ASSESSING VISUAL NOISE PRODUCED WITH REGULAR SCREENS, RANDOM SCREENS AND «SCREENLESS» TECHNIQUES

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Abstract: The new non-regular screens, especially FM screens, produce a problem which has been unknown with regular screens, i.e. the phenomenon of graininess or visual noise.
Dependent on the screening algorithm noise can be stronger or weaker leading to the question as to which noise level is acceptable for prints.
A comparison is made between prints produced with the following processes:
- FM screens (Velvet, Cristal, Diamond, Scitex)
- regular screens
- random screens
- «screenless» techniques
- Collotype

The visual noise is assessed by image analysis. It is shown that a distinction has to be made between «blue noise» and «white noise», the latter being the far more objectionable form.

What is noise?

Noise is a term being originally used for characterising the zero signal in radio transmission. Similarly this term can be applied to TV transmission when no image signal is broadcasted on a channel. In this case a pattern is visible on the screen which is similar to the grain of a photographic emulsion. Therefore the term noise can also be applied to describe the random nature of the photographic grain. In this context noise is used as an equivalent term to graininess.

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Assessment of the density profile

In silver halide photography the density profile of a uniform gray tone has been traditionally used to assess graininess. Figure 1 shows the density profile of a gray tone printed on photographic paper and scanned over a length of 1.5 mm. Instead of density, the CIELAB lightness L* has been plotted where L* = 100 is equivalent to paper white. The lightness scale has the advantage to give a better comparison of profiles at different gray levels. A measure for noise or graininess is now the variation of the density profile. A numerical quantity for the variation is the root mean square deviation which, in the photographic literature, is referred to as the RMS granularity. In this context, the term granularity is considered as the objective equivalent for the subjective sensation of graininess.

The density profile (or lightness profile) is strongly influenced by the size of the aperture used to make the measurement. Within a series of measurements with the same aperture, however, profiles can be easily used to compare different processes. The density profile is especially suited to assess processes which show a certain continuous-tone appearance, but are based on a grain structure such as collotype or screenless lithography (see figure 2 and 3). The collotype process makes use of the grain structure of a light-hardened bichromated gelatin coating. In screenless lithography, the grain peaks of the printing plate are used as ink-receptive elements. Comparing the collotype process with screenless lithography, it can be seen that the RMS deviation for the collotype process is almost twice as large as the value for screenless lithography. This is also confirmed by the visual appearance of the printed samples. Figure 4 shows the profile curve of a further screenless process based on a certain grain structure, i.e. the so-called photolithography or asphalt process. Experts of this process know its low graininess which can be explained by the low RMS deviation of the profile curve.

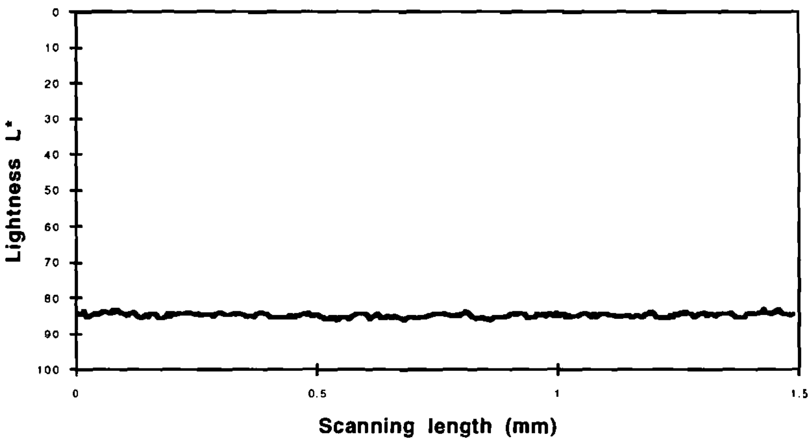


Figure 1 **Density profile of a continuous-tone print, print density D = 0.31 Root mean square (RMS) deviation 0.6**

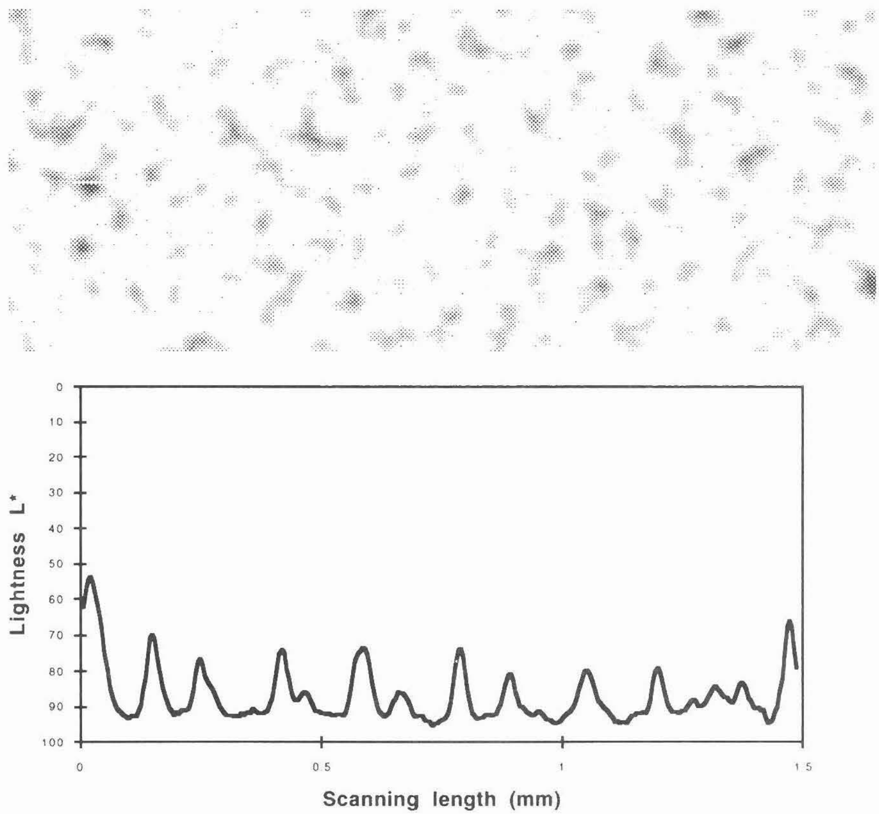


Figure 2 **Collotype, print density D = 0.27**
RMS deviation 7.6

If the density profile is used to assess binary structures such as prints from random screens or conventional halftone screens (see figure 5 and 6), the RMS deviation is no longer a measure for the visible noise, because conventional halftones can show an even larger deviation. The difference between a random screen and a regular screen is whether the printing elements are regularly ordered or whether they show a random distribution. This criterion is called the periodicity of the dot pattern.

Assessment of periodicity

The periodicity of a dot pattern can be assessed from the profile curve by making a Fourier transform. The measure for the periodicity is then the maximum amplitude value of the Fourier analysis. To obtain meaningful values, the amplitude of a conventional halftone screen printed with an ideal contrast can be considered as 100 %. The density

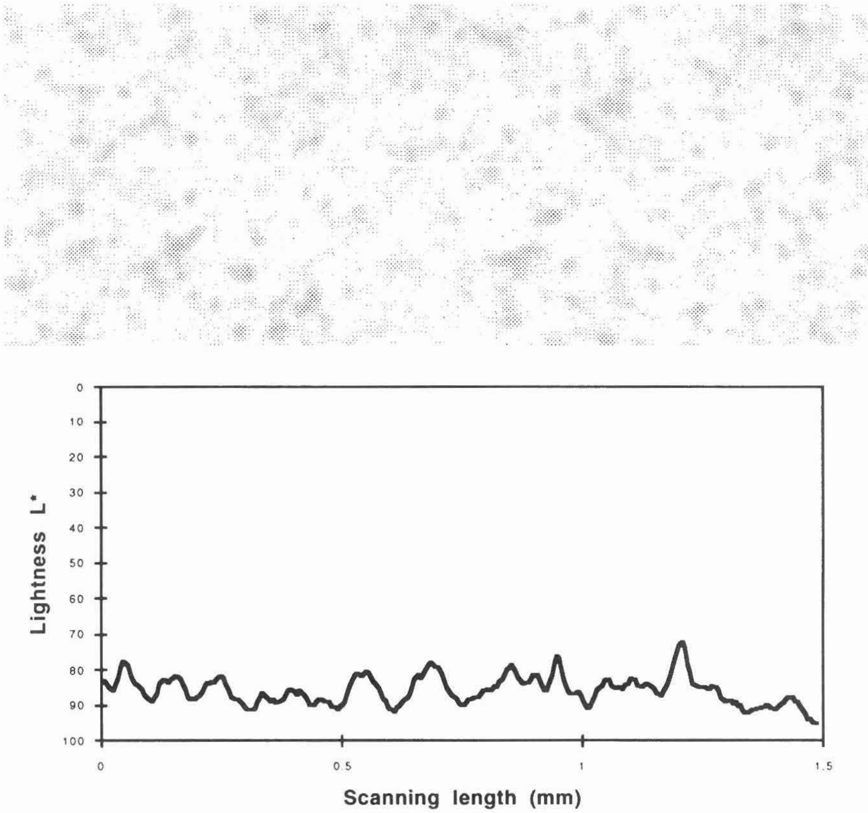
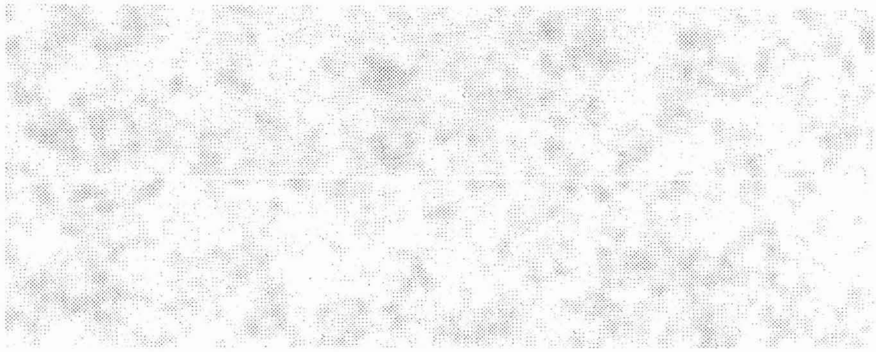


Figure 3 **Screenless lithography (UGRA process), print density D = 0.27 RMS deviation 4.0**

profile of a random screen shows then a very low periodicity. If a frequency modulation screen (FM screen) is compared with a random screen, the periodicity of the random screen can even be smaller without necessarily showing more visible noise. This means that the periodicity value alone is not sufficient to assess noise. Only in case of a high periodicity the conclusion can be drawn that no noise is existent.

If an FM screen (see figure 7) is compared with a random screen, a further property for classifying the graininess becomes evident, i.e. the number of printing elements or dots per unit area. The comparison of figure 5 and 7 shows clearly that the FM screen has a higher number of printing elements than the random screen. This property is called the dot density.



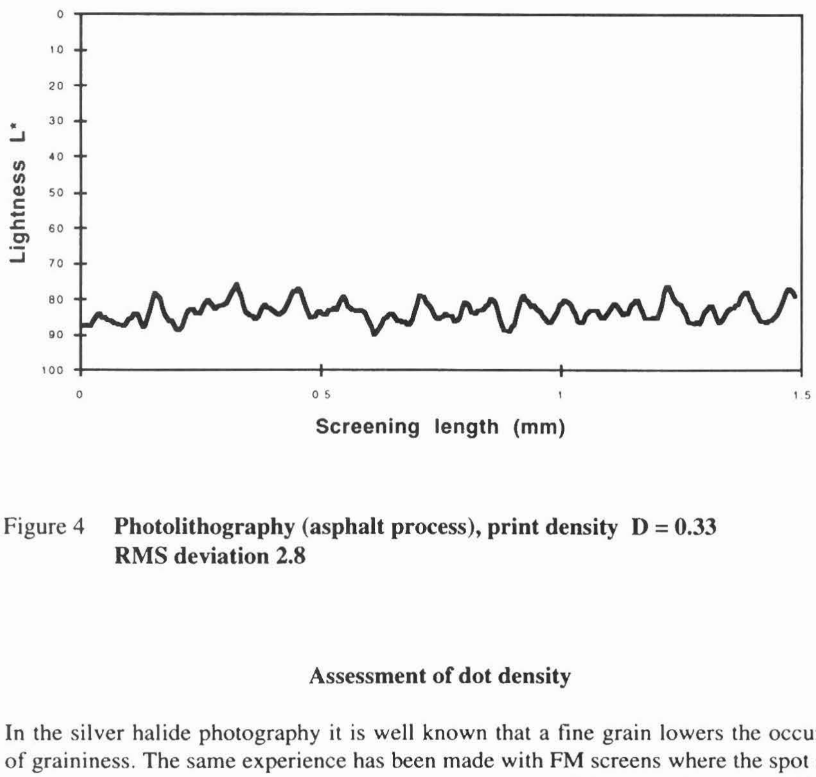


Figure 4 **Photolithography (asphalt process), print density D = 0.33 RMS deviation 2.8**

Assessment of dot density

In the silver halide photography it is well known that a fine grain lowers the occurrence of graininess. The same experience has been made with FM screens where the spot size is a mean to control the graininess. If the spot size is large, FM screens show a considerably higher graininess than in case of a small spot size. The dot density can be determined from the profile curve where the number of peak values is a measure for the dot density. As the profile gives only a result in one dimension, a better way to determine the dot density is a two-dimensional assessment. In this way it can be measured that the random screen shown in figure 5 has a dot density of 53 dots/mm^2, whereas the FM screen of figure 7 shows a dot density of 159 dots/mm^2. This number can be compared with a conventional halftone screen whose screen frequency can be converted in a dot density

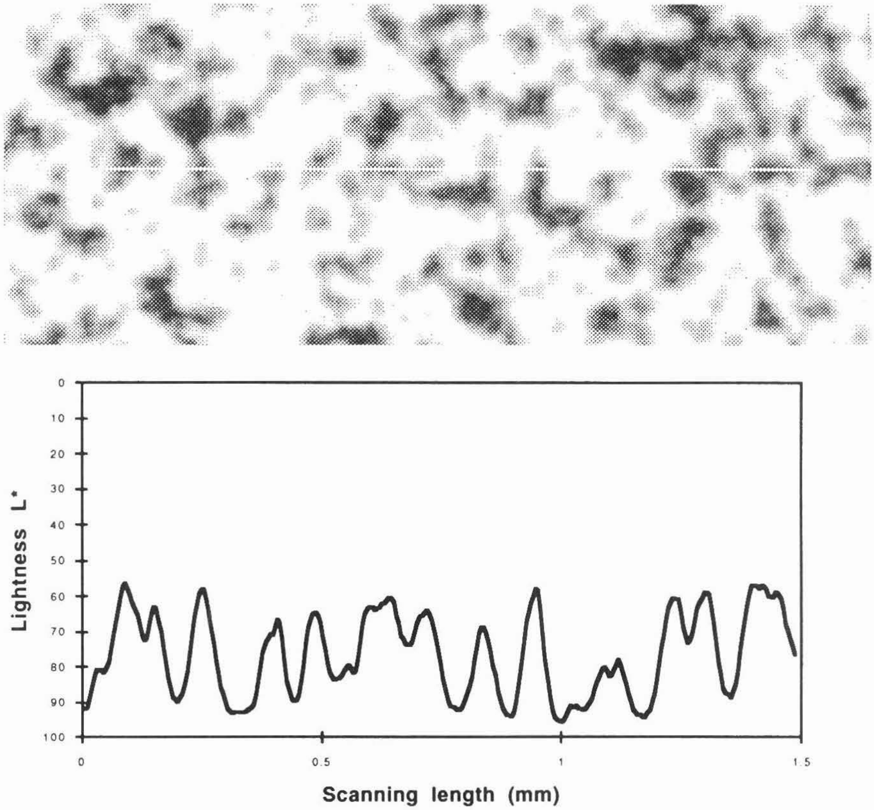


Figure 5 **Random screen, print density D = 0.35**
RMS deviation 11.6

number. For instance, a screen of 80 lines/cm (200 lpi) has a dot density of 64 dots/mm^2. Compared to this the random screen (see figure 5) has an equivalent screen frequency of 75 lines/cm, whereas the FM screen of figure 7 has a value of 125 lines/cm. It is important to note that this assessment is only valid for the measured dot area. With increasing dot area the dot density of random screens and FM screens becomes smaller, because the single dots merge to dot clusters.

Difference between «blue noise» and «white noise»

If different FM screens of the same dot density are compared, differences in visual noise are still possible. The nature of these differences is shown in figure 8 where two artificial dot arrangements have been plotted both showing no periodicity and having almost the

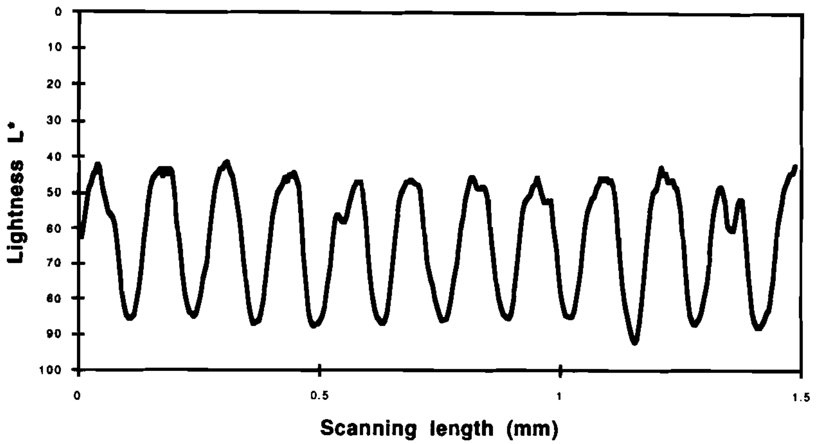


Figure 6 **Density profile of a conventional halftone of 80 lines/cm (200 lpi)**
print density D = 0.28
RMS deviation 17.7

same dot density. The dot arrangement on the left appears clearly to have more noise and is referred to as «white noise». The dot arrangement on the right showing less noise is called «blue noise». The difference between white noise and blue noise has to do with the variation of the dot size and the dot distance. While white noise is characterised by a large variation of the dot size and distance, blue noise shows a more uniform distribution of the dot size and distance. In order to obtain comparable values the variation of the dot distance and diameter can be expressed in percentage of the mean value. To give a practical example: A regular halftone screen has a variation of the dot size and distance in the range of 3 %, whereas the FM screen of figure 7 shows a dot size variation of 81 % and a distance variation of 32 %. The average of both values can hence be considered as a measure for the degree of noise or graininess in a printed sample. Together with the criterion of dot density, an assessment is possible in a two-dimensional diagram.

A diagram to assess noise

Noise can be assessed in a diagram (see figure 9) where the horizontal axis exhibits the dot density (in terms of dots per mm^2) and the vertical axis shows the variation of the dot diameter and dot distance. A low variation value (below 5 %) symbolizes a high uniformity of the dot pattern what is typical for regular screens. This is hence the area of no noise. A medium variation of the dot diameter and distance is typical for blue noise, whereas a high variation characterises white noise. With the criterion of the dot density an additional type of noise can be defined, i.e. pink noise as a low frequency variation of blue noise. (The terms white, blue and pink refer to the colors of light and the

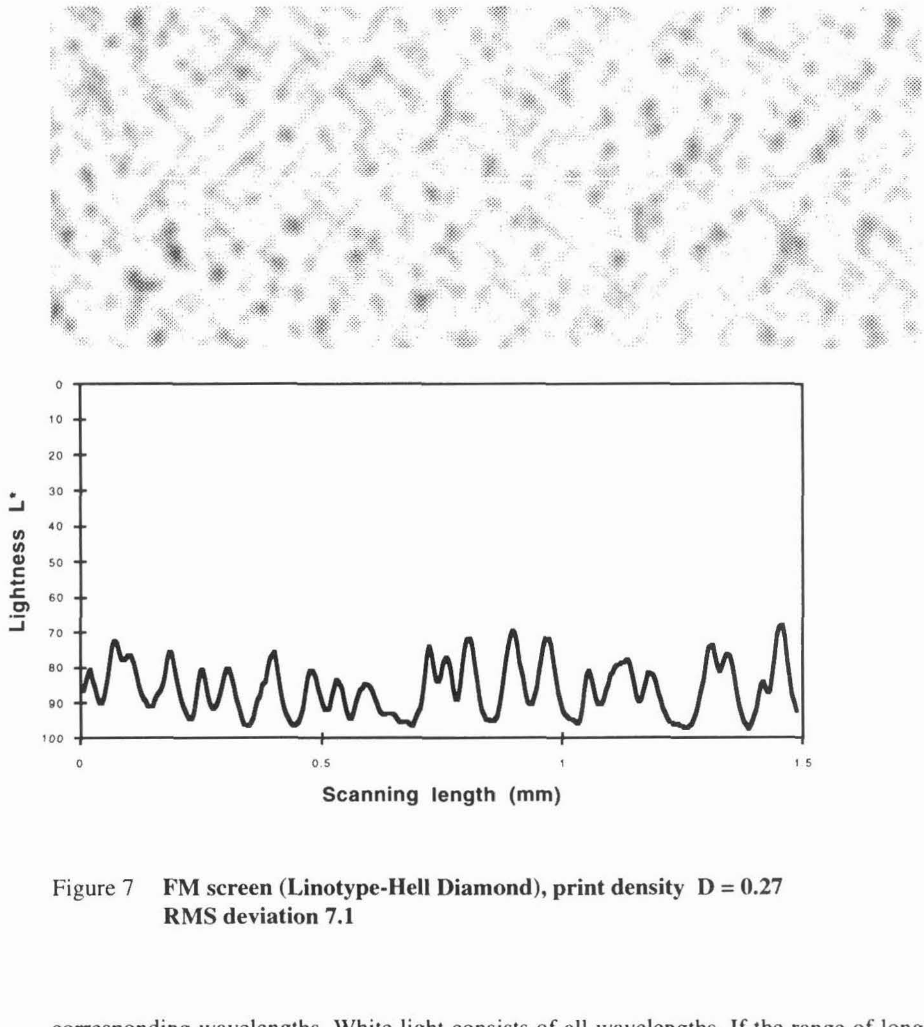


Figure 7 **FM screen (Linotype-Hell Diamond), print density D = 0.27 RMS deviation 7.1**

corresponding wavelengths. White light consists of all wavelengths. If the range of long wavelengths is removed from white light, the result is blue light. On the other hand, removing the range of short wavelengths yields red or pink light.)

If the value of the dot density exceeds a certain limit, noise disappears, because the human eye can no longer perceive the dot structure. This limit is higher for white noise than for blue noise. It is important to note that the ability to perceive noise depends strongly on the viewing distance, the contrast of the printed dots and the illumination conditions. Moreover it should be noted that this diagram is only suited to classify dot patterns of a certain dot area. If the dot area changes, a different dot pattern results leading to other measured values.

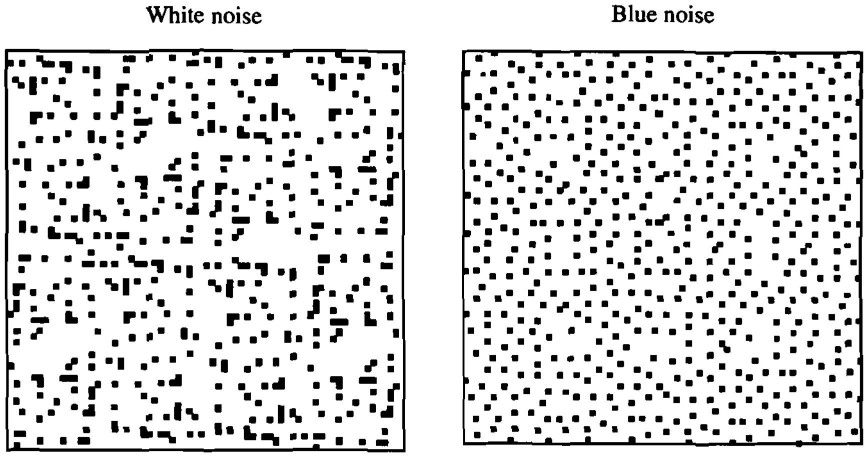


Figure 8 **Comparison between white noise and blue noise (plotted bitmap 72 x 72)**

If the two dot patterns of figure 8 are analyzed with respect to their variations of the dot distance and diameter, the transition from blue noise to white noise can be assumed to take place above 25 %. The ability to perceive a dot structure can be derived from regular screens where it is well known that a screen ruling of 120 lines/cm is no longer visible. This corresponds to a dot density of around 150 dots/mm^2. In the range of white noise this limit is likely to be higher and may reach 200 dots/mm^2. The range of objectionable noise can therefore be located above 25 % in terms of the variation of the dot distance and diameter and below 200 dots/mm^2.

Assessing noise of FM screens

As FM screens and random screens belong both to the category of non-regular screens, FM screens are often classified as a subgroup of random screens. The random nature of the dot pattern obtained with FM screens is hence also considered to have the same graininess as random screens. If some commercial FM screen products are visually examined, it cannot be denied that some show indeed a white noise character. A comparison of different FM screens, however, reveals that clear differences in the degree of noise can be found. In order to classify FM screens with respect to noise, the following commercial products have been compared:

- UGRA Velvet Screen (20 µm and 40 µm)
- Linotype Hell Diamond Screen
- Agfa CristalRaster
- Scitex Fulltone Screen.

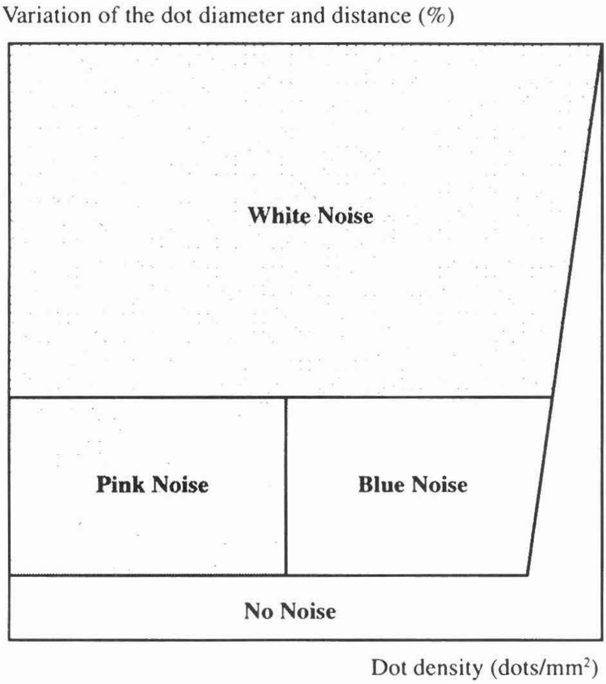


Figure 9 **Diagram to assess noise**

In addition a random screen and two screenless processes (collotype and screenless lithography) have been included. The measurements were made on printed samples at density levels between D = 0. 15 and D = 0.30 what corresponds to a dot area between 18 % and 30 %. It has been found that this range of dot areas is most sensitive to produce visible noise. If the dot area is below 15 %, the gray level is too low to exhibit noise. At higher dot areas the noise is less visible, because the dot pattern is gradually replaced by a coherent ink film. The measured values for the variation of the dot diameter and distance and for the dot density are shown in table 1 and in figure 10. As can be seen, some FM screens fall into the area of low noise or no noise, whereas random screens and screenless processes can be found in the area of strong noise. Noise in FM screens can be avoided, if a small spot size is used leading to a dot pattern which is beyond the perception limit for noise. A spot size of 15 µm would theoretically yield at 10 % dot area a dot density of 566 dots/mm^2, if single dots are printed rather than clusters. A spot size of 20 µm still yields a dot density of 318 dots/mm^2 which is beyond the perception limit. A «good» FM algorithm has therefore to make sure that the microdots are isolated and, if they start to form clusters, that the

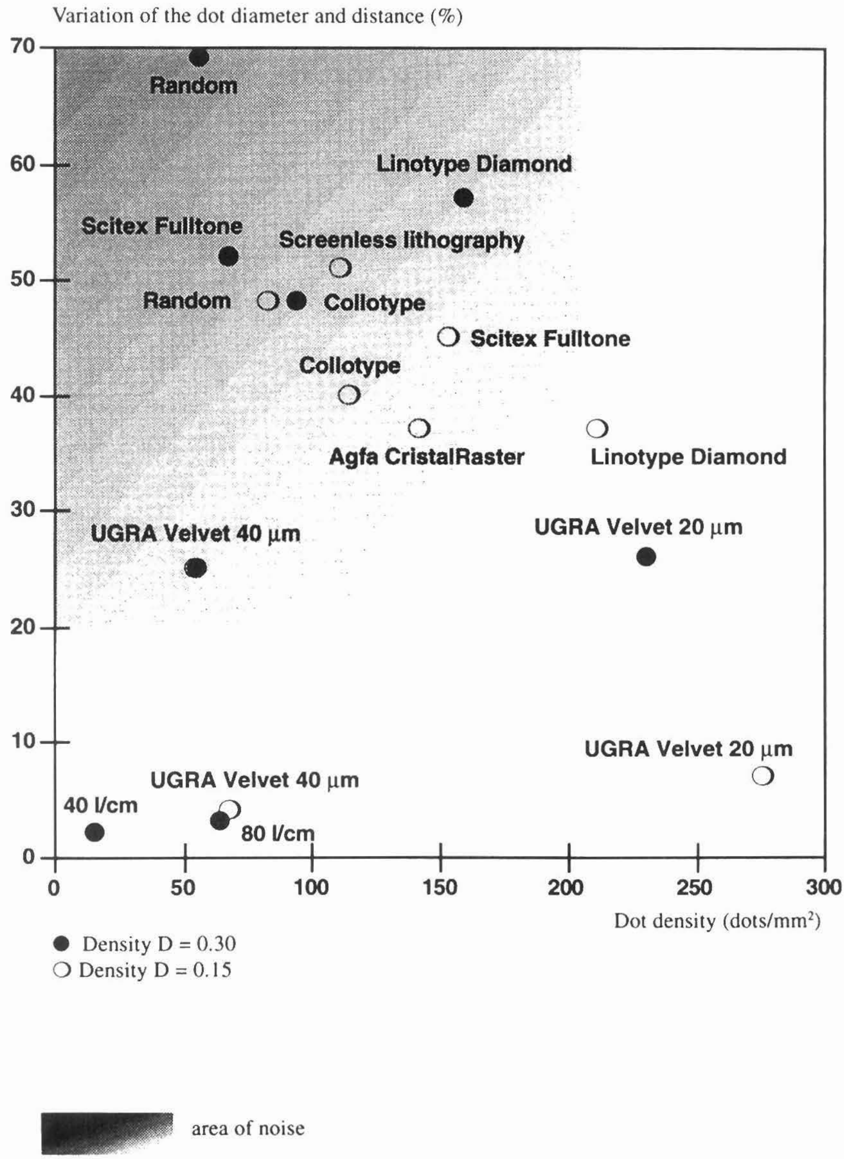


Figure 10 **Classification of FM screens and other non-regular screens with respect to noise**

Sample	Density	Periodicity %	Dots per mm^2	Variation of dot diameter %	Variation of dot distance %
UGRA Velvet 40 µm	0.15	30	68	3	4
	0.32	41	55	32	17
UGRA Velvet 20 µm	0.19	14	276	9	5
	0.28	10	231	33	19
Scitex Fulltone	0.13	14	154	60	29
	0.34	21	68	68	36
Linotype Diamond	0.14	8	212	51	23
	0.27	10	159	81	32
Agfa Cristal Raster	0.15	9	142	47	27
Collotype	0.17	10	115	51	29
	0.27	13	94	57	38
Screenless lithography	0.14	7	111	67	34
Random screen	0.15	9	83	62	33
	0.35	20	56	102	36
Halftone 40 l/cm	0.32	94	16	2	2
Halftone 80 l/cm	0.28	69	64	3	3

Table 1. **Classification of different screening and screenless technologies with respect to noise**

size of the clusters is again uniform. Figure 10 shows clearly that this condition is better fulfilled for the Velvet Screen than for other commercial FM screens. This can also be seen, if magnifications of FM dot patterns are assessed (see figure 11).
As a consequence from this, second order FM screening where different spot sizes are produced is not recommendable, because it is far more sensitive to white noise than first order FM screening.

To summarize, the question as to the nature of noise can be answered as follows: Noise is visible if
- the dot distances show a large variation,
- the dot diameters show a large variation,
- the dot density is low,
- the periodicity is low
- the RMS deviation of the density profile is high.

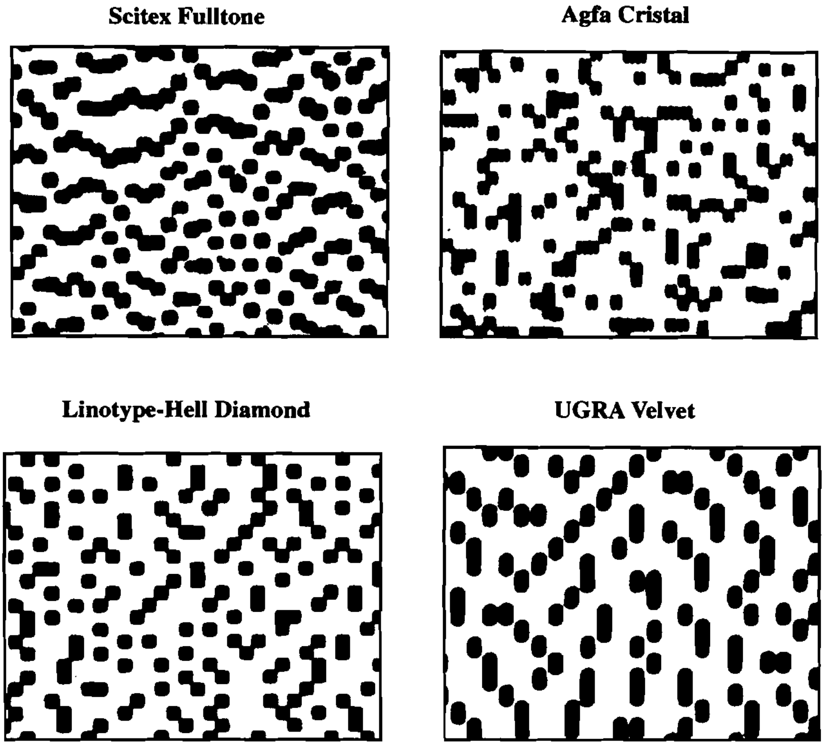


Figure 11 **Dot structure of four commercial FM screens at a dot area of 25 % (Magnification 120 x)**

Experimental

Hardware and software configuration

Microscope:	Stereomicroscope Zeiss SV-11, magnification max. 50x
Camera:	Bosch B&W valve-camera
Workstation:	Macintosh Quadra 900
Programs:	PrismView, PrismCalc

Image caption

Scanning resolution:	480 x 640 pixels
Scanned image area:	2.4 x 3.2 mm

Lightness profile

Length:	1.5 mm
Number of pixels:	300
Pixel size (aperture):	5 µm
Program:	Mathematica
White reference:	substrate