Preservation Microfilm Scanner Target and Imaging Performance Software (*Mscan*)

User Guide

Version 2.0
25 May 2010

1.0 Target Description

1.1 Introduction

Four identical target frames, each one covering the full width of 35mm silver halide B&W film, are spliced onto a microfilm spool with 6 ft. of leader and trailer. They are intended to be used for grayscale image performance evaluation of digital scanners for preservation microfilm formats. The nominal background density is 1.00. In addition to providing for microfilm grayscale metrology between optical densities of 0.10 to 1.40, it allows measuring film plane resolutions to 210 cy/mm (10617 dpi) in a single integrated target. The tables below lists how these numbers translate to equivalent maximum sampling rates for common preservation microfilm reductions when referred back to the original document.

Reduction	Max. Equivalent DPI at original document		Desired sampling rate (DPI)	Max. allowed Reduction
10x	1061 dpi	or	200 dpi	53x
15x	708 dpi		300 dpi	36x
20x	530 dpi		400 dpi	27x
25x	424 dpi		600 dpi	18x

1.2 Target Features

A thumbnail image of a single frame of the target is provided in Fig. 1.1.

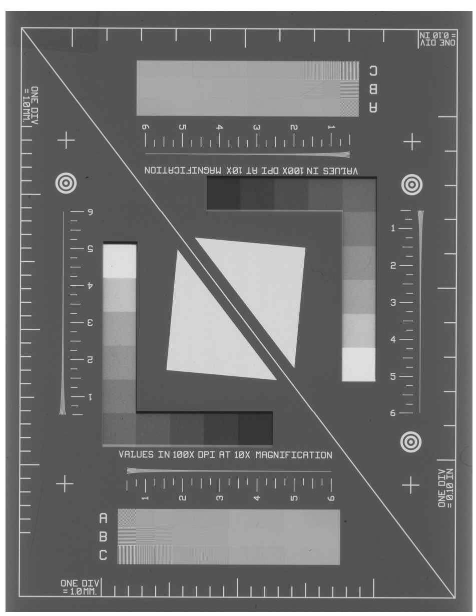


Fig. 1.1, Grayscale rendering of a single frame of the preservation microfilm grayscale target

For ease of documentation, a graphically annotated depiction of the target is presented in Fig. 1.2. The features indicated by the circled numerals are described in detail below.

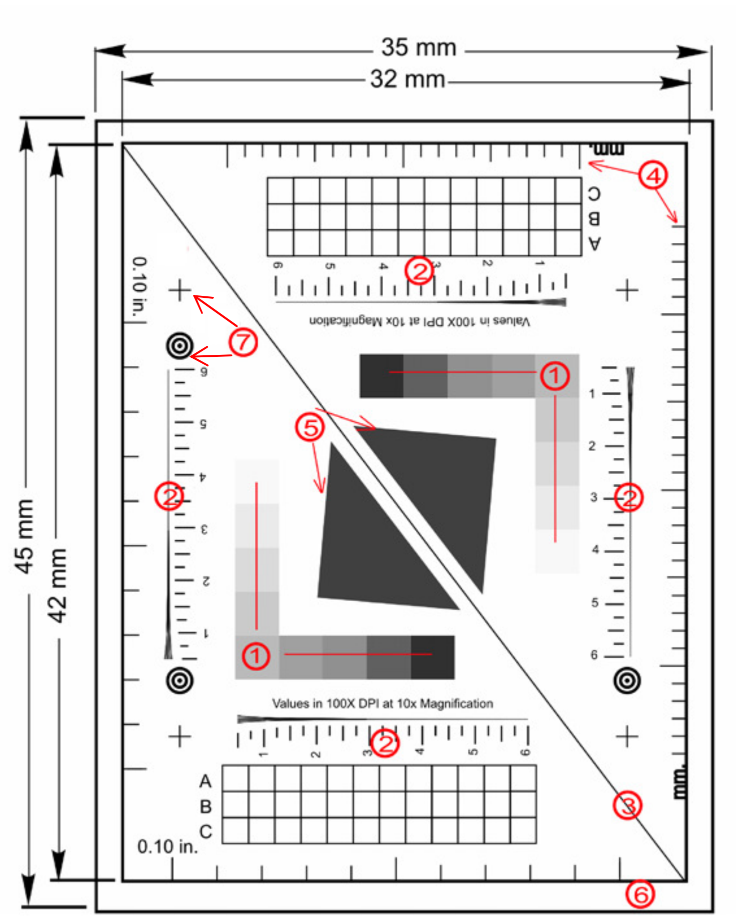


Fig. 1.2, Annotated rendering of microfilm target

1) Grayscale patches – Intended to measure the Opto-Electronic Conversion Function (OECF) as described in ISO 14524. Two identical sets are provided to insure consistency. Optical transmission densities range from 0.10 to 1.40. The supplied software displays a graph of the OECF in terms of count value vs. optical density.

2) Visual Resolution Features- Both horizontal and vertical 5-line resolution elements are provided for separately evaluating vertical and horizontal resolution performance. Two identical sets are included for each direction. The labeled numerical values along each element are scaled (100x) indicators of resolution imaging performance (in dots per inch) relative to the original imaged document assuming a 10x reduction. Translating to other magnifications can be done by multiplying by the ratio of 10 to the desired reduction level. For instance, if the five line features visually disappear at the "4" level, this would indicate a 4 x 100 = 400 dpi true resolution at a 10x

reduction. The equivalent resolution level at 20x reduction would be 400 x 10/20 = 200 dpi.

A matrix of periodic resolution patterns is also included near the top and bottom of the frame. This is intended to complement the neighboring 5 line resolution features. A magnified view of this feature is shown in Fig. 1.3 below.

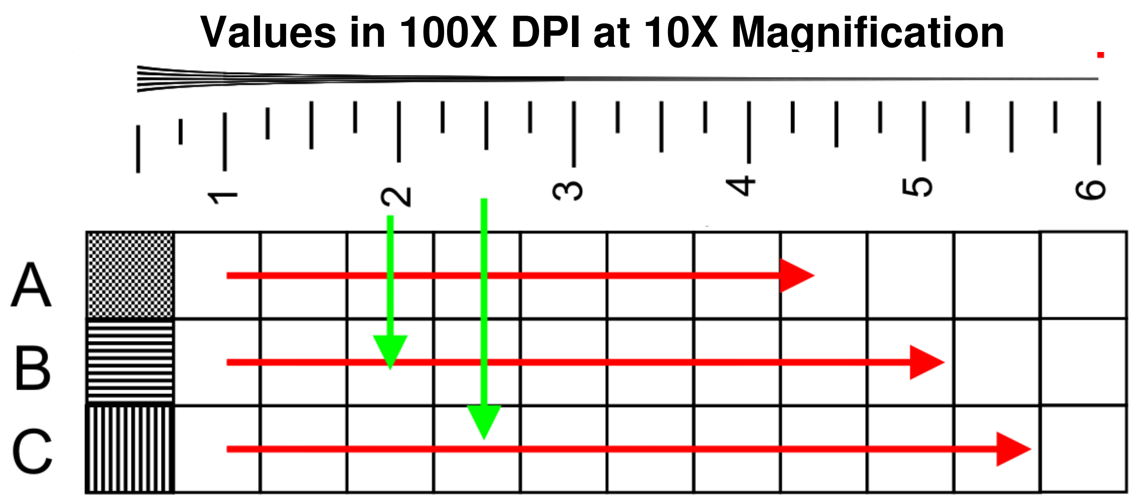


Fig. 1.3, Checkerboard and repeating line patterns of microfilm target
Row A - checkerboard pattern   Row B - horizontal line pattern   Row C - vertical line pattern

The labeled numerical values are resolution indicators for both the 5 line resolution wedge and the ABC matrix elements beneath them. The matrix boxes in each row are incremented by 50 dpi (at 10x reduction) and increase in spatial frequency as illustrated above.

3) Corner-to-corner diagonal line – This is a common feature used in linear array scanner testing and is intended to measure sampling and scan motion fluctuations. The image of the line should be straight but will appear to wane or wobble along its length where fluctuations occur. The companion software provides a deviation metric and graph to help measure these fluctuations.

4) Metric and English rulings – These features are intended to act as verifying tools for sampling frequency (e.g., dpi)

5) Slanted Edges – These edge elements provide the means to measure spatial frequency response (SFR) in both the horizontal and vertical direction as described in ISO 16067-2. SFR is a fundamental resolution metric. It also provides a measurement of the modulation transfer function (MTF). The spatial frequency associated with the 10% SFR response is often considered a threshold value for limiting spatial resolution. These values are reported in the results panel of the software used to analyze the scanned images. For more

information on SFR and MTF and its utility the reader is referred to What is an MTF… and why should you care?, Williams, Donald. 1998. RLG DigiNews, v.2, no. 1 (Feb. 15). Available from *Here.*

6) Uninterrupted film width – This area can be used to define a full width rectangular region of interest (ROI) to characterize banding and streaking problems often associated with improper illumination or detector corrections of scanners.

7) Crosshair and circle fiducial marks – There are four crosshair marks in a one inch square formation. The distance between these marks are used to measure spatial distortion between the horizontal and vertical dimensions. Ideally, the ratio of the number of pixels between the horizontal crosshairs to the number of pixels between the vertical crosshairs should be one. Any deviation from this ratio is considered distortion.

2.0 Scanner Testing Procedures Guidelines

Microfilm scanners have a variety of software settings that will yield a variation in performance results. For instance, while high speed scanning modes provide good throughput, resolution and distortion performance is likely to suffer compared with those from lower speed operations. Similarly, auto-exposure modes give variable tone responses (i.e. OECF) compared to fixed settings. Scanner performance and analysis results are dependent on software driver settings as well as hardware configurations. An imaging system, not just a camera, is being assessed. The choice of scanner settings can dramatically affect performance.

It is vital, therefore, to document the settings used when scanning the targets. As a start, these settings should reflect, as much as possible, the settings used in daily production work. From there, changes to the scanner settings can be made to improve peak imaging performance and consistency. It is perhaps the latter item, consistency, which is of most importance for imaging workflows. While achieving optimal imaging performance from a scanner is an admirable goal, maintaining that performance from scan-to-scan can often be a challenge, especially in day-to-day operations. Often accepting a larger number of good scans rather than a smaller number of excellent ones is a more practical goal.

The target could be used for the purposes of benchmarking new equipment as well as validating of session-to-session performance consistency. Some suggestions for each follow. Also, mechanical damage to the target is inevitable due to film transport in scanners. Be sure to replace it when dust, scratches, and digs render it useless for good metrology practices.

Also, practice good scanner and film target hygiene. Prevent dirt and dust accumulation. Clean the film targets, optics, and transport systems before benchmarking experiments and do so periodically afterwards.

2.1 Benchmarking Procedures

Scan film target under typical operating conditions using speed, dpi, and exposure settings established for testing. Be judicious in selecting sharpening settings by moderating the selections. Over sharpening an image can lead to un-natural looking image content as well as increased noise levels. To the extent possible, as much of the full width and length of the target area should be scanned. Any one of the four replicate frames is suitable but one of the middle two is preferred.

A generalized benchmarking test plan would include scans at a variety of scanners settings, For instance,

- For a given sampling rate (i.e. dpi setting) and scan speed, perform grayscale scans at 10x, 15x, and 20x reductions. Repeat at least three times.

- Change the scan speed from the above and repeat for one scan each.

- For a given sampling rate and reduction setting, vary the tone settings or sharpening settings and perform a grayscale scan.

- If multiple film targets were purchased, include them as part of the benchmarking experiment. While the film targets were characterized, they were done so on a statistical batch basis. Variability within the batch does occur. Be sure to somehow document each target with a unique label.

The results of the benchmarking session will allow one to make decisions on the scanner settings to use for the best combination of image quality and workflow production (speed of operation) for a given task. Once established, these task specific scanner settings should be documented and used consistently. They will provide the basis for future session to session performance tracking.

2.2 Periodic and Random Performance Verification

The benchmarking results will act as an aim for periodic scanner performance monitoring. A good starting point for monitoring performance variability is on a session-to-session basis. Scanning the target and comparing the imaging performance at the beginning and end of every session to the benchmark aim are common and standard procedures. Verification scans should also be done when operator, scanner hardware, physical location, or scanner setting modifications are made. Random audits are also helpful for identifying unexpected performance variation.. Occasionally, there is even film target variability. If a new target does need to be used, do not immediately dispose of the old targets until you are confident that the transition performance is acceptable.

3.0 Using Imaging Performance Software (Mscan)

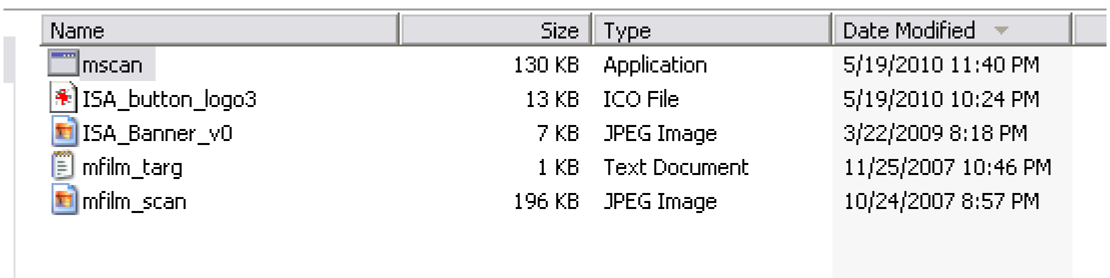
Two software components are required to begin running the microfilm performance software. One is MCR (Matlab Component Runtime, 2008b), which loads all of the libraries and structures required for the second executable form of the software, Mscan. Once these libraries have been installed, all executable versions of the software can be easily updated and run without having to perform any further installations. The first task is to install the libraries.

3.1 Library Installation

Section 5.0 provides detailed instructions for installing the runtime libraries. Once completed, return to section 3.2 below.

3.2 Running Mscan executable

1) After un-compressing the mscan.zip file, the following folder content is provided.



Unzipped Mscan Folder

2) Launch the imaging performance evaluation software by double-clicking on *mscan.exe.* After doing so, a black command window (below left) appears that provides software launch status and error feedback information throughout the session. After a brief time, a new user interface window appears (below right) with instructions on how to proceed. Be patient for this new window to open while the appropriate libraries are loaded.

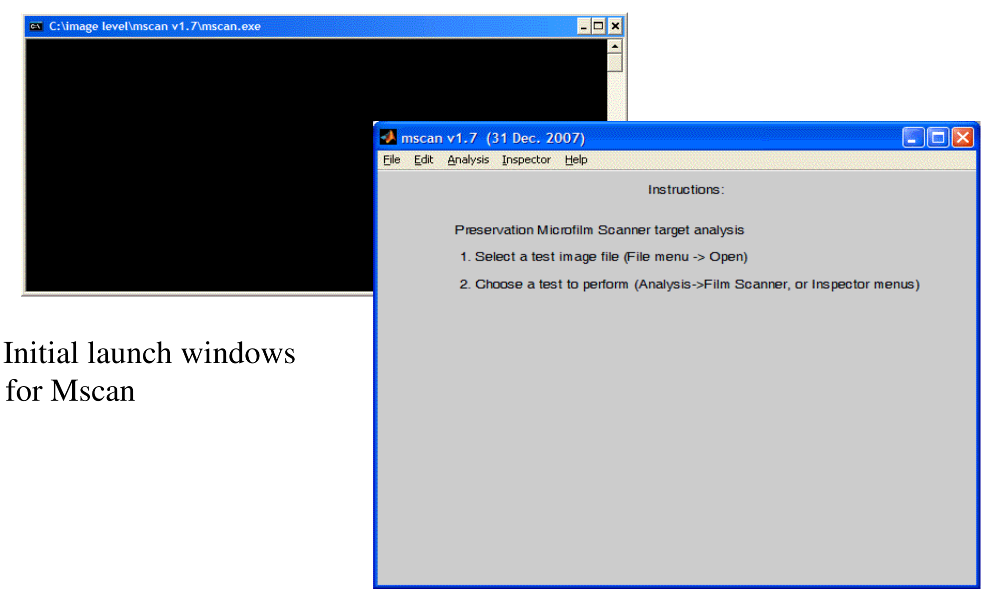


Fig. 3.2 – Initial launch windows for Mscan

3) As instructed, select a scanned image file to open (using File->Open menu) and evaluate from the menu bar. Currently, 8 bit grayscale images in JPG, uncompressed TIFF, BMP, and GIF formats are supported. Once an image file is selected, a thumbnail version is displayed as shown below along with its filename.

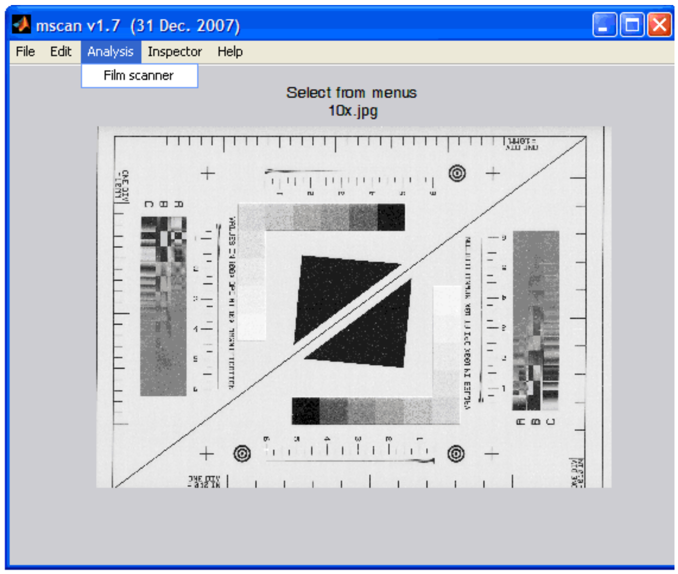


Fig. 3.3 – Thumbnail of selected image for analysis

4) Then choose *Analysis -> Film Scanner* from the menu bar. After a brief period a new window will appear with a set of moving crosshairs. Move the crosshairs via the mouse over the center of the first circular marks nearest the diagonal line (below left) and click the mouse button once. Do the same on the second set of circular marks nearest the diagonal line (below right).

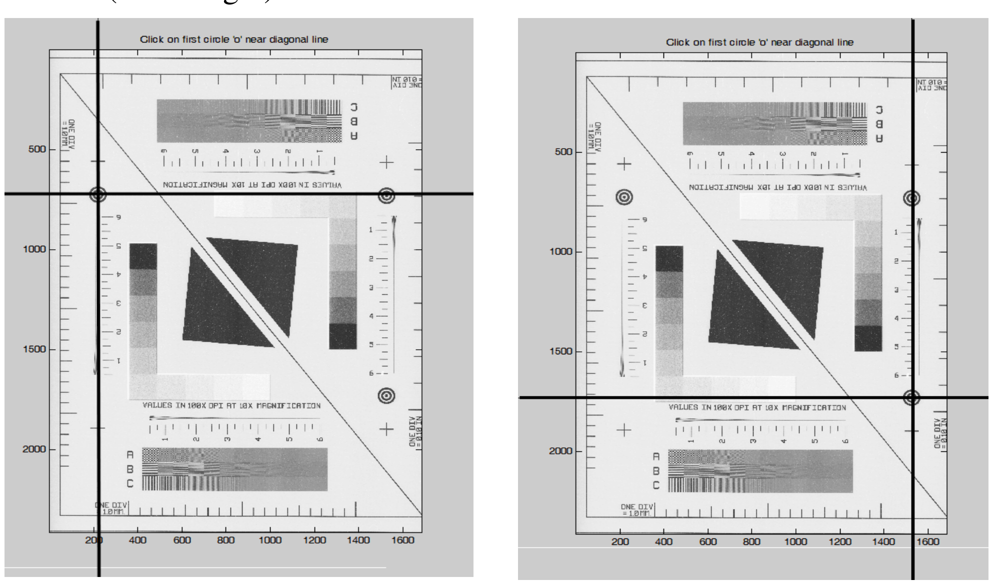


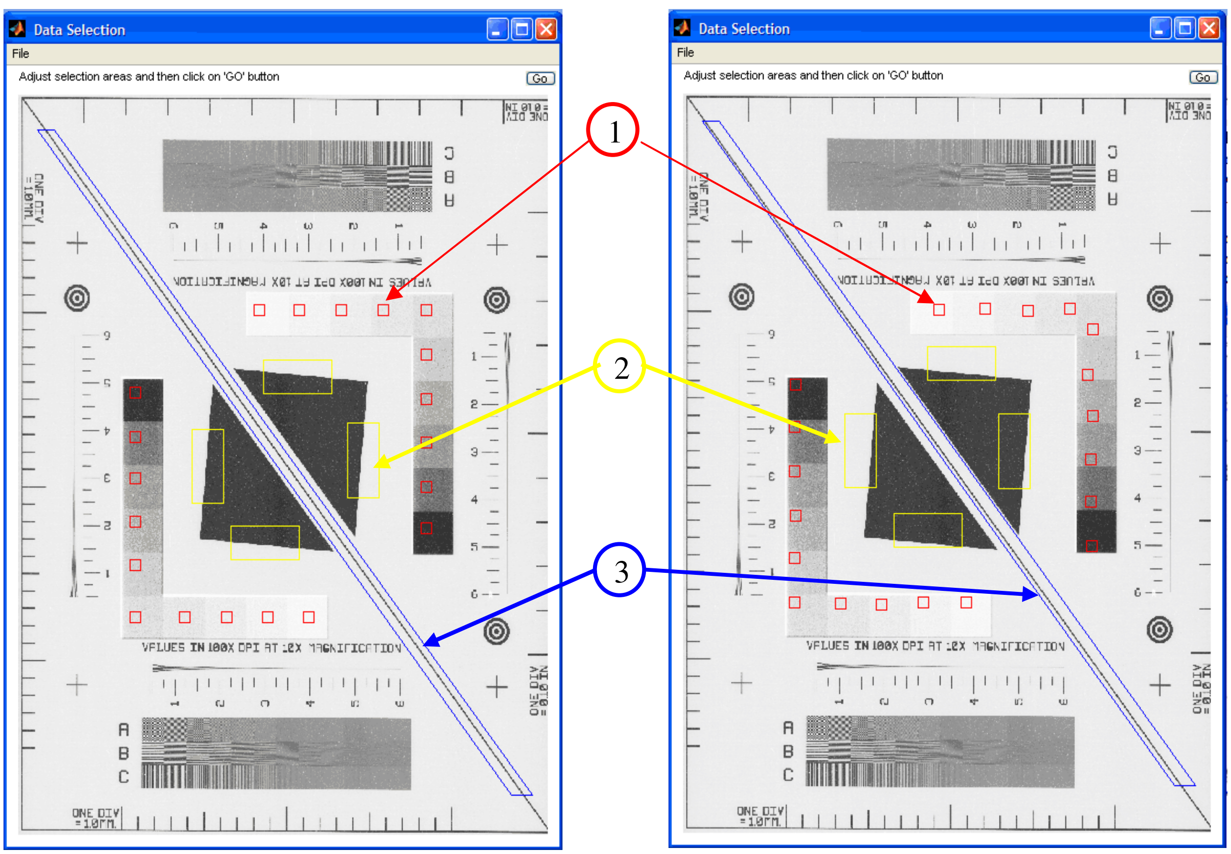
Fig. 3.4 – Fiducial selection windows

5) Finally, a new window appears (below) of the selected image with movable regions of interest (ROI) overlaid. Examples of proper and improper ROI placements are shown in the figures below. There are three sets of colored overlays, each associated with a different performance metric. They are:

1) Grayscale Density Patches (red) – used for calculating the OECF and such items as over or under exposure. The placement of these regions is not too critical. Try to avoid being too close to the patch edges as well as avoiding dust and scratches by moving the ROIs accordingly.

2) Slanted Edge Regions (yellow) – used for calculating resolution and SFR in the vertical and horizontal directions. The yellow box regions should straddle light and dark portions of the edge transitions somewhat equally.

3) Diagonal Line Region (blue) – Used for calculating wobble or micro distortion. The ROI should be located so that the line bisects the ROI as well as possible.



Proper ROI placements Improper ROI placements

Fig. 3.5 – Examples of proper and improper ROI placements

6) When satisfied with ROI placements, click on the *Go* button in the upper right hand corner of the window panel (below). A progress bar will appear followed by a performance results window shown in Fig. 3-3. The raw performance data can then be saved in a tab delimited text format suitable for most statistical or spreadsheet utilities by clicking on the *Save as* button in the lower left hand corner of the results panel.

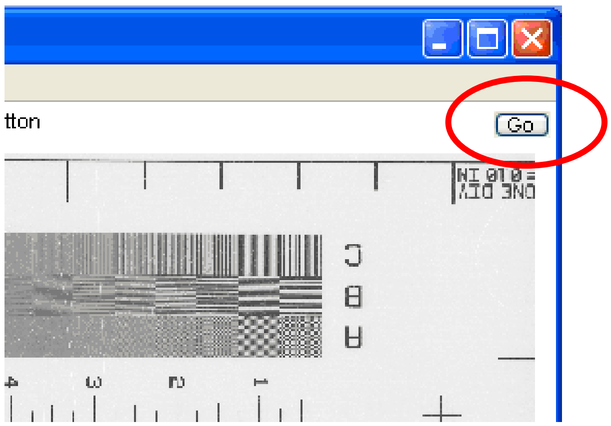


Fig. 3.6 – *Go* button location

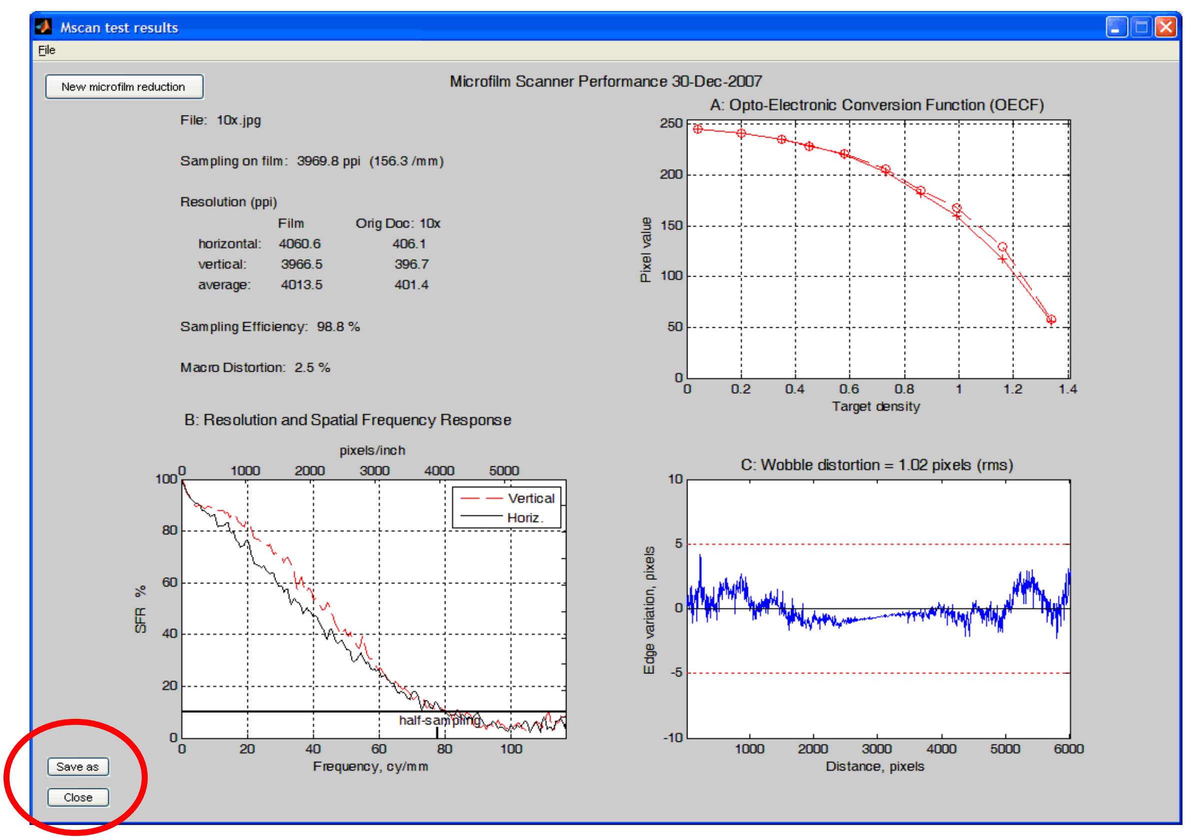


Fig. 3.7 – Test Results panel with highlighted *Save as* button

4.0 Understanding and Interpreting the Performance Results Panel and Auxiliary Target Features

Fig. 4.1 illustrates a typical performance results panel for a single image frame.

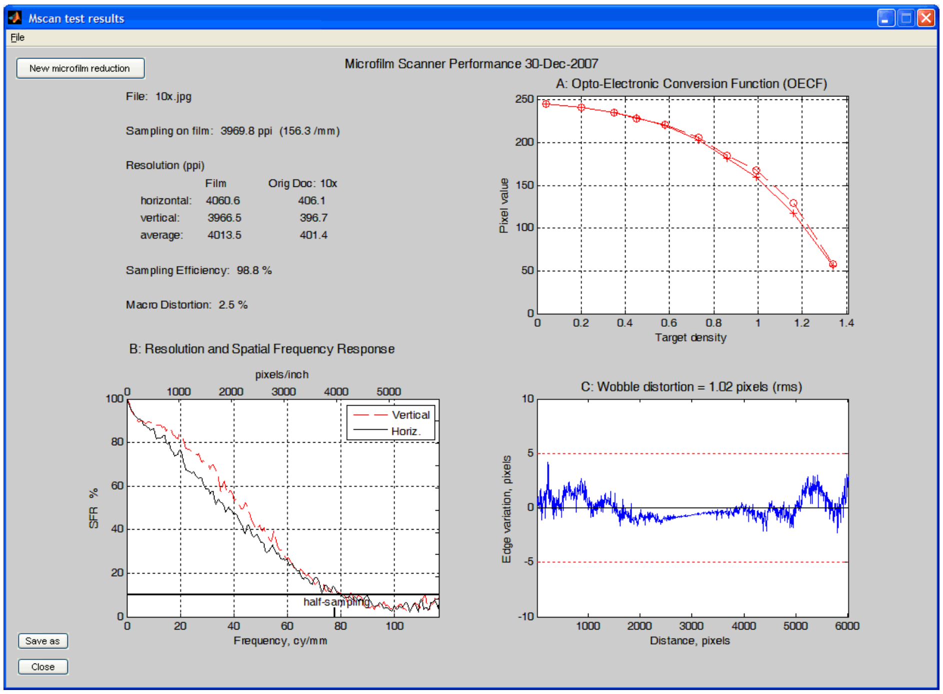


Fig. 4.1 - Typical performance results panel from Mscan software

The remainder of this section will describe what each of the graphs and supporting data on the panel mean, and how to interpret them in terms of imaging performance. There will also be a section on how to visually assess the auxiliary checkerboard and repeating line patterns for resolution.

4.1 Graph A - Tone Scale or Opto-Electronic Conversion Function (OECF)

Just as film's characteristic curve describes the relationship between input exposure and film density, the equivalent descriptor for a digital scanner or camera is the Opto-Electronic Conversion Function (OECF). As its name implies, it characterizes the conversion of optical exposure or density of the original object into electronically delivered pixel values of an image file. It is a map that describes the path from the object luminances to digital counts. An example of an OECF from the results panel is provided in Fig. 4.2. It is shown for a positively rendered image. Below it is an OECF for a negatively rendered image.

Both of the above OECFs were derived from the duplicate L-shaped gray patches that surround the slanted edge-features in the middle of the target field. Both circles and crosshair markers are plotted to reflect this duplicity. Differences in plotted pixel value for a given target density are an indication of illumination or scan non-uniformities

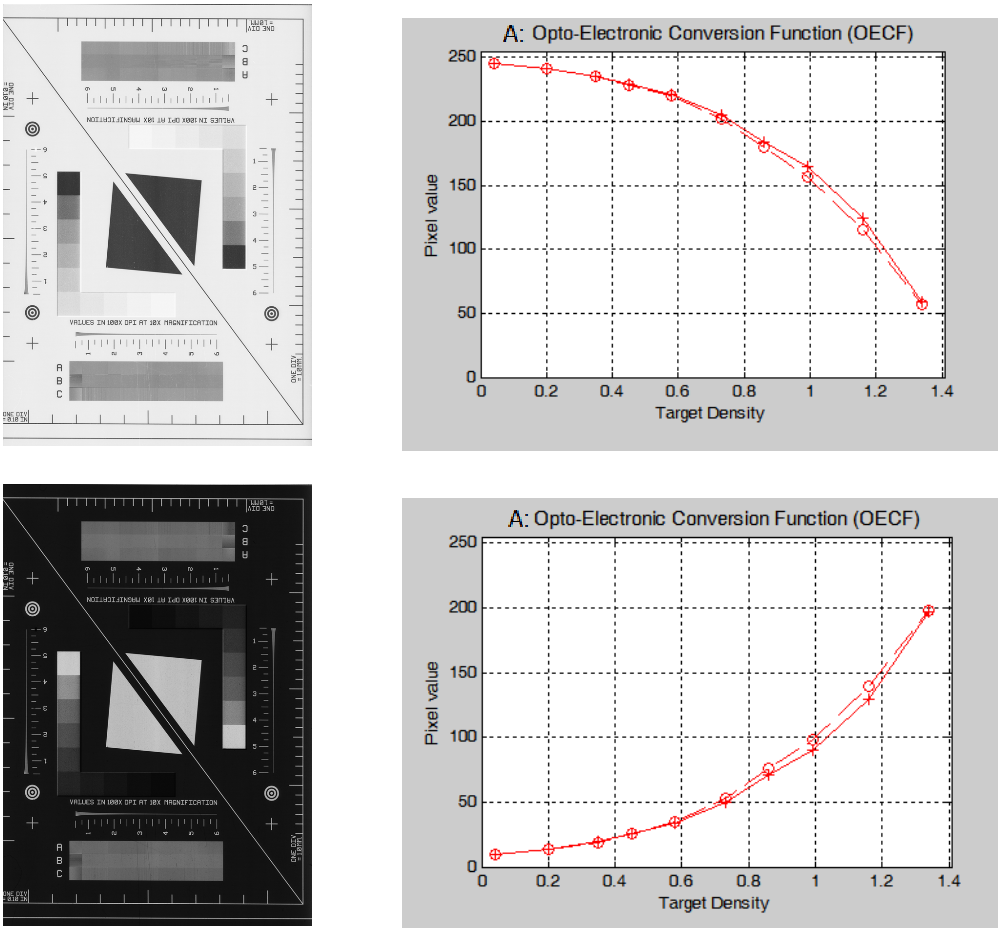


Fig. 4.2 - Positive (top) and negative (bottom) rendered target images and their companion OECF graphs.

While there is no single “best” OECF curve shape or aim, the example in Fig. 4.2 are considered well behaved OECF curves. There are two key traits that make them so. They are:

1) Discrimination - A significant difference in average pixel value between successive density patches.
2) Monotonic – Changing in one direction only, either strictly rising or falling without reversing direction

These two traits provide a resilient and unambiguous reversible path from pixel value to original film density. The density patches on the target were designed with typical microfilm densities in mind ($D_{max} \approx 1.4$). Still, some over-exposed film may have densities that exceed the design limit. The OECF curves of Fig. 4.2 accommodate well for this possibility by having a good amount of buffer pixel values available at the high density portion of the curve.

Other acceptable and unacceptable examples of OECF curves are provided in Fig. 4.2 and Fig. 4.3 respectively

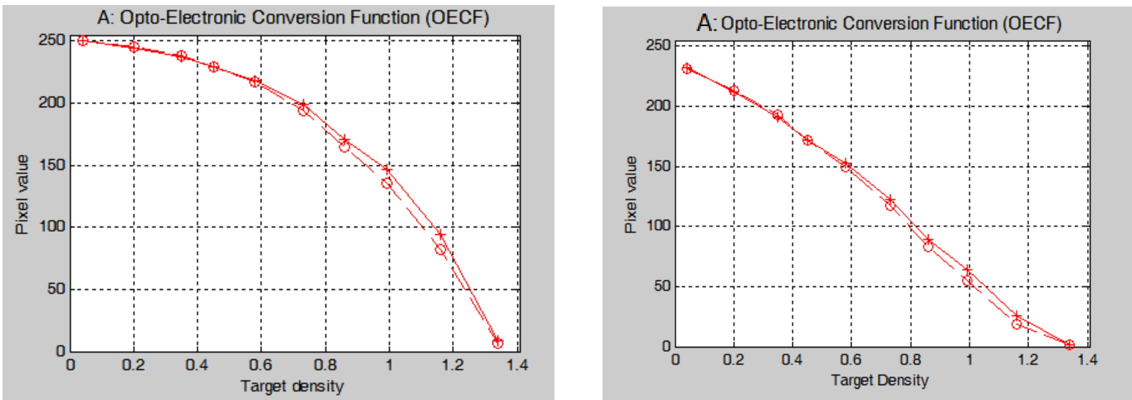
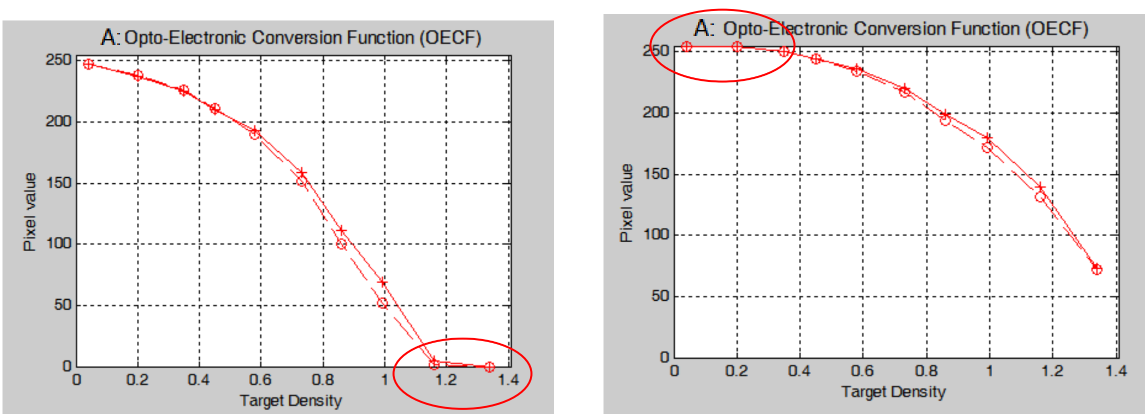


Fig. 4.2 – Examples of acceptable OECF curves that satisfy the discrimination and monotonic criteria. Note lack of pixel value buffer at high density region



under-exposure over-exposure

Fig. 4.3 – Examples of unacceptable OECF curves. Note the lack of pixel value discrimination at the high densities (left) and for the low densities (right)

4.2 Checkerboard and Repeating Line Patterns for Visually Judging Resolution

Fig. 4.4 illustrates the elements of the target that are intended for visually assessing resolution. There are two sets; a pair at the top and bottom of the frame for vertical resolution and a partial pair along the sides for horizontal resolution. Each pair's component elements are identical and are intentionally meant to be duplicates of one another in case outlier behavior occurs.

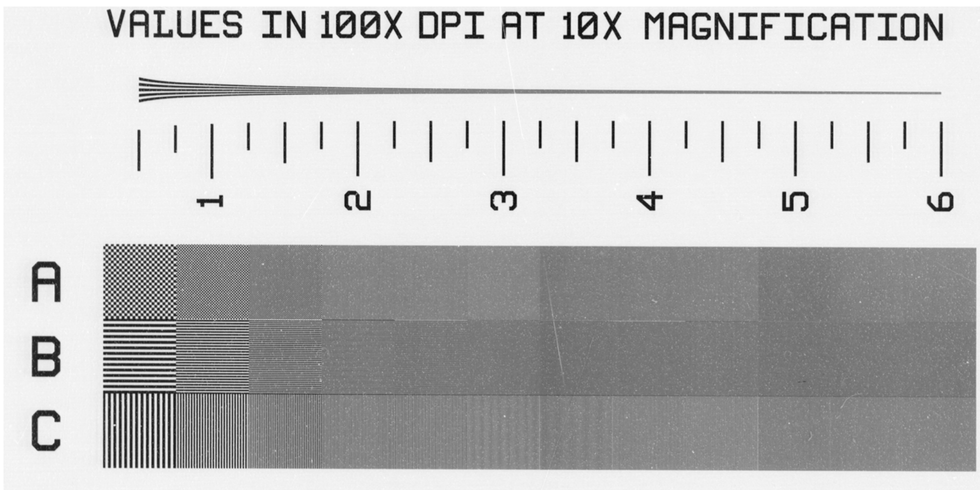


Fig. 4.4 - Checkerboard and repeating line patterns of the ABC Matrix

4.2.1 - The utility of the patterns

The features in Fig. 4.4 are primarily intended to complement, but not substitute for, the spatial resolution values derived from the ISO protocols using Spatial Frequency Response (SFR) described in the next section. Many will recognize these as classical line-and-space resolution elements used to judge microfilm spatial resolution performance. They are included here for several reasons. Because such features were heavily used in traditional microfilm operations, they act as a bridge between traditional analog and contemporary digital imaging. They are also great "stress" images for extracting imaging artifacts that digital systems tend to introduce and that are occasionally encountered in collections

These type of features create misleading patterns when judging resolution in digital imaging though. The fixed periodic sampling of digital scanners can be asynchronous with the target's periodic features. In other words, there is no guarantee that the centers of a camera's sensors will be perfectly aligned with the centers of line features. In fact, it is highly unlikely they will be. This is the primary reason such features can yield unreliable values when judged visually after being digitally scanned. Nevertheless, they do act as a good cross check for the values reported by the SFR technique especially since they are intuitive to most users. They are invaluable for helping to visually assess the types of artifacts that can occur when scanning collection content that have such features. Printed halftones and line art engravings come to mind immediately. The checkerboard pattern and line features of Fig. 4.4 can be surrogates for such content. Their description and use are described below.

4.2.2 - How to use and interpret the line and wedge features

The trumpet-like wedge features shown below are a good place to start. The sets along the top and bottom are meant to help with assessing vertical resolution while the ones along the side are for horizontal resolution. A portion of one is enlarged in Fig. 4.5 below. Beginning at the extreme left, notice that it consists of five lines that increase in spatial frequency to the right. The accompanying numbers alongside are indicators of the spatial frequency in units of dots per inch assuming a 10x reduction level. Visual resolution evaluation is accomplished by proceeding from low to high numbers and identifying the first occurrence where *all* five lines are no longer visually resolved. For this example (and evaluator's opinion), this occurs just prior to the tick mark labeled "4". This is shown with the inset of Fig. 4.5.

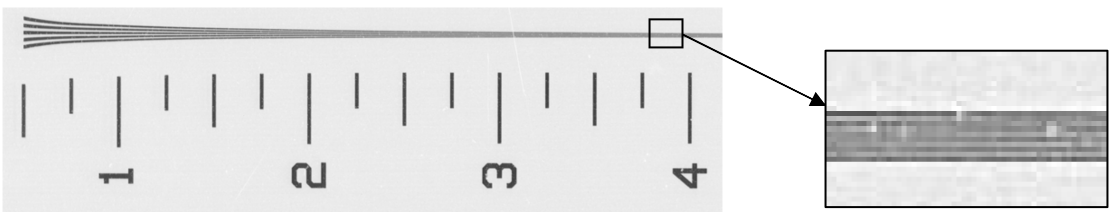


Fig. 4.5 – Enlarged wedge section showing w

For illustration purposes, consider the point where the five line resolution are unresolvable to be at the 3.8 level. The supplemental text, "VALUES IN 100X DPI AT 10X MAGNIFICATION", allows the user to interpret this number as effective resolution, in terms of dots per inch (dpi).

One would multiply the 3.8 value by 100 to get 380 dpi. This would then be the rough estimate for effective resolution at the 10x reduction level. If one wished to know the equivalent resolution at a different reduction level, simply take the ratio of 10x to the desired reduction level and multiply it by the scaled value just calculated. For instance, for 20x reduction, the effective resolution would be

$$(380 \text{ dpi}) \times (10x/20x) = 165 \text{ dpi}$$

If one wishes to know the effective resolution at the film plane this would translate to a 1x reduction. The effective resolution relative to the film plane would then be,

$$(380 \text{ dpi}) \times (10x/1x) = 3800 \text{ dpi}$$

Remember, these numbers are ultimately derived from visual judgments. They can be unreliable depending on where a viewer considers all five lines are "just resolved".

Together with the asynchronous properties of digital sampling it is emphasized that resolution numbers using these techniques are only rough indications of spatial resolution. This is the reason duplicate features are included on the target. The values derived from the SFR graphs shown in the next section are more reliable and consistent with ISO protocols.

4.2.3 - The deal with the ABC matrix

The three rows of resolution features below the wedge are intended to reveal the types of sampling artifacts associated with extended repetitive patterns such as halftones and line engravings encountered in many collections. To reflect this, checkerboard (Row A), horizontal (Row B) and vertical (Row C) line elements are included. Unlike the wedge feature, these patterns do not vary continuously from left to right, but rather at 50 dpi increments associated with the scale above them. This is depicted in Fig. 4.6 by way of the arrows. An example of the type artifacts these elements can reveal is shown with the magnified inset of row C at the 200 dpi level. Notice how the elements vary in blur level across the field even though the line spacing is equivalent everywhere.

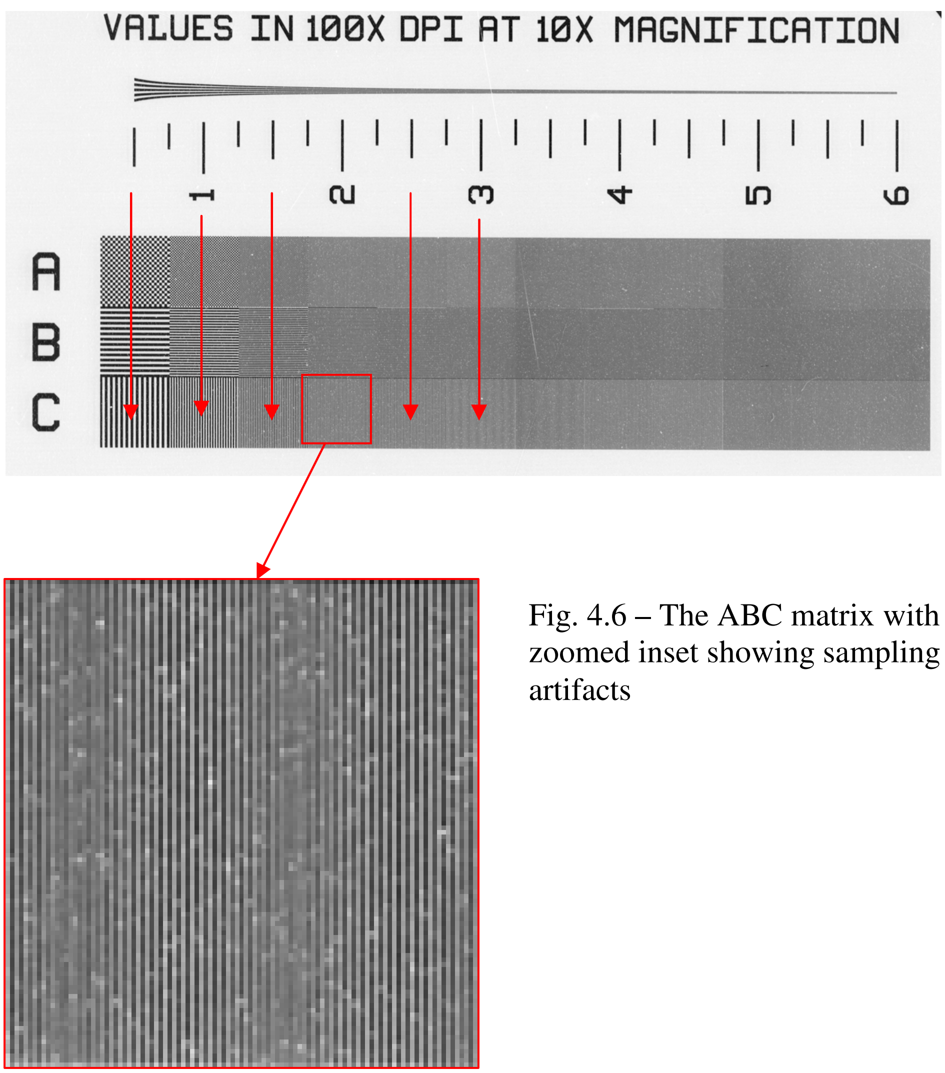
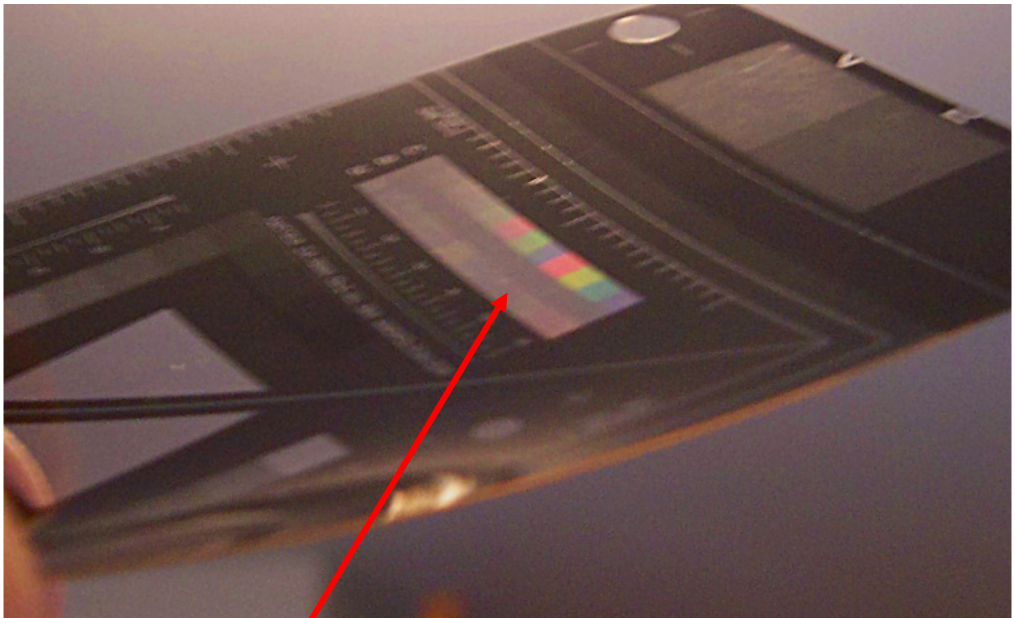


Fig. 4.6 – The ABC matrix with zoomed inset showing sampling artifacts

4.2.4 - But wait, there's more!

To ease the technical onus of this section, let's conclude with some fun. To prove just how finely spaced the line patterns in the ABC matrix actually are, hold the film target up to a light at arms length with the target between the eyes and a light source. View the ABC matrix of boxes at a glancing angle. Move the target to-and-fro as if you're panning for gold. You should see either a rainbow or a shimmering effect in the matrix area. The finely spaced lines are actually acting as a diffraction grating splitting the transmitted light into its color components. An unexpected feature, eh? It's neat in a geeky sort of way.



Look Here! …with no Photoshop tricks either

4.3 Graph B - Resolution and Spatial Frequency Response (SFR)

Well before digital imaging became popular a well regarded career engineer was quoted, "Resolution can serve so many purpose, because it doesn't serve any of them very well." This statement largely stemmed from the same behavior observed today in digital imaging. Practitioners have latched onto resolution and its many vernacular uses as a handy, but mythical, mantra for their own brand of imaging performance that in fact adopts quantity metrics over ones of quality. Resolution used in this document follows the latter and adopts current ISO measurement protocols. A brief introduction to the differences is first offered followed by a description of the ISO methods presented in the software results panel.

4.3.1 The difference between sampling and resolution.

For digital imaging, there are primarily two items that determine effective resolution.

1) *Sampling rate*; usually referred to in dots-per-inch (dpi). The equivalent term for digital cameras is MegaPixels
2) *Optical effects*; determined and limited by factors like focus, camera motion, lens F-number, optical glass quality and assembly.

The critical thing to realize is that while these two items can be configured independent of one another, in a digital imaging system they also act to limit each other in determining effective resolution. If the sampling rate (dpi or MegaPixels) is low one cannot compensate by using high quality optics. Similarly, high sampling rates cannot compensate for low quality optics. Basically, the weakest performing element determines the effective resolution. Because digital scanners and cameras can be arbitrarily set to any high valued sampling rate, or dpi, the optical quality is what ultimately determines the highest effective resolution of a device.

4.3.2 A preferred way to measure resolution.

Sampling rate then is a necessary, but insufficient, element in determining resolution for digital cameras and scanners. It sets the upper limit on resolution, but it is often the optical effects that limit optimal resolution performance as set by the sampling rate. The Spatial Frequency Response (SFR) is a popular method for analyzing the combined influence of both sampling rate and optics on effective resolution. It is also an accepted ISO protocol for measuring resolution of digital capture devices. This is primarily why it is used here. SFR serves a much greater purpose though by providing an objective means for predicting image quality and for imaging system diagnostics. Characteristic SFR shapes are often used to identify sharpening, flare, and digital artifact behaviors. Examples of these are shown later.

4.3.3 Summary metrics for resolution

An example resolution and SFR results panel from the companion software output is illustrated below in Fig. 4.7.

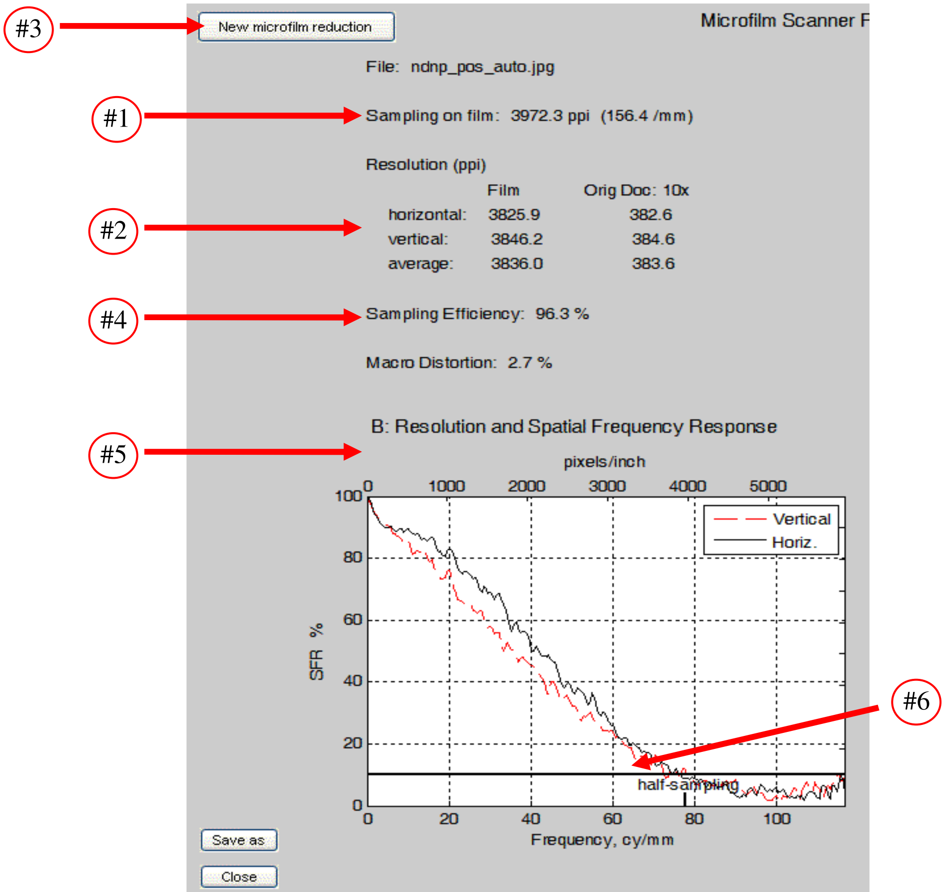


Fig. 4.7 – Summary resolution and SFR graph from Mscan with designated items described in the narrative below.

At the top are summary resolution statistics derived from the SFR graphs below them. The way they are calculated from the SFR will be explained shortly. For now an explanation of the summary resolution values will be provided since they will be used as the primary pass/fail criteria for resolution performance. The actual sampling rate at the film plane (i.e., 1X reduction) is reported first (#1). This is equivalent to treating the film target as a simple document without reference to the original object that was imaged. Remember this is the sampling rate alone and only indicates the best possible resolution. It does not account for optical influences that yield the (effective) resolution for the imaging system as a whole, or as delivered. These are reported in the set of numbers below (#2).

These resolution values account for the optical influences on resolution and are reported relative to the film and relative to the original document, at a 10X reduction level. One is just one-tenth the value of the other. If one is interested in the effective resolution at a different reduction level, a change can be made using the "New microfilm reduction" button in the upper left hand corner (#3) of the test result panel. The second column will then be updated to reflect effective resolution at the new chosen reduction level.

The three rows of data in the resolution report are further dissected according to horizontal, vertical, and average resolution. And yes, there can be substantial differences between horizontal and vertical resolution values. For microfilm scanners with linear sensor arrays that scan the film much as a flatbed scanner does, the mechanical motion of the scanning array can introduce a loss of resolution in the direction of the scan motion. This would most likely show as a lower resolution in the vertical direction.

4.3.4 What is sampling efficiency?

Sampling efficiency (#4) is a way of gauging how the optical quality reduces the highest possible resolution set by the sampling rate. It is not a comprehensive metric but is a very reasonable way to present a normalized, single number that indicates the extent to which optical effects limit the sampling rate. It is very much like an efficiency rating for a home furnace. Furnace fuel has a maximum BTU potential, but combustion inefficiencies limit this potential. The same goes for resolution in a digital imaging system. The sampling rate sets the maximum potential resolution while optical deficiencies limit it. The ratio of the effective resolution determined by the optics compared to the potential resolution of sampling is the sampling efficiency. Typically, sampling efficiencies of 80% or greater are acceptable. Values much below this indicate low information content per pixel and should be considered as underperforming for the selected sampling rate.

4.3.5 What is SFR?

Recall, the OECF characterizes how a digital camera or scanner responds to input light intensities for a given set of software or lens settings. Spatial frequency response (SFR) is also a response curve but one that characterizes how an imaging system maintains the relative contrast of increasing detail content. The input variable along the horizontal axis of the SFR curve is spatial frequency (Fig. 4.7, #5) increasing to the right. The output response along the vertical axis is the change in contrast of those spatial frequencies after being imaged by a camera or scanner. Ideally then, one would like as little loss in spatial detail contrast (i.e. the % response value of the y-axis). This is reflected by the SFR curve remaining high with increasing spatial frequency (i.e. the x-axis). Due to the factors cited earlier though (e.g., defocus, camera motion, or poor optical components) blurring occurs. This blurring reduces the contrast of spatial details by merging the light spaces with dark lines and it does so progressively as the spatial frequency content increases. The spatial frequency at which fine detail is no longer detectable, either visually or with detectors is the effective resolution. This is illustrated using the five line wedge feature and the accompanying plots of Fig. 4.8.

These plots show the rise and fall of the line and space features in terms of count value after being imaged. Several frequency regions are shown. As the spatial frequency of the lines in the wedge increases from left to right, the contrast, (i.e., the difference in count value between the peak and valleys of the plots indicated by the dashed lines) of the line features is proportionally reduced. Characterizing this contrast change over a continuum of spatial frequencies and comparing them to the contrast of the original input target yields the SFR. For example, a 66 % SFR value indicates that at the associated frequency only two-thirds of the contrast of the original input target's frequency was maintained. It is, as its name suggests, a contrast response curve over a range of spatial frequencies and is what is illustrated in Fig. 4.8.

The four slanted edge features in the middle of the frame are used to characterize the SFR according to ISO protocols. By measuring the rate at which the edge transitions from light to dark regions, mathematical techniques are used to calculate the SFR.

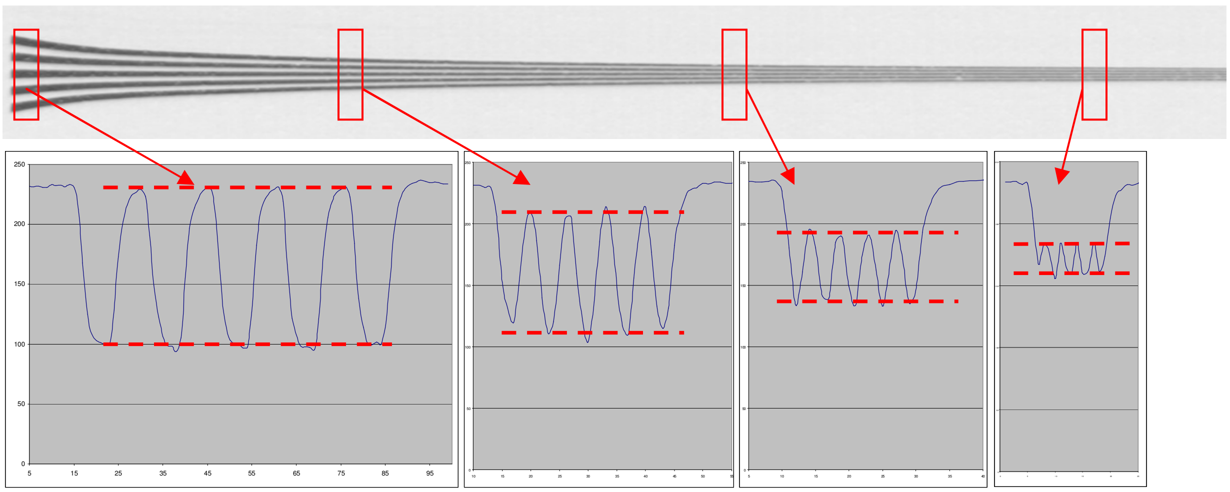


Fig. 4.8 – Indication of how feature contrast is reduced as spatial frequency increases.

4.3.6 How SFR is used to determine the reported resolution value.

The reported resolution value in the results panel is based on a 10% SFR value. This is why the 10% SFR line has been highlighted in the SFR results presentation. Experience has shown this value to be consistent with historical treatments of resolving power and effective resolution over the past century. It is also correlates well with proposed ISO software solutions for reporting camera resolution using the wedge feature. Notice too that a small vertical tick mark (labeled "half-sampling") is placed at the sampling rate frequency (#6). This is intended to provide a 100% sampling efficiency aim for the 10% SFR response. Occasionally, the spatial frequency associated with the 10% response will go beyond this aim point. While this is normal behavior, there is no way to exploit these higher frequencies because of insufficient sampling. Therefore, resolution values beyond this point are reported as being 100% efficient.

4.3.7 What else SFR is useful for.

As indicate earlier, the SFR is used for more than deducing single limiting resolution values. The SFR is also useful for evaluating image quality, sharpness, and directional resolution behaviors. Examples of these follow.

4.3.7.1 Image Quality Prediction:

Though limiting resolution is a reasonable summary metric for objectively reporting spatial resolution, it does have limitations, particularly in predicting image quality. The illustrations in Fig. 4.9 below show how limiting resolution can fail to predict image quality and why the SFR is better for doing so.

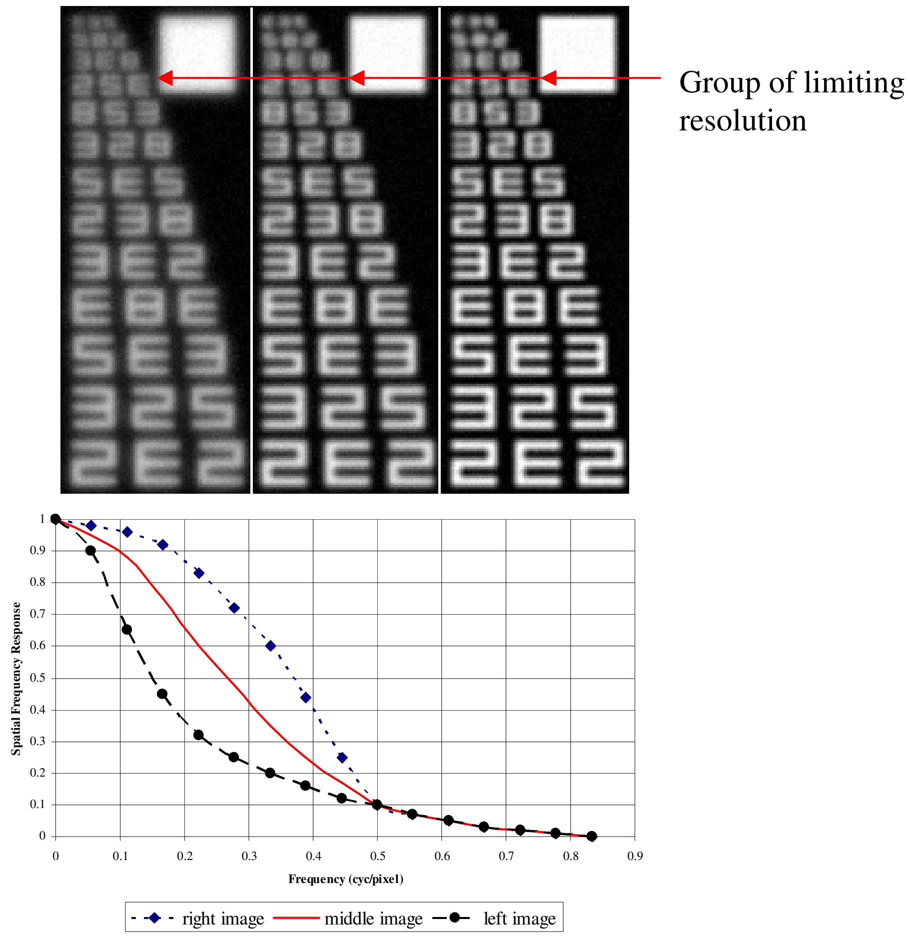


Fig. 4.9 - Illustration of equivalent limiting resolution but different image quality and SFR

Using a 10% SFR criteria, each of the above image sets have the same limiting resolution. This is supported by the loss of text visibility near fourth text grouping from the top in each of the three vertical cells. Notice however the remarkable difference in image quality. The right most grouping clearly has the best image quality. The higher SFR values at all of the spatial frequencies in the companion graph predict this. This is followed by the middle and left most cells with decreasing image quality, but all with equivalent limiting resolution.

4.3.7.2 SFR sharpening behavior

SFR shapes also give insight into image processing functions such as sharpening. An example is shown below. Aggressive sharpening behaviors are indicated by the non-monotonic bumps that rise above the 100% SFR level. The example in Fig. 4.10 is considered quite aggressive.

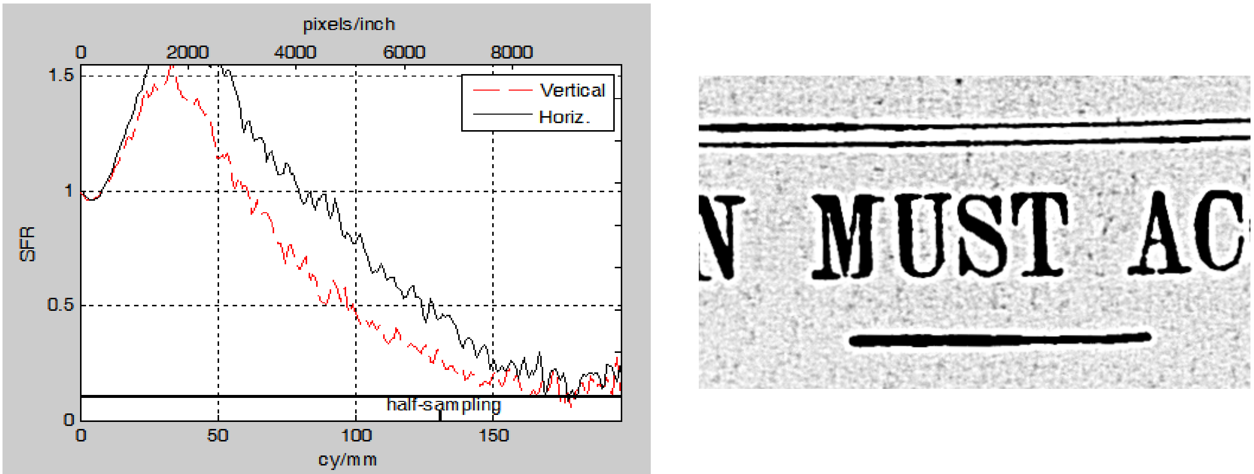


Fig. 4.10 – Illustration of sharpening signatures manifested in the SFR response (left). Note the greater than 1.00 SFR response. Such aggressive sharpening often leads to haloes at light to dark edge transitions as illustrated in the example on the right.

4.3.7.3 Differences between horizontal and vertical SFR

Fig. 4.11 gives an example of the type SFR differences one may see between horizontal and vertical components due to scanner head motion. It is accompanied by the wedge features that support the SFR results. While there are frequently differences between horizontal and vertical SFR components, the ones shown in Fig. 4.11 are of a wholesale nature. It is this type of dramatic difference that is consistent with scanner motion.

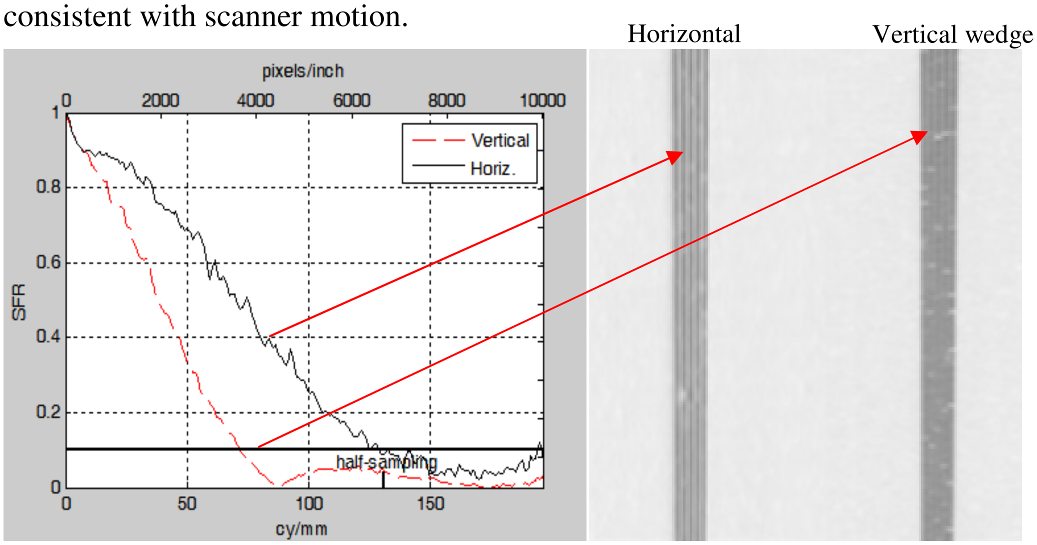


Fig. 4.11 – SFR differences due to scanning motion

4.4 - Spatial Distortions: Macro and Wobble (Graph C)

Two types of spatial distortion are reported. Macro distortion is measured over a large area by way of the circular and crosshair fiducial marks on the target. The diagonal line running from corner to corner provides the means to measure the wobble component, sometimes called micro distortion.

4.4.1 - Macro distortion

Very simply, macro distortion is the overall departure in sampling rate between the vertical and horizontal components of a scan. Most microfilm scanners use linear detector arrays that scan the film. If the transport rate of the array as it scans the film is improperly matched with the sampling rate of the detector array itself, spatial distortions can occur in the delivered image file, specifically, a spatial stretching or compression in one direction. Zero percent distortion is always the desired goal. Most casual observers can begin to detect this class of spatial distortion at about 5% distortion.

One can manually confirm the amount of distortion reported in the results panel by examining the number of pixels between the crosshair marks of the target in the horizontal and vertical directions. Since the software reported values are calculated with feature detection algorithms, there may be slight differences when calculated manually.

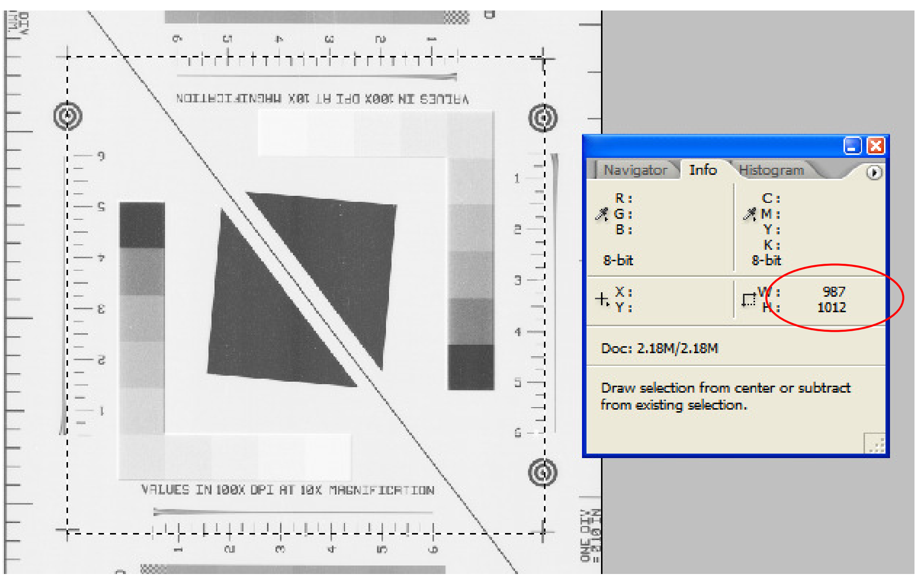


Fig. 4.12 – Example of manually calculating macro distortion using Photoshop®

In the above example (Fig. 4.12) taken from a Photoshop® session, the info panel shows a difference in the width (987 pixels) and height (1012 pixels) of the selected region of interest using the marquee tool indicated by the corner crosshairs. These differences would yield a distortion of

$$[1 - (987/1012)] \times 100 = 2.5\ \%$$

4.4.2 - Wobble or micro distortion

Often, the mechanical motion in linear array scanners will introduce small perturbations or unsteady movements while scanning. This wobble will manifest itself in the diagonal line through deviations in the expected center positions of that line. These micro deviations are plotted on the wobble graph as a function of distance and reported as a single root-mean square (rms) value. An example plot is shown below.

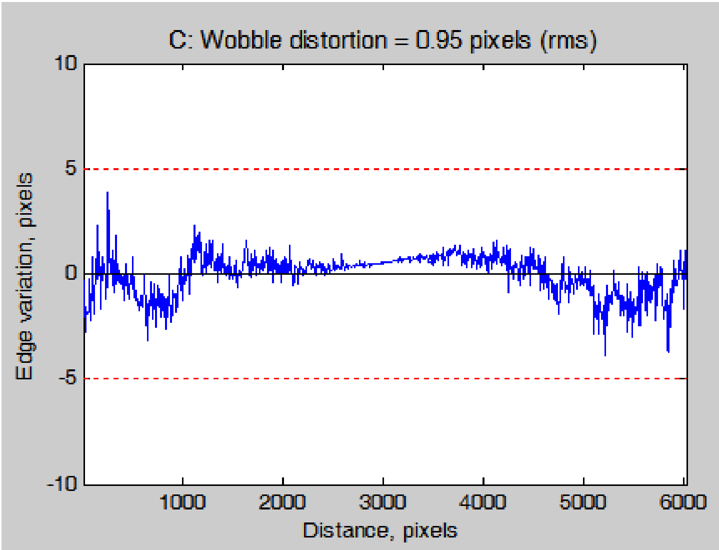


Fig. 4.13 – Micro or wobble distortion graph

Historically, such features have been analyzed visually. The wobble distortions and graphs are the first broad attempt to do this analytically. So, the resilience and sensitivity of this metric is still under scrutiny. There are no known standardized practices to calculate wobble that the authors are aware. The wobble test, as presented here, is intended as a test bed for future performance protocols.

5.0 Mscan Installation Guide*

Mscan is for use with digital image files of the Digital Preservation Microfilm Target.

The software was generated using the Matlab Compiler, and requires MCR (Matlab Component Runtime†) software libraries from The Mathworks Inc. The MCR should be installed before attempting to install and run *Mscan*. The program is currently only available for computers running the Windows operating systems. *Note that you will need administrative rights to install this software.* You may distribute this software feely. Please contact the e-mail address, software@imagescienceassociates.com for an updated version or questions.

5.1 - Installing MCR

† *mscan* is compatible with the MCR libraries for Matlab version 2008b1 and the correct installer file, **MCRInstaller.exe**, has a 'last modified' date, Sept. 18, 2008. This file can be downloaded from the web site that also posts *mscan*. Do not use the MCR libraries for another version of Matlab.

a. Locate **MCRInstaller.exe**. This file should have a 'last modified' date, August 11, 2005. and is supplied with the *Mscan* distribution zip file (or on the *Mscan* distribution CD ROM.
b. Double-click on this file.
c. The MCRInstaller opens a command window and begins preparation for the installation.
d. When the **MATLAB Component Runtime** startup screen appears, click **Next** to begin the installation.

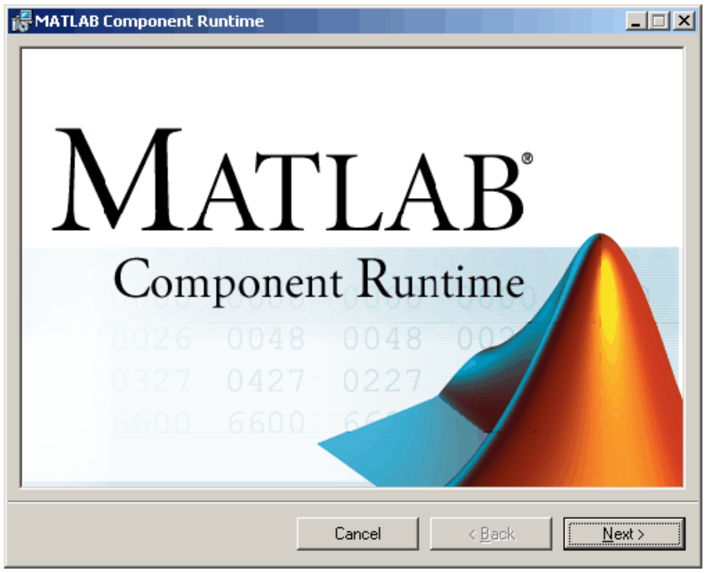


Fig. 5.1 -MCR installation screen

e. The setup wizard starts. Click **Next** to continue.
f. The **Select Installation Folder** dialog lets you choose where you want to install the MCR. This dialog also lets you view available and required disk space on your system. You can also choose whether you want to install the MCR for just yourself or others. Select your options, and then click **Next** to continue.

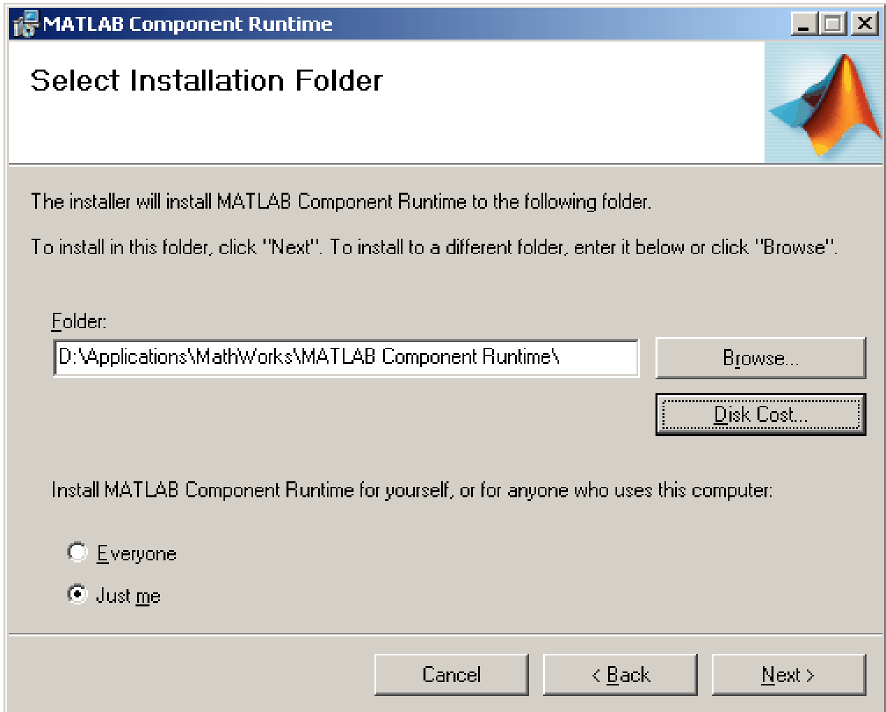


Fig. 5.2 - MCR installation screen folder selection

g. Confirm your selections by clicking **Next**.
h. The installation begins. The process takes some time (5-10 min.) due to the quantity of files that are installed.
i. When the installation completes, click **Close** on the **Installation Completed** dialog to exit.

5.2 Installing *Mscan*

a. Save the file **Mscanv*xx*.zip** to a location in your computer C: drive where you have permission to write files. For example in the, *My Documents* folder whose path is, *C:\Documents and Settings\your_name\My Documents*\)
b. Unzip this file to the same folder. A folder, *Mscan xx* should be created.
c. Inside this folder find **mscan.exe** (or make a shortcut to **mscan.exe**), and double-click on this.
d. This will open the Windows Prompt window.
e. The console window (Fig. 3.2) will appear in about 30 sec.

Target Purchase & Software Downloads

Software available from Image Science Associates here
MCR Installer (260 Mbytes) requires user name and password. Make a request at the above software at this URL. Mscan is available without these requiresments. If a CDROM is preferred, please let us know.

Microfilm targets available here

Credit Card, PayPal or PO accepted

http://www.imagescienceassociates.com