POWER SPECTRUM ANALYSIS OF LASER GENERATED HALFTONE PATTERNS

R.S. Fisch*

3M Printing and Publishing Systems

ABSTRACT

A technique to measure the halftone dot that relies on an analysis of the Fourier Transform, or optical power spectrum of a large nominally uniform array of halftone dots is discussed. The technique uses optical computing to enable an optical transfer function of the dot pattern without digital computation and then provides a quick mathematical analysis.

INTRODUCTION

Several different processes for the study of halftone dots are routinely used at the 3M Color and Image Reproduction Center (1)(2). These include optical phase effects, optical staining of individual and clusters of dots where the dot's fringe is colored differently than the dot itself, densitometry, computer driven electronic image analysis devices, and the microdensitometer. Microdensitometry is a very important tool for the study of the shape and size of the dot. Because of its geometry, microdensitometer aperture alignment is more important for irregular laser dots than for conventional dots. In the case of halftone dots of irregular shape and high perimeter (such as laser generated dots) small changes of alignment distort the microdensitometer output and limit the usefulness of the resultant information. One tends therefore to concentrate on samples containing very few dots. Matrices of dots up to about fifteen at one time, are the practical limits of such a scan.

Although not immediately obvious, the scenes and patterns we see and recognize are interpreted by our brain as shape related objects; a chair or desk or a microphone. These images, or spatial objects, are made up of various periodic frequencies. These frequencies can be regarded as two-dimensional harmonic waves whose individual contributions can be determined and calculated.

From childhood, we're trained to recognize assemblies of frequencies or patterns and call them by names, such as chairs, hats, or pots. What we see and recognize during our daily activities are interpreted by our brain to be spatial or shape related. An analysis of these frequencies can help categorize or clarify differences between otherwise similar objects.

As one of our foremost modern philosopher scientists, Norbert Wiener succinctly put it, "one of the most interesting aspects of the world is that it can be considered to be made up of patterns. A pattern is essentially an arrangement. It is characterized by the order of the elements which it is, rather than by the intrinsic nature of these elements."

---

* Printing & Publishing Systems Division, 3M Company
St. Paul, Minnesota 55144

EXPERIMENTAL

Howe, Maurer, and Yule (3) utilized three different techniques in an attempt to study the optics of a halftone crossline screen. These included: 1) determining the intensity distribution of dots along a line from the center to the corner of a dot in the crossline image plane by zones, 2) Fourier or harmonic wave distribution analysis of the image of a film exposed to the screen using microdensitometry, and 3) matrix systems to analyze the diffraction image of a point source modulated by the crossline screen. These techniques required many samples and was labor and time intensive. Even today with the availability of digital computing the time required to perform a microdensitometric scan and analyze it are uneconomic in practice.

Coherent light can convert a dot pattern into its collective frequencies and image these onto a detector for computer analysis in a matter of seconds. If one were to place a piece of unexposed film at the output plain and develop it, one could, if you will, take a photograph of the frequency or the diffraction pattern formed by the dot target.

These patterns take the shape of a diffraction pattern peculiar to the shape of the particular dot being studied.

Such an arrangement enables us to immediately transform our dot targets from the familiar spatial mode we see, to the frequency mode, for analysis purposes, without the need of microdensitometry.

Laser illumination while an efficient coherent light source provides some difficulties. Not every halftone pattern absorbs the limited wavelengths available from a laser. Laser replacement and realignment in some optical systems tend to complicate use and instrument availability.

A classical arrangement of lenses, called a Fraunhoffer optical train (Figure 1), also produces coherent light. With a relatively monochromatic small aperture light source used as the illumination, and a uniform halftone dot tint as a spatial modulator, the frequency transform of dot pattern is quickly available in the image plane (Figure 2).

In the device described, a simple optical train converts up to a 2 x 2 inch dot sample into its collective frequencies, and images these onto a detector for computer analysis.

The system uses a uniform dot array, in this case 2-1/4 inches square. Therefore, for a 150 line screen, about 60,000 dots, and for a 300 line screen, about 200,000 dots are studied simultaneously.

Broken dots or discontinuities of the dot pattern are ameliorated by the statistics inherent in such a large sample size.

The figures provide a visual image of some comparative diffraction patterns. Figure 3 provides an example of a pattern from a gray contact screen and one from a sharp ruled gravure screen. The soft dots of a commercial gray contact screen do not contain complex high frequencies found in the sharply ruled gravure screen, and therefore its pattern is more diffuse.

Figure 4 is a sample of single enlarged dot images from dot patterns. Those patterns are a part of a series of halftone dot images which were produced in a manner that

Optical Power Spectrum Halftone Dot Analysis

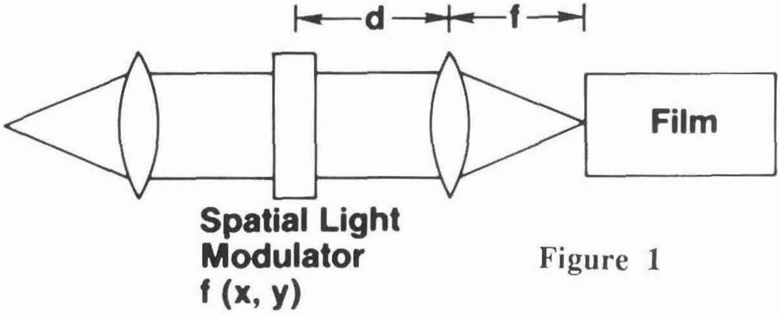


Figure 1

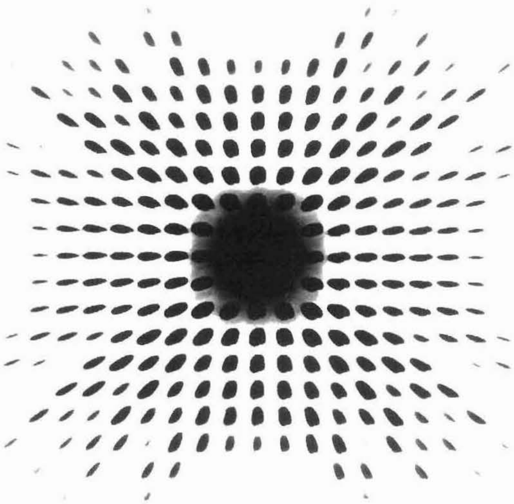
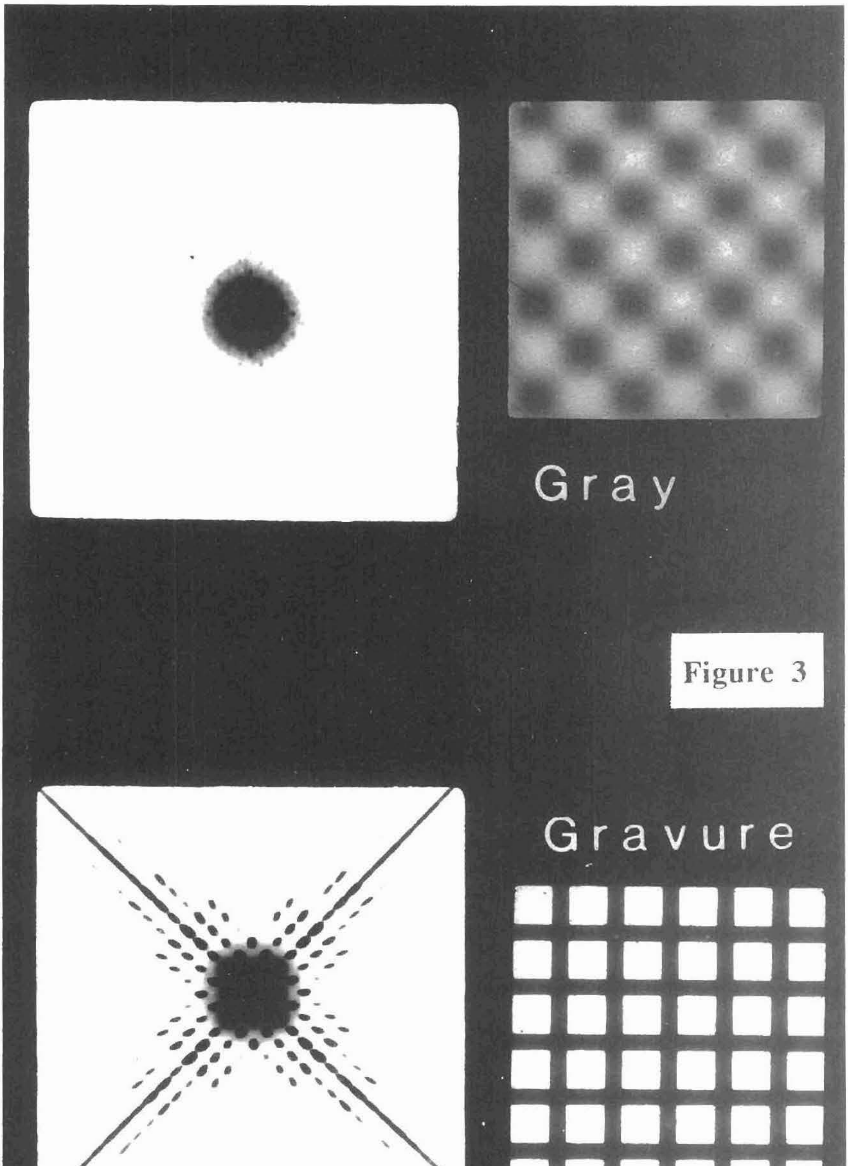


Figure 2


Gray
Figure 3
Gravure

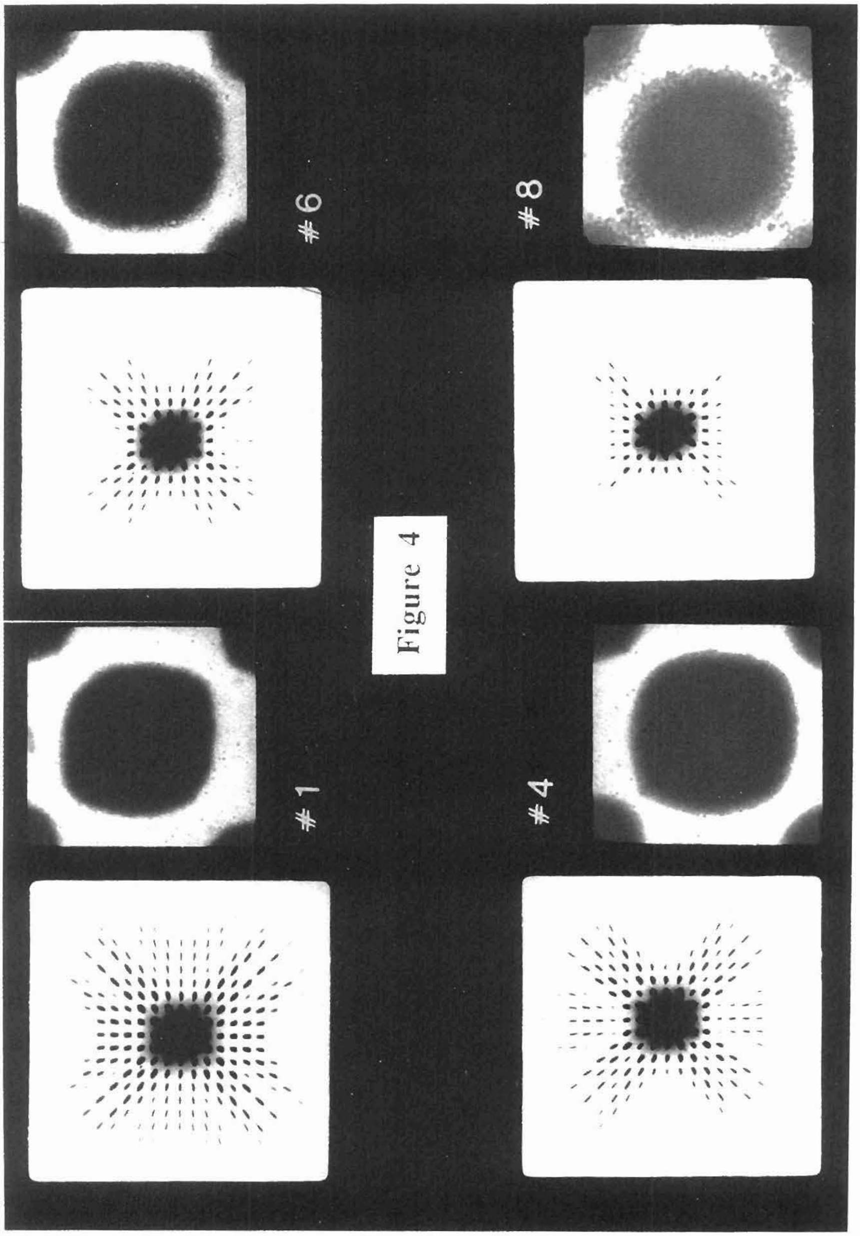


Figure 4

enabled a dot image series graduated from sharp to soft dots. The diffraction pattern of each is different.

Frame 1 dot is a sharp dot, Frames 2 and 3 (not depicted) were progressively less sharp. In frame 4 you can see that sections of the diffraction pattern at about the 3 and 9 o'clock positions are gone. As we decrease the sharpness further, the patterns at the 6 and 12 o'clock positions fade. When, finally, the dot goes completely soft, the diffraction pattern exhibits less of the original star-like pattern, and is less detailed (a lack of high frequency content).

The following examples depict different 50% dot area samples. Three of these samples are laser generated. In Figure 5, the image marked QA-4 is a dot pattern made by conventional means. The Crosfield dot was electronically generated, it is not as sharp as the QA-4 dot and, therefore, the diffraction pattern has less detail.

The patterns in the figure represent two other electronically generated dot patterns, one produced by a Hell scanner and the other by a DS Scanner. Because of the way in which the dots were produced, each has a more spike like pattern indicating higher frequency content.

The diffraction pattern formed by a glass or gray screen is relatively simple compared to that generated by a computer generated laser drawn dot. Because of the high frequencies generated by laser dots the diffraction pattern is more segmented.

Thus far only the visible image of the power spectrum for different halftone patterns has been illustrated. Visual estimation serves its purpose, one look is worth a thousand plots. Howe et al. (3) divided the simple crossline screen pattern into zones for planographic or integrated density analysis (Figure 6). In this technique, a similar but more sophisticated numerical and graphical analysis of the aerial images can also be done in discrete zones. An electronic solid state photosensor, a ring and wedge detector is employed. Figure 7 depicts the front surface of the detector. There are 64 light sensing elements built into the detector, 32 pie ones and 32 rings. Each of these "zones" acts independently.

The ring and wedge detector is placed in the Fraunhoffer output image plane instead of unexposed film when numerical values are needed (Figure 8). Such a detector design allows photometric readings corresponding to the various orders and radial positions of the diffraction image. In the detector of choice the elements are capable of being addressed by the computer individually in a 360 degree manner. The wedges read the various orders and position and density of the spikes or arms of the pattern. These signals are fed into a computer for analysis.

The following practical test was analyzed with this device;

The quality of the dot produced in the lith system was modified by making small processing machine changes. Exposed but undeveloped samples of the same halftone pattern were processed to produce images that varied in dot quality from off standard to normal and then to off standard again. This process was repeated five individual times for statistical validity.

Figure 9 depicts the computer output of the Fraunhoffer derived ring and wedge signals form these same dots. The X axis represents the five replications. Figure 10 is a graphical representation of an analysis of the ring portion of the signal after a very comprehensive statistical analysis. Figure 11 is a further computer analysis of this

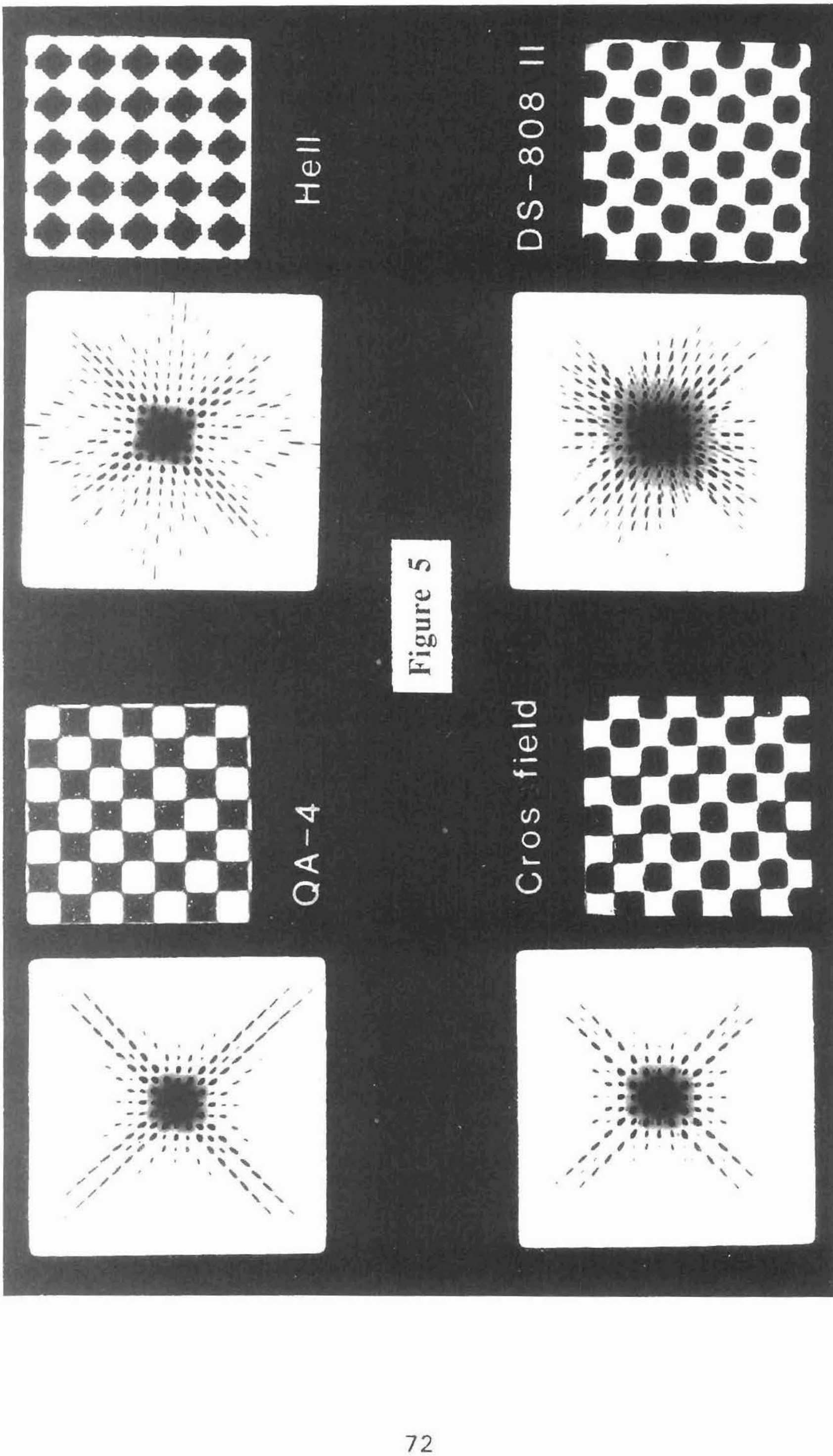
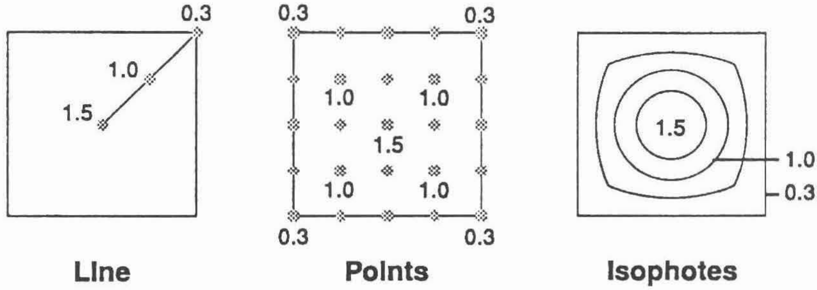


Figure 5

Methods of Specifying Intensity Distribution Within a Dot



Division of Whole Aperture Into Zones

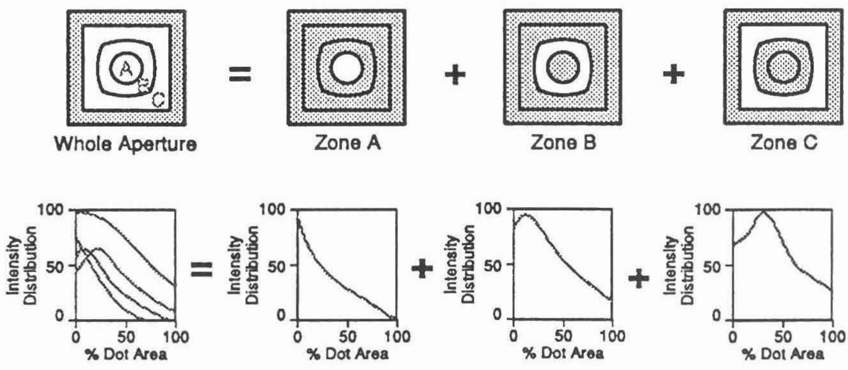


Figure 6

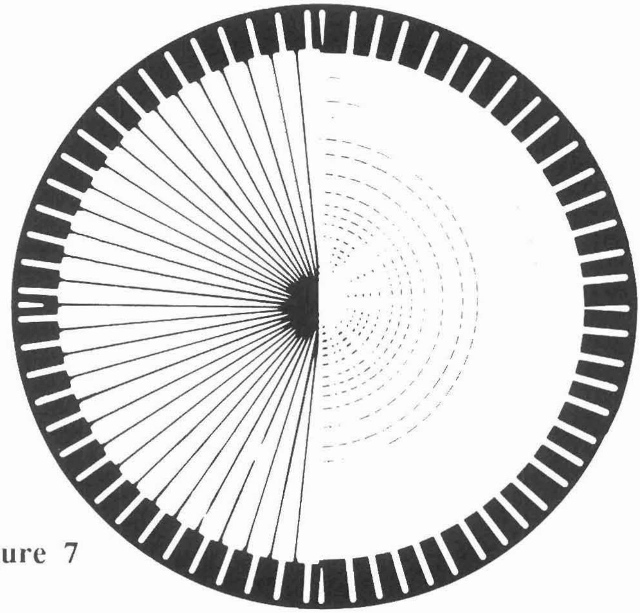


Figure 7

Optical Power Spectrum Halftone Dot Analysis

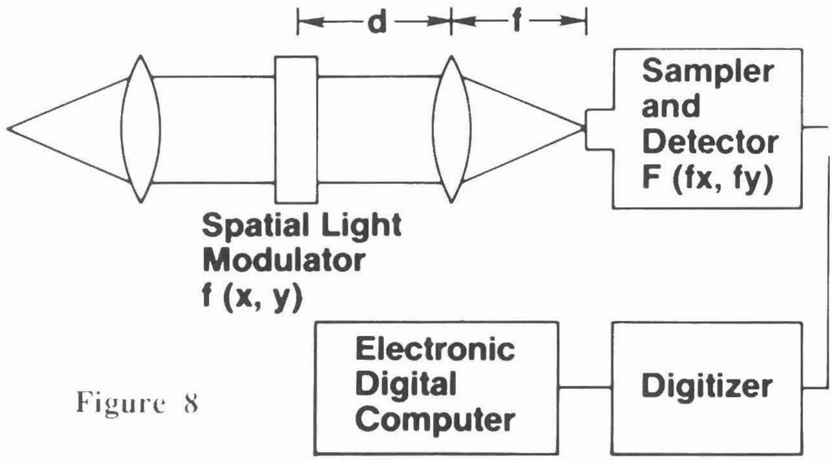


Figure 8

Figure 9

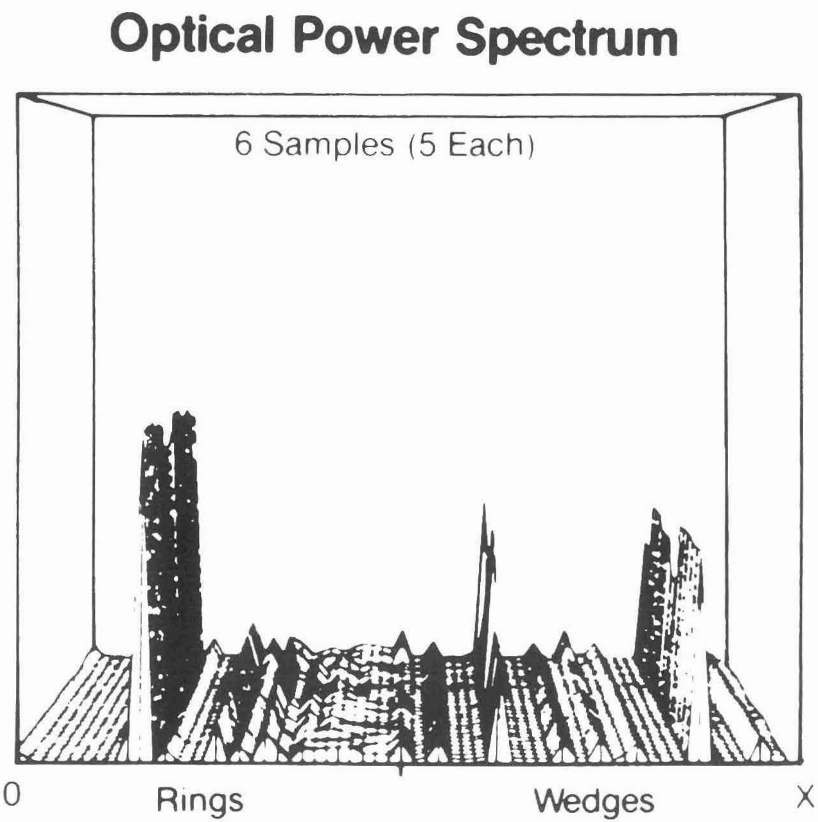
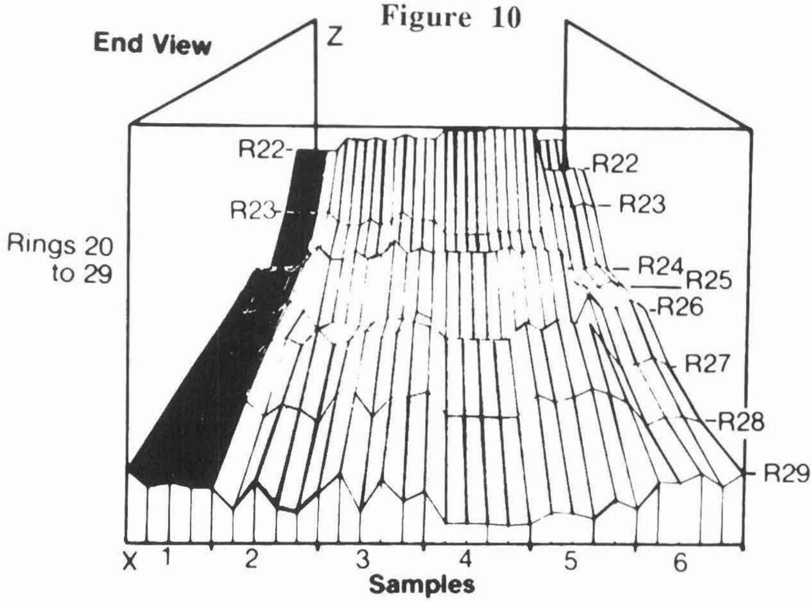


Figure 10



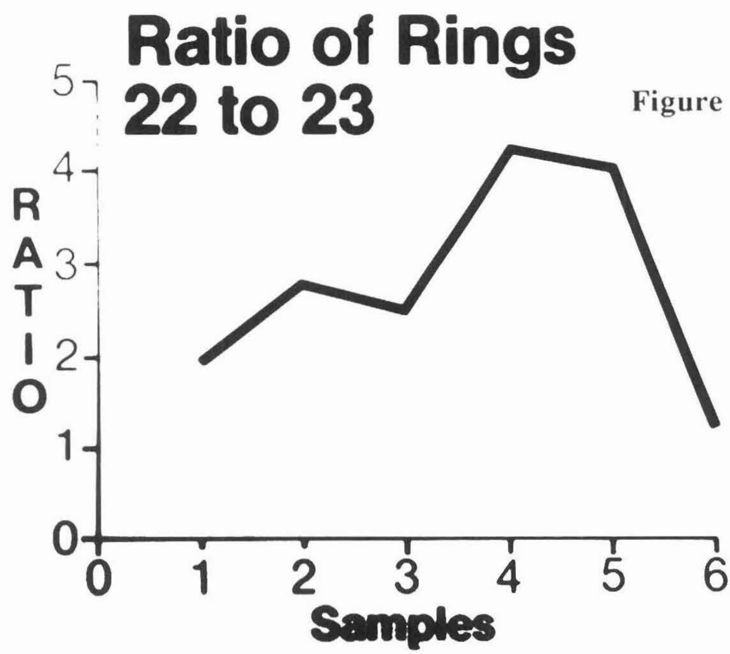


Figure 11

data. The shape and height of these items indicate a change from the off standard dot condition to an optimum dot, and through the optimum to a less satisfactory condition. These data correlate well with microscopic assessment.

Why all the fuss about dot shape and dot design differences? All dots change as they go through the reproduction chain. The trick in obtaining good reproduction is to maintain consistency and keep the change as small as possible. If the change in dot gain on both sides of the dot area range is different, tone reproduction can suffer.

Figure 12 shows both photographs of a 90% and a 10% dot area and their diffraction patterns. If the dot gain curve is symmetrical (equal dot response at both ends of the dot scale) the 10% dot should fit inside the 90% hole. The 90% hole and the 10% dot should add up to a solid area.

The hot spot in the center of the 10% diffraction pattern is from overexposure on the film image. A 10% dot area allows more light to reach the film plane of the material making these images and so overexposes it. The center portion of these diffraction patterns is called the zero order, this phenomenon is due to zero order fog.

Interestingly, the optical power spectrum, Figure 13, for both the 90% and 10% dot areas are identical. They can be superimposed. The 10% dot fits within the 90% diffraction pattern indicating equal dot gain response on either side of the dot gain curve.

Various dot patterns are available on commercial CEPS systems, still more on todays imagesetters. Laser drawn halftone dots are more irregular than those produced by conventional camera means. Irregular shaped dots are more prone to dot gain during the reproduction chain. Fogra, for positive systems, has shown that irregular shaped dots exhibit a dot gain of at least 3% over the dot gain of conventional dot shapes.

Such a technique besides being useful for product research can be used to study and define dot gain.

Another difficulty associated with the use of electronically generated dots is the change in dot shape caused by screen angle change. In color printing we change dot halftone angles to minimize moire. In hand screened films this was accomplished by a physical movement of the screen to a different angle. In conventional halftone dot generation the dot shape does not change with a change in screen angle. In the case of electronically generated dots, a screen angle change is accomplished by adjusting the length of exposure time per fiber exposing one or more segments of the dot structure.

Figure 14 shows an electronically generated 20% dot at the correct angle for one separation of a four color job. Which one of these is the 20% dot ? Some of these dots are so small and symmetrically segmented they will wear on press, contributing to print quality and printing difficulties.

Here, only very large sample sizes such as those produced by large area analysis is effective.

CONCLUSION

When one electronically generates dot structures they tend to be less uniform, and more irregular, in nature. The small sample size used in routine halftone analysis systems may no longer be statistically sufficient when studying the effects of dot

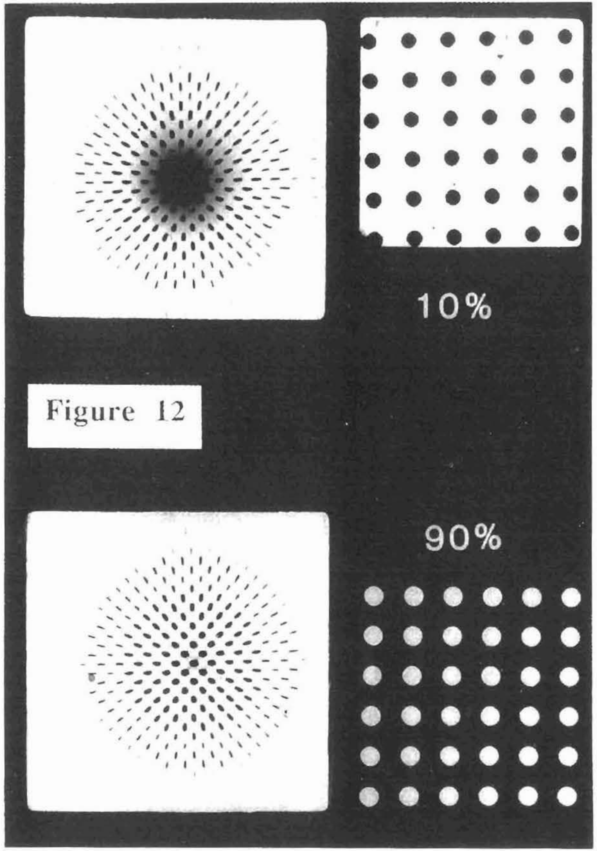


Figure 12

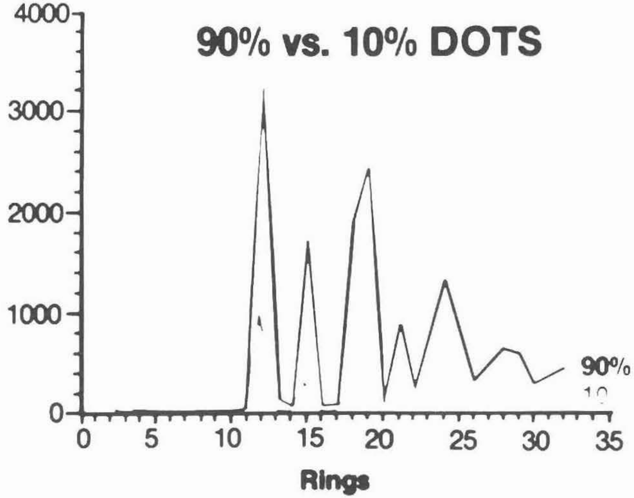


Figure 13

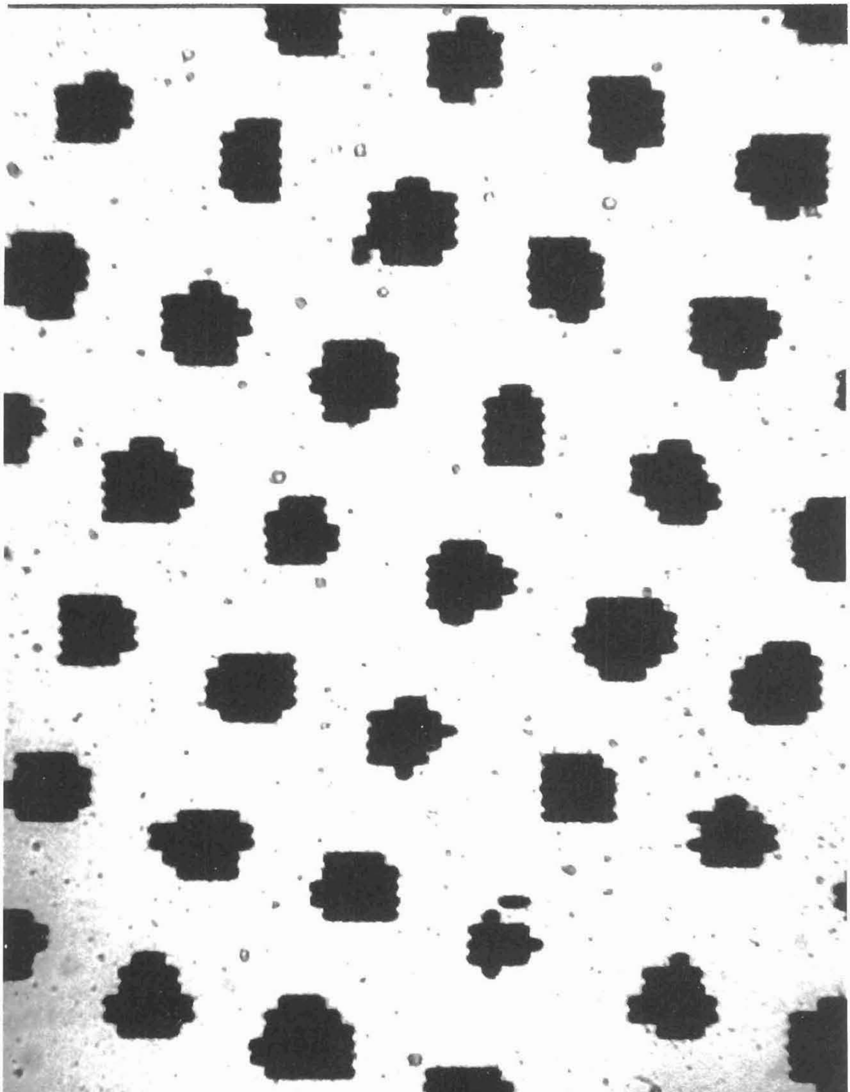


Figure 14

shape as well as tone changes in the reproduction chain. The technique of rapid Fourier analysis by optical computation assisted by solid state segmented photosensor analysis provides one way to accomplish the study and classification of halftone images in large as well as small sample size.

This paper has presented a brief view of a different dot analysis system, one that is facile, fast and accurate. One that enables the use of large sample sizes.

No individual dot analysis system is used exclusively at 3M. We like to choose the right instrument for the right job. For some applications this is the right instrument.

I would like to acknowledge the assistance of Ms. Sharon Bartels and Mr. Dave Dorenberg of the 3M Color and Image Analysis Center and, Drs. Michael Snyder and Michael Overstreet of the 3M ESST Laboratory and Richard Swing of the Federal Bureau of Investigation for their assistance in this project.

LITERATURE CITED:

(1) Fisch, R.S.
Need for Standardization for Graphic Arts Control
Lasers in Graphics 1985 vol. 1 pp. 194-206

(2) Fisch, R.S.
Dot Shapes and Their Reproduction
Lasers in Graphics 1984 vol. 1 pp. 391-403

(3) Howe, D.J. Maurer, R.E Yule, J.A.C.
An Analysis of the Optics of the Crossline Screen
TAGA Proceedings 1961 pp. 17-30