Many people ask how much data they should scan to properly reproduce an image. The best answer is, “It varies” but the most common response is, “Twice the screen ruling.” Those who want to show off will say that you scan for twice the screen ruling because of the Nyquist criterion. But what is the Nyquist criterion and why do people apply it to scanned images?

For background information, refer to the Linotype-Hell Technical Information articles entitled, *Scanned File Size* and *Line Art.* These articles appear in the scanning section of the 1992 Linotype-Hell technical information notebook.

Nyquist

Harry Nyquist was a Bell Laboratories mathematician who did a lot of work in the area of signal processing. In 1927 he devised the “Nyquist criterion for the stability of negative-feedback amplifiers.”[1] Nyquist’s work has been applied to a range of disciplines, including computer music and graphics.

Very briefly, it states that “…the sampling frequency must be at least twice the highest frequency of the signal being sampled.”[2] Most people in the graphic arts translate that to mean that the scanning resolution must be *at least* twice the screen ruling. In practice, most scan for *no more* than twice the screen ruling, because it is generally assumed that nothing is gained by the extra resolution. In fact, many people are willing to scan for less than twice the screen ruling, particularly because of the large file sizes involved.

However, if you look closely at the quote above, it is clear that it is not talking about the relationship of the resolution of the scan and the fineness of the screen ruling, instead it is talking about the amount of data that should be sampled based on the frequency of the image being sampled. Within the graphic arts, we don’t think too much about the frequency of the image being sampled. If we did, we would realize that it relates to the amount of detail in an image. Obviously, an image containing a car grille or a screen window contains more detail than a shot of clouds.

[1] Source: *Signals, The Science of Telecommunications,* by John R. Pierce and A. Michael Noll, ©1990, Scientific American Library, p. 222.

[2] Source: *Digital Communications Systems Design,* by Martin S. Roden, ©1988 Prentice Hall, p. 96.

Aliasing

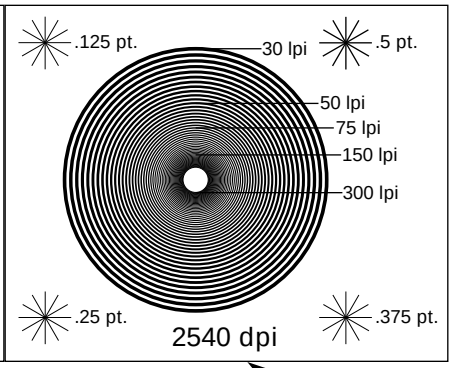
Scanning at too low a resolution (i.e., not using a high enough sampling rate or frequency) may produce a visual artifact known as aliasing (sometimes called pixelization or stairstepping). This is most visible in detailed areas, but is also obvious in less detailed areas when pixel size becomes large enough.

This artifact is shown in an earlier technical sample called *How do you keep scanned file size low while maintaining quality?* That article, which showed a typical image and how it looked when scanned at different resolutions, is part of the 1992 Linotype-Hell technical information notebook.

Grays and detail

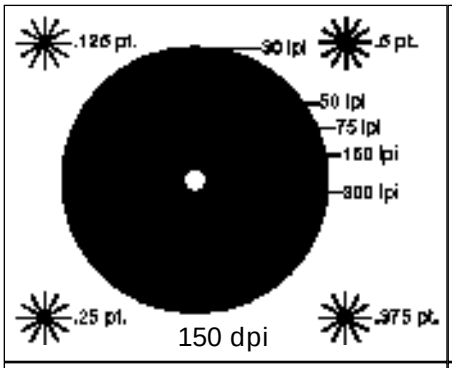
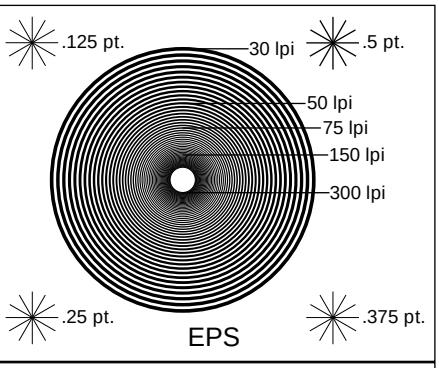
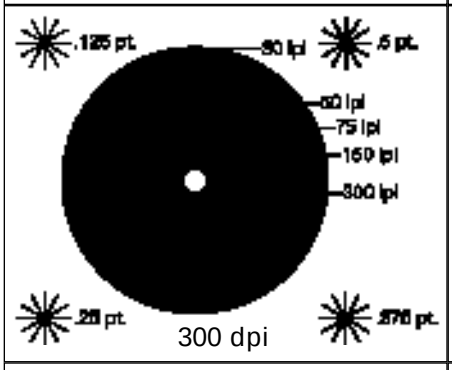
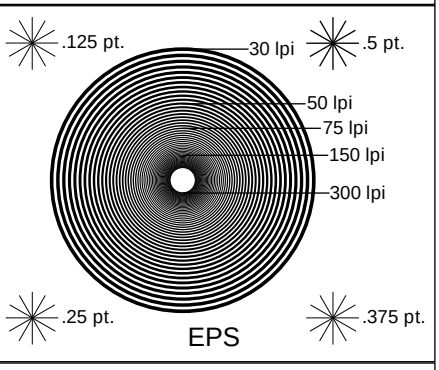
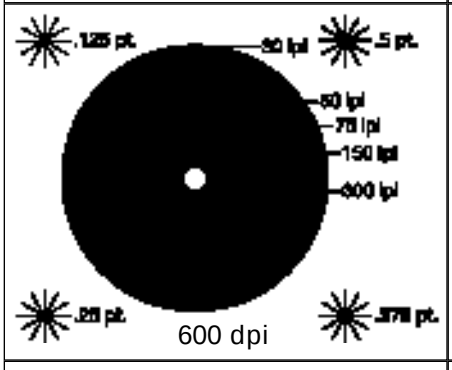
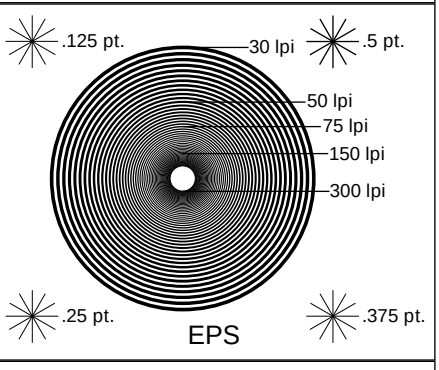
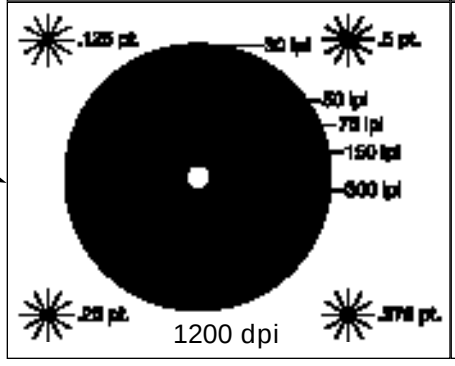
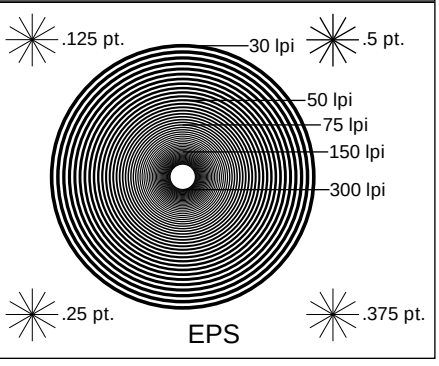
In reproducing an image, most of us are concerned with both detail and gray scale reproduction. The test shown on the following pages explores detail only. A good test of grayscale reproduction is a blend. (The topic of blends has been explored in two other technical articles in this series: *Blends and Shadestepping* and *Blend Update.* Both appear in the 1992 notebook.)

Addressability test

Replace with supplied film	Replace with supplied film	
635 dpi	1270 dpi	2540 dpi

Notice how increased addressability improves the rendering of the test target.

Solid sampling test (output at 2540 dpi addressability)

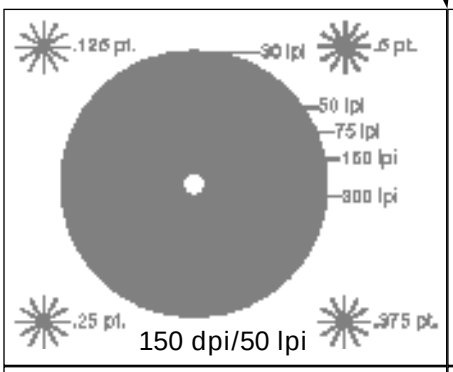
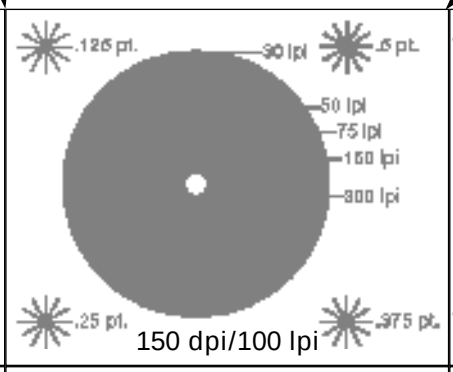
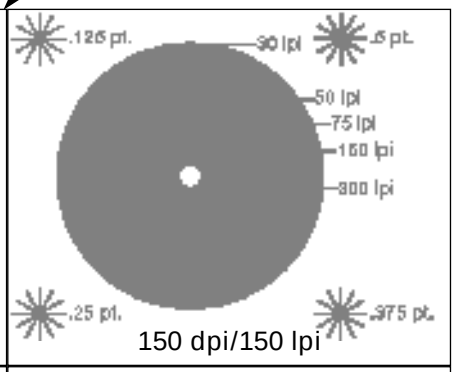
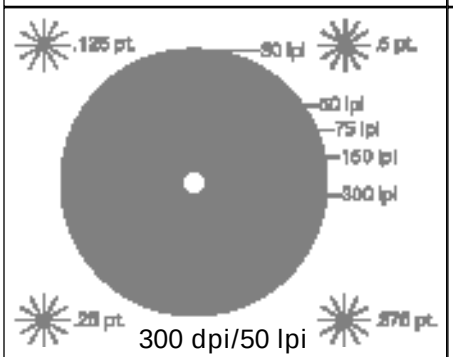
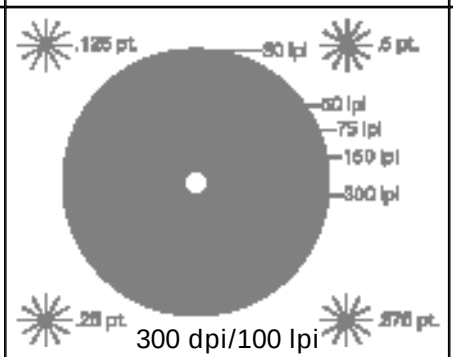
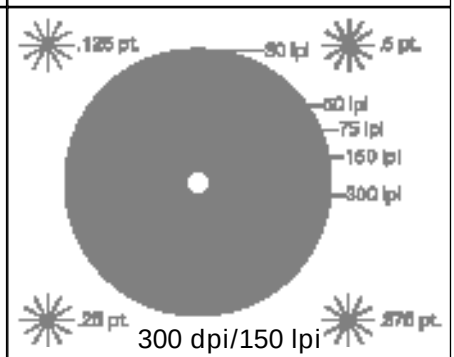
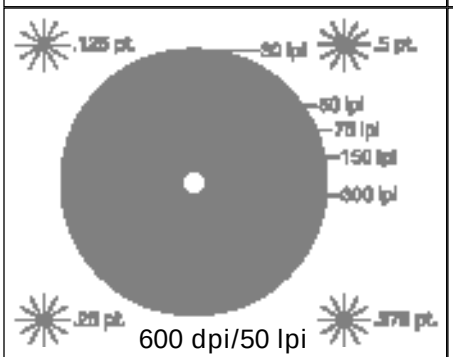
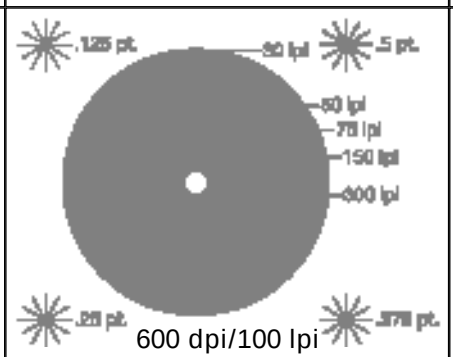
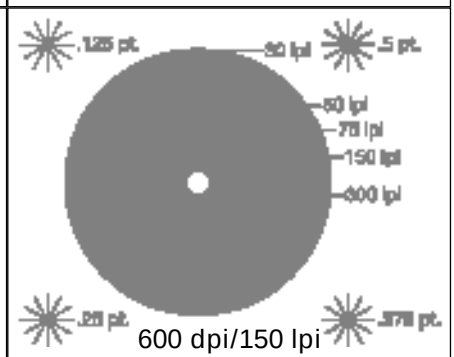
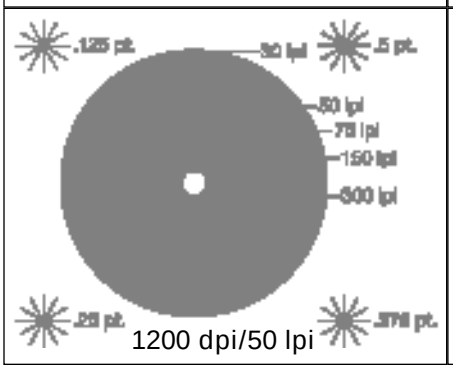
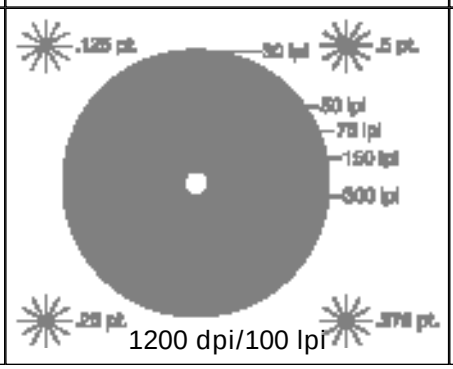
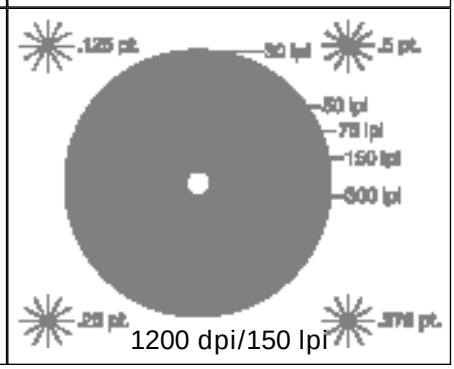
1 bit sampled	EPS
 150 dpi	 EPS
 300 dpi	 EPS
 600 dpi	 EPS
 1200 dpi	 EPS

In this case, addressability remains constant. The improvement comes from the higher sampling rates. (The EPS file is repeated to provide a side by side comparison to the sampled test targets.)

Both screen ruling and sampling rate vary in this example. The upper left hand corner has the lowest screen ruling (50 lpi) and the lowest sampling rate (150 dpi). The lower right hand corner has the highest screen ruling (150 lpi) and the highest sampling rate (1200 dpi). Compare the results shown here with the comparable solid examples on the previous page. From that comparison you will be able to deduce how well the tinted version reproduced the original.

Look for improvement in the quality of the test target as screen ruling increases (from left to right) or as sampling rate increases (top to bottom). Also not the appearance of interference patterns.

50% tint sampling test (output at 2540 dpi addressability)

1 bit sampled 50 lpi screen ruling	1 bit sampled 100 lpi screen ruling	1 bit sampled 150 lpi screen ruling
 150 dpi/50 lpi	 150 dpi/100 lpi	 150 dpi/150 lpi
 300 dpi/50 lpi	 300 dpi/100 lpi	 300 dpi/150 lpi
 600 dpi/50 lpi	 600 dpi/100 lpi	 600 dpi/150 lpi
 1200 dpi/50 lpi	 1200 dpi/100 lpi	 1200 dpi/150 lpi

Description of the test

The test targets shown on the previous pages ,show the ability to capture detail. These tests present a worst case scenario for detail.

The test target was created using Adobe™ Illustrator.™ The innermost circle has a diameter of about an eighth of an inch and is approximately an eighth of a point in width. The succeeding circles increase in diameter and line width by about 105% from the previous one. This makes the distance from the center of the innermost rule to the center of the next rule approximately 1/300th of an inch. To give an understanding of the role of each step in the production process, the test target is shown both solid as an EPS file, solid as a sampled file, and halftoned as a sampled file.

The sampled images were created using Adobe Photoshop.™ It is possible to open an encapsulated PostScript™ (EPS) file with Photoshop and sample the image at a user-selected resolution. This mimics the scanning process without having to scan the actual target. Photoshop allows you to perform anti-aliasing on these images, but this feature was not invoked, since the examples are meant to show the effects of aliasing. A constrain check box was left checked on. The files were saved as TIFF, and converted to one bit in Photoshop using a 50% threshold. Once converted, all of the files were under a megabyte in size.

The TIFF files were dropped into a QuarkXPress® page as both 100% solids and 50% halftones. The sampled targets had screen ruling and a 50% tint value assigned to them. Output was done at a 2540 dpi addressability setting on a Linotronic® 330 and a RIP 40. The screening filter was set to default so that the range of screen rulings could be achieved at 2540.

Results of the test

The results of the test are somewhat surprising in light of some common assumptions about the Nyquist criterion. Some added detail does appear to be rendered beyond the two times the screen ruling limit that most people adhere to. This may be in part due to partial halftone dots that allow some rendering of detail at frequencies beyond the screen ruling.[3]

[3] The partial halftone dots are quite visible on the film. They may not be quite as visible once the job has been printed.

Interference patterns appear in several places:

- In the solid sampled test targets, where it is a result of a conflict between the frequency of the test target and the frequency of the sampling.
- In the tinted test targets, where it is a result of a conflict between the frequency of the test target, the frequency of the sampling, and the frequency of the screen ruling.
- In the solid EPS test targets, particularly at lower addressability settings, where it is a result of a conflict between the frequency of the test target and the frequency of the addressability setting.

Conclusion

What can be generalized from these results? First of all, remember that these tests supply information on reproducing detail. In extremely detailed images, scan resolutions higher than two times the screen ruling may reduce interference patterns caused by detail and sampling frequency conflicts. However, other possible sources of interference include the addressability of the output device and the screen ruling. There is some indication that certain interference patterns may diminish as screen ruling increases.

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