly 1/3 of the image width of typical digital cameras, as shown in the example below.

The charts have been encoded with gamma = 1/2.2 = 0.4545 (identical to Adobe RGB color space and close to sRGB). The orientation takes advantage of the lossless compression of PNG files, which operates along horizontal lines. We recommend rotating the chart 90 degrees counterclockwise.

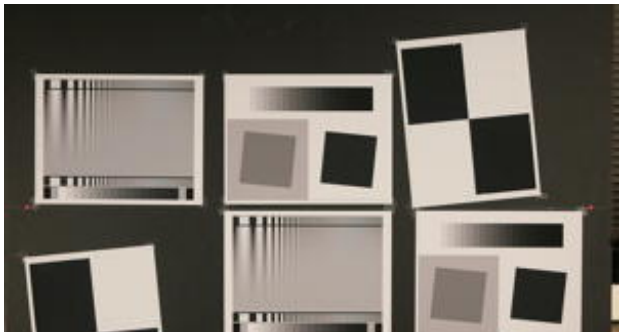
Test Charts has a number of options. The dialog box and recommended settings are shown below.



Box	Recommended setting
Pattern	Log Frequency-contrast.
Pixels per	Depends on printer. For best results set to 720 (Epson) or 600 (HP, Canon)

inch (PPI)	and print at the indicated Height.
Height (cm)	Print height (refers to landscape orientation). To get the indicated PPI— for best print quality— the image should be printed at this height.
Highlight color	Usually White, but can be set at any of R, G, B, C, M, or Y.
Contrast ratio	Only affects the bar region; not important for this pattern.
Type (bar or sine)	Determines pattern type. Use sine for MTF measurements. Bar may be of interest to some users. Sine (single) is used for the examples on this page.
Gamma	Should be same as the gamma used for printing or the color space, e.g., 2.2 if you print using sRGB or Adobe RGB (1998).
Frequency ratio	The ratio between the lowest spatial frequencies (on the left) and the highest. 200 usually works well.
Chart lightness	Only affects bar region; not important.
Ink spread comp.	Best left at 0.
Max. frq cycles/width	This number refers to m = the maximum cycles/width of the ***printed chart***. 1000 is a good choice in most cases. If a photographic image of the chart occupies a fraction f of the image pixel width W, the maximum spatial frequency (in cycles/pixel) of the chart image is $m_{image} = m/fW$. For example, if a chart occupies $f = 0.3$ of the image width W of 3000 pixels, $m_{image} = 1.11$ cycles/pixel. Should be set for a maximum image spatial frequency of *at least* 0.7 cycles/pixel (1.4x Nyquist frequency). 1 cycle/pixel is a good number to aim for, leaving a little margin. See text below.

Example: The Log Frequency-contrast chart shown on the right occupies 857 of 3504 horizontal pixels of an original image taken with the Canon EOS-20D. f = 857/3504 = 0.2446. The chart was created with m = 1000 cycles/pixels. The maximum spatial frequency in the chart image is m_{image} = 1.17 cycles/pixel— slightly higher than optimum, but not excessive because the



highest frequencies occupy relatively little chart real estate. The chart image spatial frequencies are detected automatically.

When the settings are correct, select the TIFF output file name using the **Test chart directory** and **File name** boxes on the lower-right and click . Do not print from the preview image. Print the image from the TIFF output file using your favorite image editor or viewer, paying careful attention to the printed image size and color management settings. More details can be found on Test Charts. Examine the printed chart carefully for defects and for image quality, especially at high spatial frequencies. The tones in the 16-step grayscale step chart at the bottom of the test chart should be compared with a standard chart such as the Kodak Q-13/Q-14 with density steps of 0.1. (There may be some divergence in the darkest zones, but zones 1–12 should be very close.) The sine pattern tones will be accurate if the tones match visually.

Photographing the chart and running the program

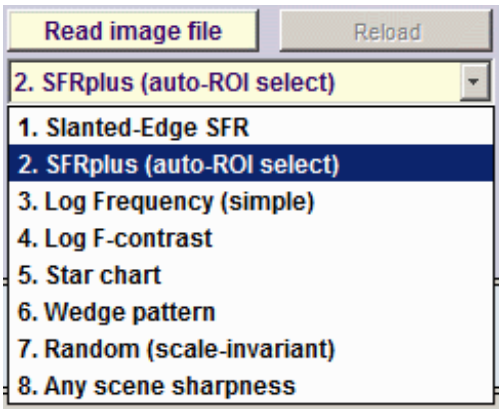
Mount the chart on a flat dark board— 1/2 inch foam board works well; thinner board warps more easily. Depending on the number of horizontal pixels in the chart to be analyzed, the chart should occupy 1/3 to 1/4 of the horizontal frame. Other charts can be mounted along with it.

Orientation. The pattern may be rotated by multiples of 90 degrees from the orientation shown: it may be have portrait as well as landscape orientation.

Photograph the chart using the sort of lighting described in Imatest Lab or How to test lenses, taking care to avoid glare. Save the image in any one of several high quality formats, but beware of JPEGs with high compression (low quality), which will show degraded quality, unless, of course, you are testing JPEG degradations. (Unlike the slanted-edge, the Log f-contrast pattern reveals JPEG losses quite clearly). RAW images decoded with dcraw tend to produce *very* different results from in-camera JPEGs.

Open Imatest, then click on . The Rescharts window is described in the Rescharts page.

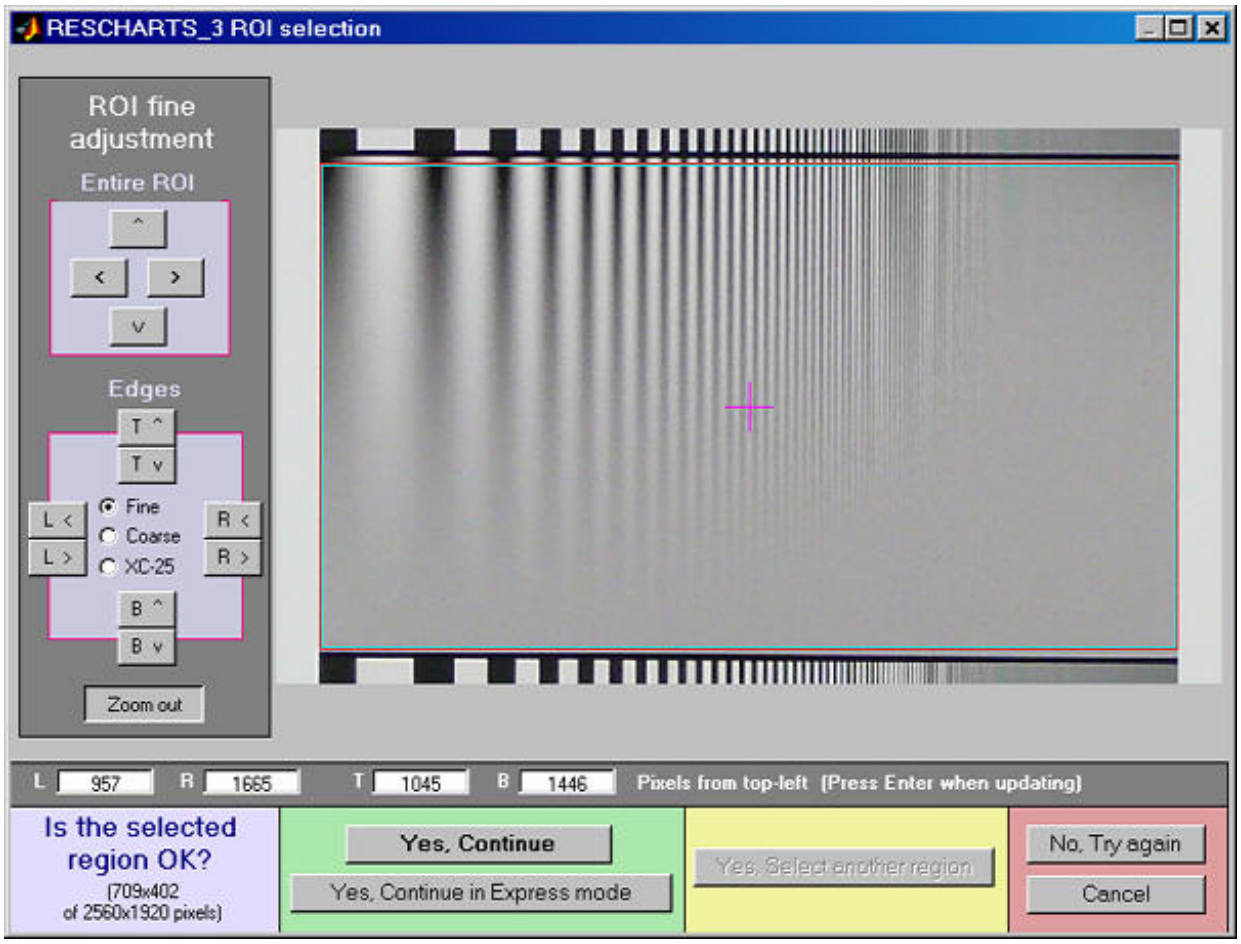
Select a pattern to analyze (in this case, **Log F-contrast**) by clicking on one of the entries in the popup menu below **Chart type** or by clicking on if **Log F-contrast** is displayed. The button and popup menu (shown on the right) are highlighted (yellow background) when Rescharts starts.



Select the image to read. If the pixel size is the same as the previous Log F-contrast run, you'll be asked if you want to use the previous ROI, adjust the previous ROI, or crop anew.

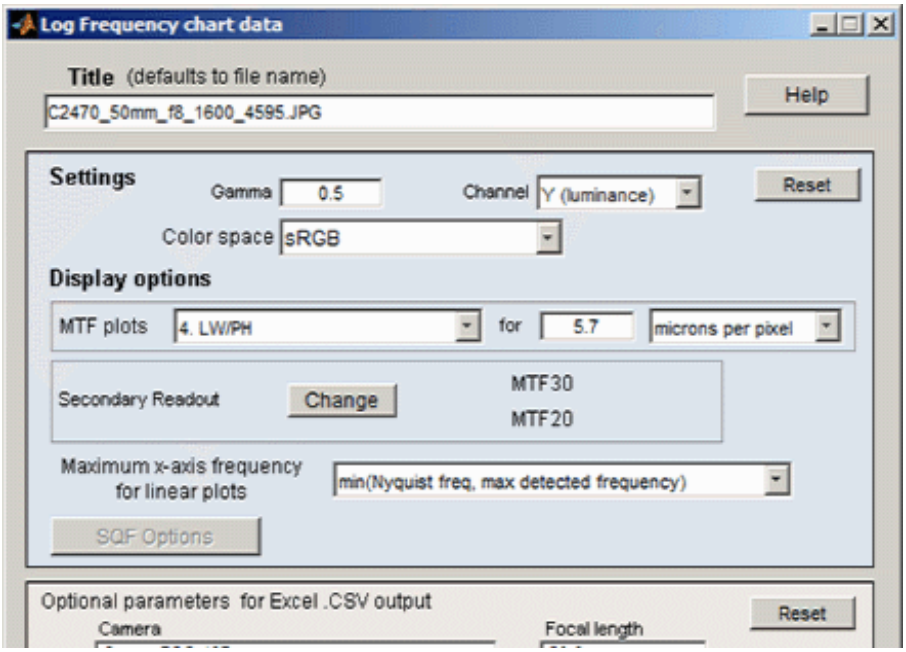
Cropping The pattern should be cropped to leave a small

margin (about 1/2 – 1% of the image height) at the top and bottom of the pattern, as shown below. The fine adjustment window may be maximized to facilitate fine selection.



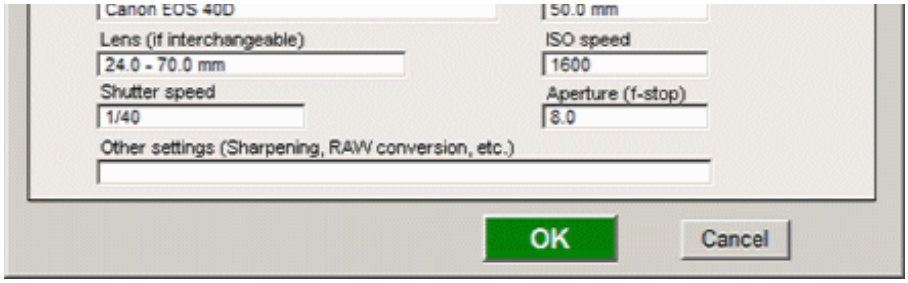
Crop for the Log Frequency-contrast chart. Leave a small margin (1/2 – 1% of the image height) at the top and bottom.

If **Express mode** is ***not*** selected, the input dialog box shown on the right appears. Since this dialog box is used for several modules, some entries, such as Color space and SQF, are not relevant to Log F-Contrast.



Gamma is used to linearize the test chart. It can be measured by Stepchart or Multicharts using the 16-step (0.1 density increment) grayscale below the Log F-C pattern. 0.5 is a typical value for

color spaces intended for display at gamma = 2 2 (sRGB, Adobe RGB, etc.).



Channel is R, G, B, or Y (luminance; the default).

MTF plots selects the x-axis scaling. If Cycles/inch or Cycles/mm are selected, the pixel spacing (um/pixel, pixels/inch, or pixels/mm) should be entered.

X-axis scaling for linear plots selects the maximum spatial frequency to be displayed.

Don't worry about getting all settings correct: You can always open this dialog box by clicking on in the Rescharts window.

After you press , calculations are performed and the most recently-selected display appears.

Output

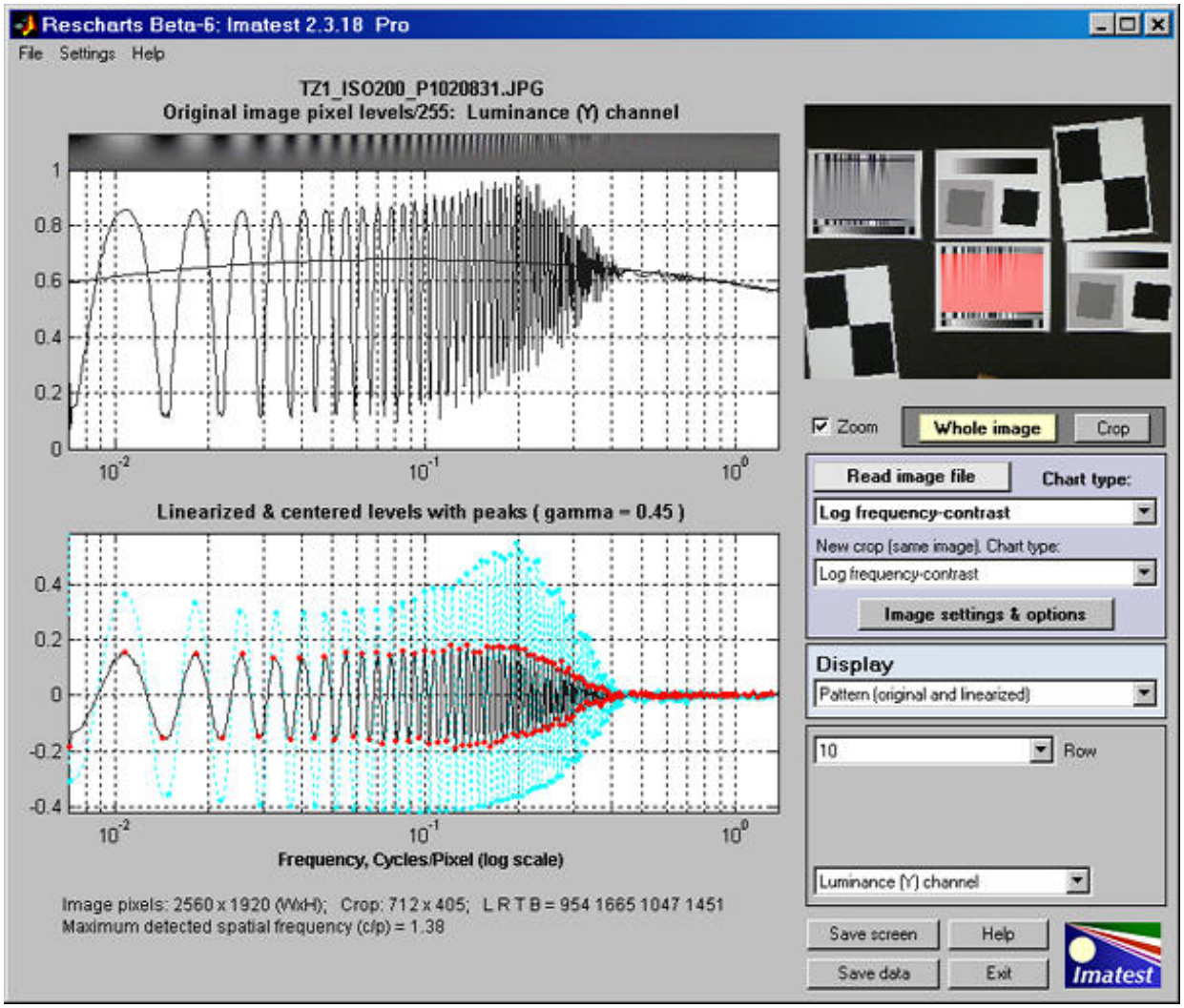
The **Display** box in the Rescharts window, shown below, allows you to select any of several displays. Display options are set in boxes that appear below Display. All displays except Exif data have a channel selection option (Red, Green, Blue, or Luminance (Y) (0.3R + 0.59G + 0.11B).

Display	Description
Pattern (original and linearized)	Show pattern: normalized pixel levels (max contrast) on top; linearized (max contrast and selected row) on bottom
MTF (Linear frequency scale)	Display MTF for several contrast levels (rows 1-22 in steps of 3, where the chart is divided into 25 rows for analysis) with a linear frequency scale.
MTF (log frequency scale)	Display MTF for several contrast levels (rows 1-22 in steps of 3) with a log frequency scale. A thumbnail of the pattern is also displayed on the same scale.
MTF/contrast (2D pseudocolor contour)	Only affects the bar region; not important for this pattern.
MTFnn	Displays MTFnn or MTFnnP (frequencies where MTF = nn% of low frequency

(frequency where MTF = nn%)	values or peak, respectively). Displayed in selected frequency units (cycles/pixel, LW/PH, etc.) or normalized
EXIF data	Show EXIF data if available.
	Saves an image of the Starchart window as a PNG file. If you check Display screen in the Save screen dialog box, the image will be opened in the editor/viewer of your choice. (Irfanview works well, and it's free.)
	Saves detailed results in a CSV file that can be opened by Excel and also in an XML file.

> ***In addition to the displays, two buttons allow you to save results.***

Pattern (original and linearized)

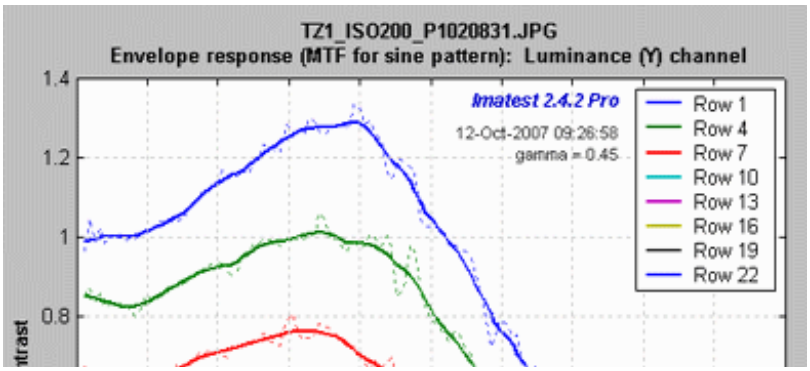


Pattern: original and linearized

The entire Rescharts window is shown. The upper plot is the normalized pixel level (pixel level/255 for bit depth of 8) of the top of the image (row 1 of 25; where contrast is maximum). The lower plot (linearized using the gamma setting) allows the row to be selected: The cyan plot is the top of the chart (the highest contrast). Note that row 10, which is displayed in black, has much less sharpening (much less of a peak around 0.2 cycles/pixel) than maximum contrast row 1.

MTF

The display on the right shows *unnormalized* MTF on a linear frequency scale for several contrast bands (rows) of the chart, which is divided into 25 rows for analysis, with the highest contrast at the top and lowest at the bottom. MTF is displayed for rows 1, 4, 7, 10, 13, 16, 19, and 22.

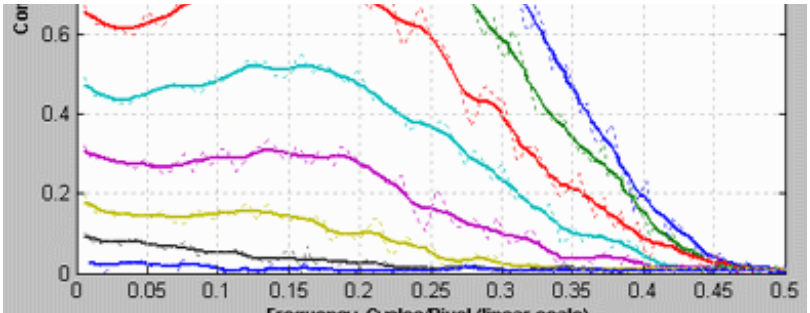


The **dark** lines have been strongly smoothed. The pale dashed lines are the unsmoothed results: the fine detail consists of calculation artifacts caused by phase variations and noise; it has ***no*** significance.

An unnormalized or normalized plot may be selected in a dropdown menu in the plot settings area.

The maximum display frequency, the display scale (cycles/pixel, cycles/mm, cycles/in, or LW/PH (Line Widths per Picture Height, where 2 Line Widths = 1 cycle or line pair)), and gamma can be set to any of several options by pressing the button.

The text beneath the plot shows the contrast (at low spatial frequencies) and MTF*nn* and MTF*nn*P (the spatial frequencies where response falls to *nn*% of the low frequency and peak values, respectively) for *nn* = 50, 20, and 10%, and for rows 1, 4, 7, 10, 13, 16, and 19. The same results appear beneath the 2D pseudocolor and MTF*nn* displays.

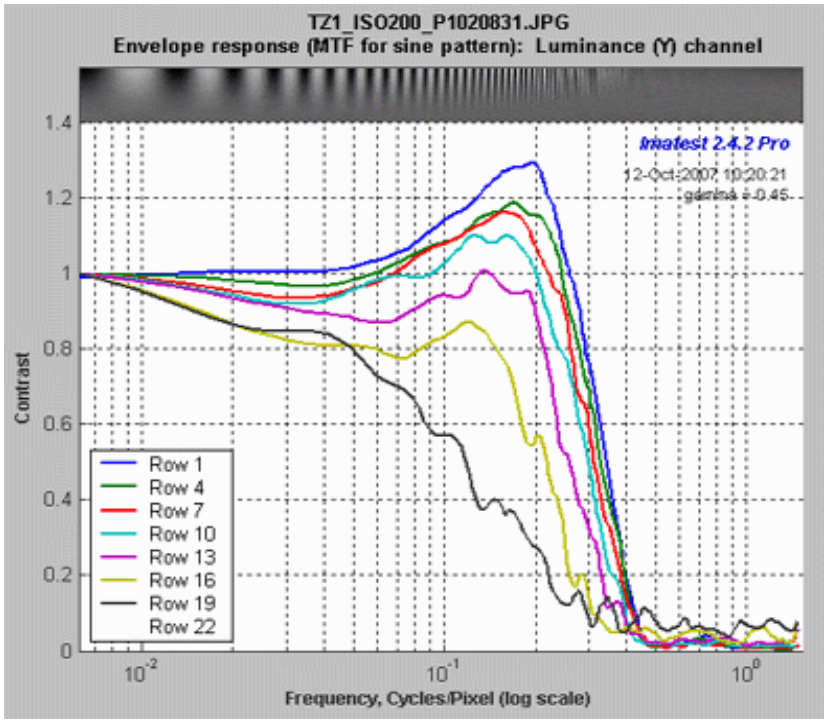


Row	Contrast	MTF50	MTF50P	MTF20	MTF20P	MTF10	MTF10P	Row
1	0.992	0.344	0.321	0.396	0.39	0.431	0.418	1
4	0.851	0.328	0.316	0.396	0.387	0.421	0.411	4
7	0.649	0.313	0.302	0.384	0.375	0.421	0.408	7
10	0.467	0.302	0.29	0.363	0.35	0.399	0.399	10
13	0.302	0.262	0.258	0.334	0.328	0.393	0.393	13
16	0.173	0.221	0.218	0.26	0.26	0.313	0.309	16
19	0.0892	0.121	0.117	0.221	0.221	0.302	0.292	19

MTF: Panasonic TZ1, ISO 200, Linear frequency scale

The display on the right shows

the same MTF results, normalized and plotted on a logarithmic frequency scale. Normalization makes it easier to compare MTF falloff and to visually determine MTF*nn*. A vertically squeezed version of the image is shown just above the plot. Row 22 (very low contrast) is omitted because normalization exaggerates noise unacceptably. The contrast for each row is shown in the table below the image.

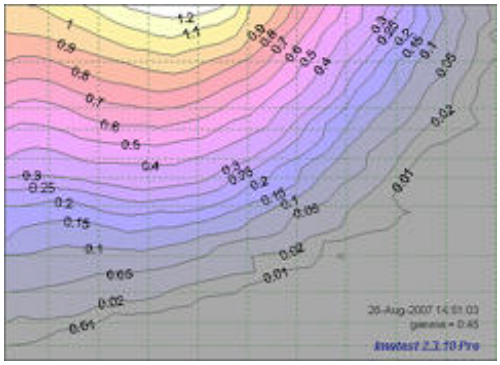
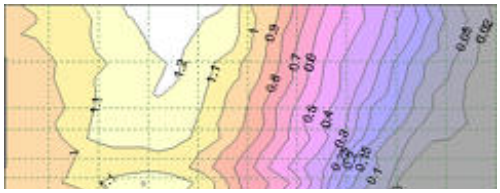


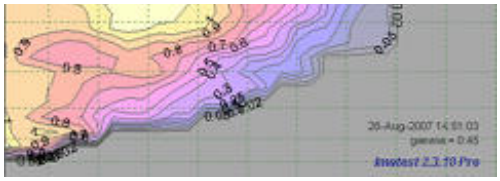
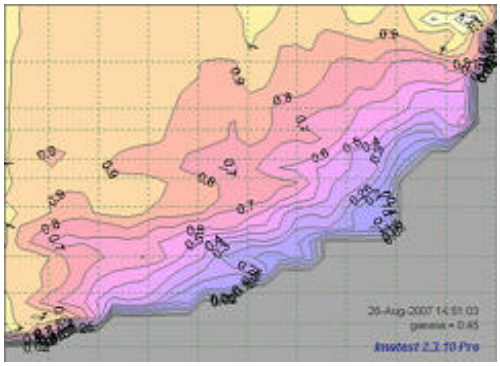
MTF: Panasonic TZ1, ISO 200, Log frequency sc

MTF/contrast (2D pseudocolor contour)

This selection produces the most detailed results. It has several options:

Parameter determines which parameter to display.

Parameter	Description	
MTF (envelope-standard)	**Displays MTF**, which decreases with chart contrast (height in the 2D pseudocolor display). The chart is divided into 25 rows for analysis. MTF at low spatial frequencies is equal to chart contrast.	
Normalized contrast level	**Displays MTF normalized to 1 at low spatial frequencies for all chart contrast levels.** ***This may be the most generally useful display*** because it clearly	

	shows how response changes with contrast level (with the low spatial frequency contrast level removed). In a camera with uniform signal processing (i.e., the same sharpening and noise reduction throughout the image, regardless of the presence of edges), ***the contour lines would be vertical***. Most cameras have a degree of sharpening (high frequency boost) in the presence of contrasty edges and noise reduction (high frequency attenuation) in their absence. This is evident in the display on the right (explained in more detail below).	
Normalized contrast loss	Displays MTF normalized to 1 • at low spatial frequencies for *all* chart contrast levels, and • at the maximum contrast level for *all* spatial frequencies (the top of the chart). Results can be difficult to interpret, especially in the presence of noise.	

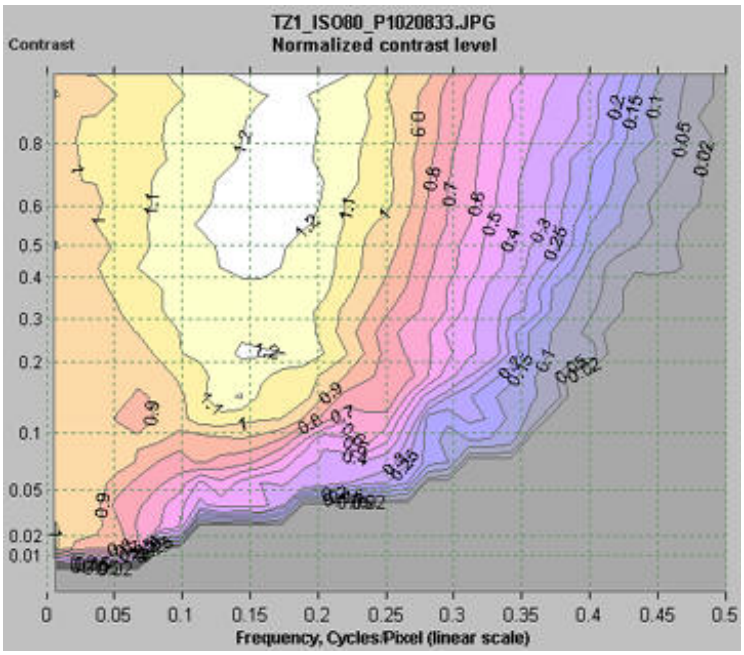
Style selects the frequency scale and whether to show a color bar to the right of the main display.

Style	**Description**
Log frequency	The horizontal axis displays frequency on a logarithmic scale. The maximum display frequency can be set by pressing .
Log frequency, color bar	The horizontal axis displays frequency on a logarithmic scale. The maximum display frequency can be set by pressing . A color bar showing the color scale is displayed to the right of the main plot.
Linear frequency	The horizontal axis displays frequency on a linear scale.
Linear frequency,	The horizontal axis displays frequency on a linear scale. A color bar showing the color scale is displayed to the right of the main plot.

color bar	

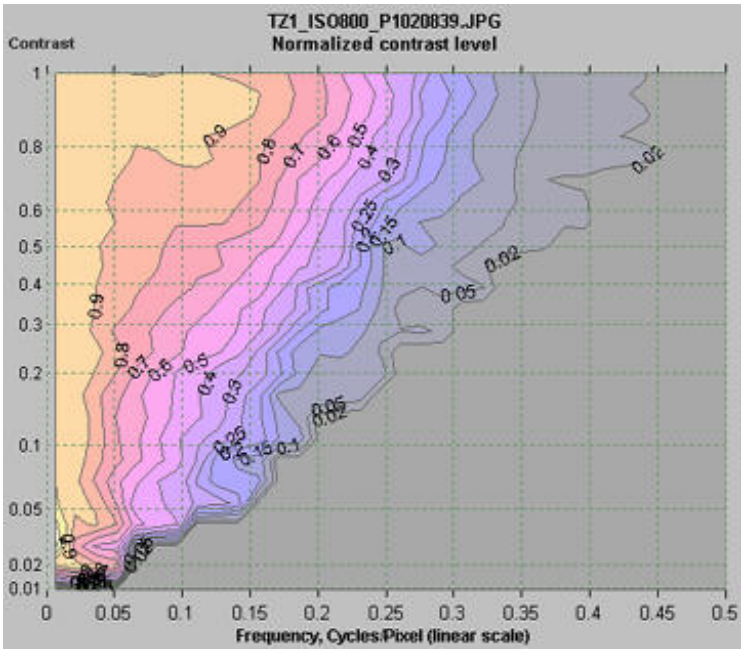
The displays on the right show the Normalized contrast level (MTF normalized to 1 at low spatial frequencies for all chart contrasts) for the Panasonic TZ1 camera with ISO speed set at 80 (right) and 800 (right, below). Spatial frequency is displayed on a linear scale with a maximum frequency of 0.5 cycles/pixel (selectable by pressing).

The image on the right (ISO 80) shows significant sharpening at moderate to high contrasts: peak normalized contrast is 1.2 or more for chart contrast greater than 0.4 and 1.1 or greater for chart contrast greater than 0.11. The amount of sharpening decreases gradually with chart contrast, ad evidence by the moderately slanted contour lines between 0.9 and 0.1 at contrasts over 0.1.



Normalized contrast: Panasonic TZ1, ISO 80

The difference between the two images is striking. At ISO 800 the TZ1 has much less sharpening and more noise reduction— and correspondingly less detail. The amount of sharpening decreases more rapidly with contrast than for the ISO 80 case, as shown by the much more slanted contour lines.



Normalized contrast: Panasonic TZ1, ISO 800

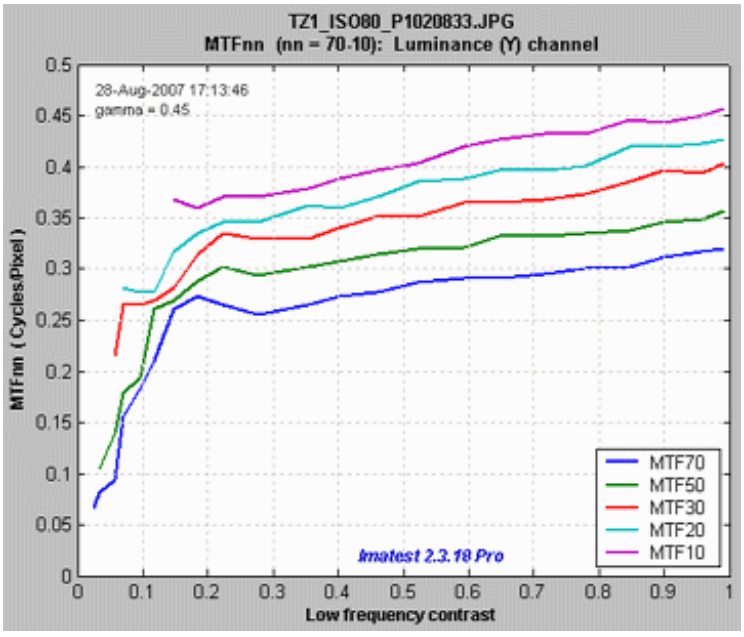
MTFnn (frequencies where MTF = nn% of low frequency or peak values)

This selection produces a concise summary of results for this module. It has several options:

Parameter	Description
MTF*nn*	The spatial frequency where MTF drops to *nn*% of its low frequency value. Curves are plotted for *nn* = 70, 50, 30, 20, and 10 (%). MTF50 is the most frequently used result; it corresponds to bandwidth in electrical engineering. The horizontal axis is the original chart contrast (analyzed in 24 rows). The vertical axis is the MTF frequency. Its scale (cycles/pixel, cycles/mm, cycles/in, or LW/PH) can be set by pressing .
MTF*nn*P	The spatial frequency where MTF drops to *nn*% of its maximum (peak) value. Identical to MTFnn for unsharpened or moderately sharpened images, but it can be lower for strongly sharpened images, which have a distinct response peak. It has a slightly better correlation to perceived sharpness than MTFnn. Horizontal and vertical axes are identical to MTFnn.
MTF*nn* NORMALIZED	The spatial frequency where MTF drops to *nn*% of its low frequency value, normalized to 1 at low spatial frequencies. This allows the percentage change of MTF*nn* with chart contrast (horizontal axis) to be conveniently compared.
MTF*nn*P NORMALIZED	The spatial frequency where MTF drops to *nn*% of its maximum (peak) value, normalized to 1 at low spatial frequencies. This allows the percentage change of MTF*nn* with chart contrast (horizontal axis) to be conveniently compared.

The plots on the right show MTF70 through MTF10 in units of Cycles/Pixel for the Panasonic TZ1 camera with ISO speed set at 80 (right) and 800 (right, below). They are derived from the same images as the Normalized contrast level plots, above.

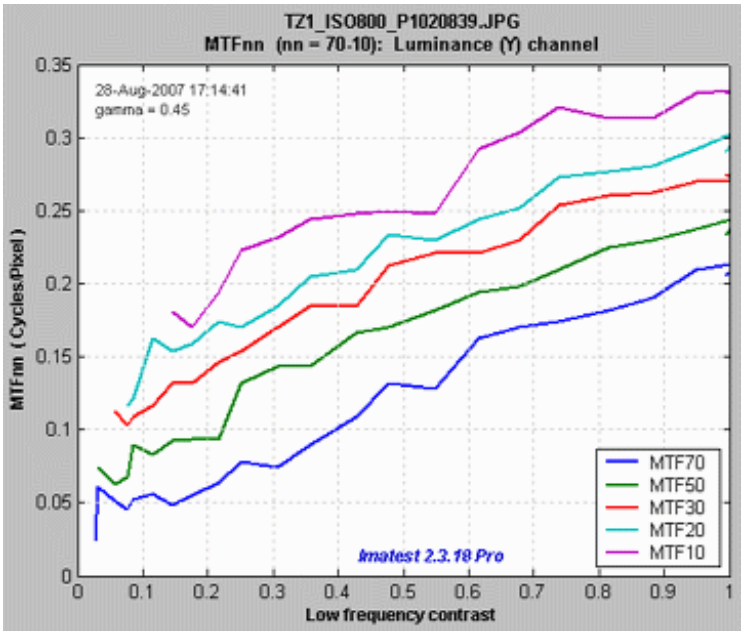
The MTF*nn* units (Cycles/pixel to Cycles/mm, Cycles/in, or LW/PH) can be selected using the button.



MTF70-MTF10: Panasonic TZ1, ISO 80

At ISO 800 the TZ1 has much lower MTF*nn* for all values of *nn* from 70 through 10. Note that the vertical scales are different: 0.5 (above; ISO 80) vs. 0.35 (right; ISO 800).It also falls off much more rapidly with contrast; evidence of stronger noise reduction, i.e., ***nonlinear signal processing***.

The MTF*nn* display shows the changes in performance between different settings (ISO 80 and 800 in this case) more clearly than the 2D pseudocolor contour plots, above, even though (or perhaps *because*) it contains less detail.



MTF70-MTF10: Panasonic TZ1, ISO 800