Frequency modulated random Screening : the fundamental idea

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Frequency modulated random Screening - The fundamental idea:

The best way to reproduce an original of any kind is to reproduce closely its characteristic pecularities.

The main characteristic pecularity of a photographic original is the frequency modulation of the tone rendering. Its simulation in the printed picture promises the highest possible standard of the reproduction quality with respect to tone rendering and resolution of details. Contrary to the sophiticated screenless processes the FM process is fully reproducible and it is therefore a really industrial process.

June 1984

Frequency modulated random Screening

The quality of photographs has greatly improved during the past 50 years. Photographic techniques are now easy to handle in the short time available and are widespread in private as well as in public affairs. In consequence, the pictures in newspapers and magazines are usually printed to make an original photographic picture available for every reader. That means that the photograph has to be reproduced. Admittedly, one could match this to the highest standards if the photographic process were to be used for the reproduction. The reasons are that the identical colourimetric colours would be used on the one hand and the picture would consist of the same components on the other. In today's halftone prints neither is the case. We discussed the question of how the character of a photographic picture could be simulated by a new screening technique.

It is useful to begin with a look at the nature of a photographic picture. In the case of black and white film, halogen-silver-grains of constant average size are exposed, and are arranged at random. The number of the exposed grains increases with the exposure. After development, the picture shows only a few silver-crystals in areas of low density and many crystals in high density areas. Thus the density is modulated by means of picture elements of about the same size arranged at variable distances. If the screen frequency is defined as is usual in halftone printing, namely as the reciprocal value of the mean distance of the printed dots, then the photographic pictures are frequency modulated pictures.

In the case of a photographic paper picture, there are little clouds of ink instead of silver grains. Therefore all kinds of photographic pictures are frequency modulated, coloured pictures as well as black and white ones.

In contrast to this, the screen frequency is constant, for example 60 lines/cm in halftone printing. All picture elements are of the same size, namely the size of the screen elements.

Picture elements of this size can hardly be resolved from usual viewing distances or even be recognized, fig. 4, page 98. The brightness is modulated by variation of the percentage dot area, fig. 5, page 98. In contrast to the photographic picture, a halftone printed picture is amplitude modulated. In the case of colour printing the percentage dot area is modulated in every basic ink. The percentage dot area is modulated in high quality reproductions from about 2% up to 98%. The diameter of the dots is about 18 microns in these extreme cases. Usually the dots are bigger, about 20 microns or more, so that the danger of missing dots is not increased.

The resolution of details is limited by the screen frequency, fig. 2, page 96. Therefore the screen frequency is usually determind by means of the desired resolution. But the tone reproduction is also influenced by the screen frequency, fig.3, page 98. The number of visual resolvable tonal steps decreases at higher screen frequencies as well as the printable density range, fig. 2, page VII. That is the reason why higher screen frequencies, which are necessary for adequate detail resolution, lead to lower contrasts, which are not acceptable. As a consequence, black has to be printed as a "fourth colour". And finally the printed halftone picture can hardly match the photographic orginal picture. In order to match the character of a photographic original picture by a printed picture there are two problems to be solved, i. e.

- how to print little ink clouds

and above all,

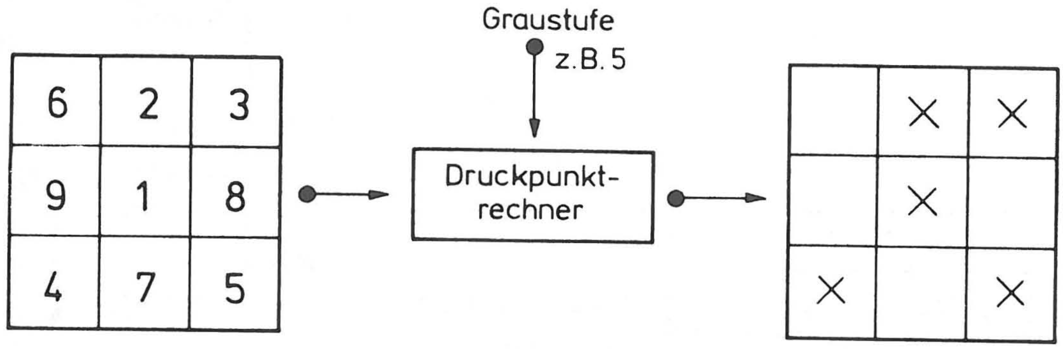
- how to determine the distances between the colour clouds or the corresponding local screen frequencies.

The first problem appears to be solved by the printing process itself. With a high magnification microscope one can see quite distinctly that not one of the bigger dots in a printed picture could be described as a dot of defined shape and of constant ink layer thickness. Furthermore, the little dots of about 20 microns are far more similar to the desired ink clouds. In fact the printed dots look more like clouds the smaller they are. The problem of generating very little dots, of 10 microns diameter, for example, is in practice known to be more a problem of plate exposure than a problem of printing. It is therefore evident that the imitation of ink clouds is produced automatically from the roughness of the paper used and by the ink layer.

The remaining problem is the calculation of the local frequencies. The frequencies are determined by the number of microdots per picture element and their positions. But this problem becomes soluble without any real difficulty when using a scanner. The density signal, which is produced for every picture element of the photographic original, has first to be transformed into a signal that shows the number of microdots corresponding to the scanned density. The positions of the microdots can be fixed afterwards.

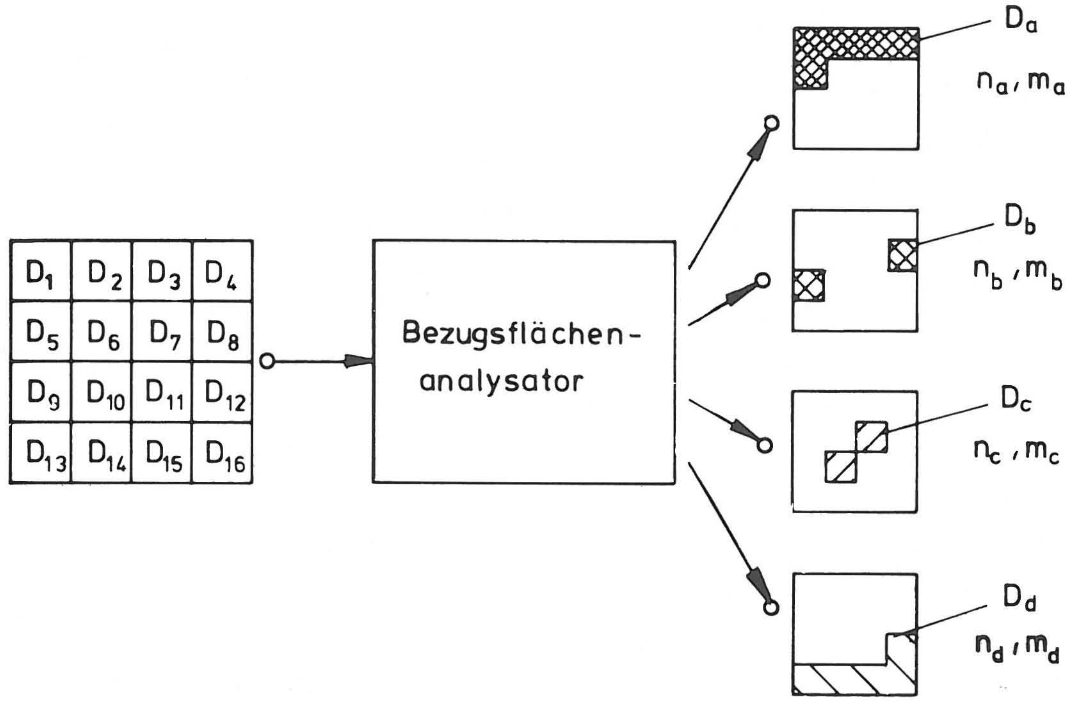
To avoid moirée-patterns it is useful to distribute the printed dots in an irregular manner within the picture elements. The random distribution is attainable in principle with an auxilliary random signal for example with a matrix of random numbers.

A simple example, with only nine places and a random distribution of the numbers ONE to NINE is shown below. The matrix corresponds to a picture element, the elements of the matrix correspond to possible positions of printed dots. According to the actual density signal there could, for example, be five dots selected for printing from the nine matrix elements. The desired random distribution results when, for example, the matrix elements with the five lowest numbers are chosen for printed dots. The matrix of random numbers may be changed from one picture element to another in a way that the printed dots are randomly distributed over the whole picture.



If it is possible to avoid the procession of picture elements one after another, which is the case for example in the CHROMACOM-System, then the matrix of random numbers may be enlarged so far that a matrix, say containing 16 picture elements, can be processed in one cycle. The diagram on page - 5 - shows the whole processing cycle. Above, you can see the matrix containing 16 density signals among which there are certain groups with identical or nearly identical tonal values. Each of these groups is characterized by a mean tonal value and a certain number of elements. The number of printed dots is calculated for each group by means of the tonal value D and the number of elements. The auxiliary matrix of random numbers leads to a random distribution of dots in the former precessing illustrated. Finally the dot distributions of the single groups are added again in the diagram below.

In conclusion, it is evident that photographic pictures can be simulated by means of the offset technology available today through three vital processes, namely the printing of ink-clouds, the density modulation via local frequency of these clouds and the random distribution of the clouds. For this reason the random screening method described permits the printing of pictures that match far better the photographic original than does the traditional halftone printing process.


D1 D2 D3 D4
D5 D6 D7 D8
D9 D10 D11 D12
D13 D14 D15 D16
Bezugsflächen-analysator
Da
na, ma
Db
nb, mb
Dc
nc, mc
Dd
nd, md

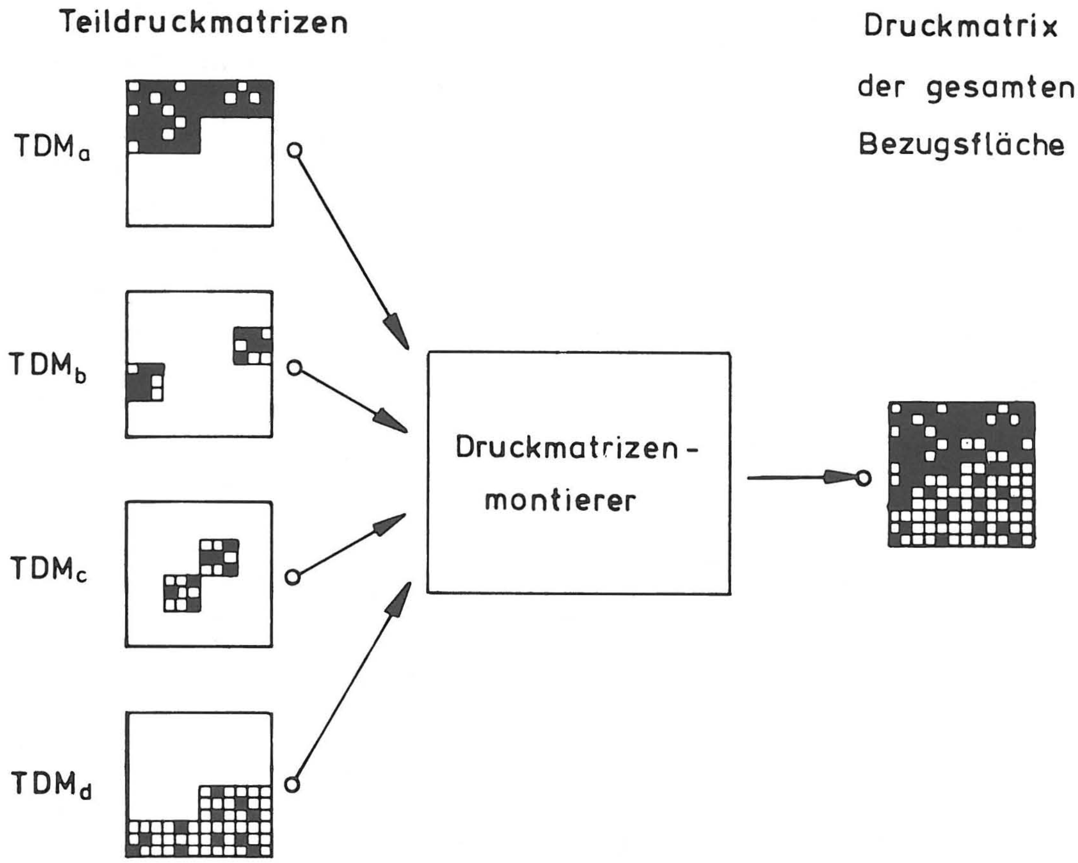

Teildruckmatrizen
Druckmatrix der gesamten Bezugsfläche
TDMa
TDMb
TDMc
TDMd
Druckmatrizen-montierer

Fig. 8, page 99, shows the typical impression of a printed picture in halftone screening compared with random screening. The different screening method, however, is visible only under high magnification on fig.1, page 94.

The picture on the left shows conventional halftone screening. The distances between the printed dots are constant, in this example 125 microns corresponding to the screen frequency of 80 lines/centimetre. The distances are constant, and that is why they do not contain any information. But they are responsible for the resolution of detail because every printed dot is a picture element. The tonal values, which represent the picture information are visible as different dot sizes.

The picture on the right shows that random screening is the inversion of halftone screening. Now,the printed dots are all of the same size and do not contain information. But they are responsible for the resolution of details. The different tonal values are given by means of the dots' local frequencies. That is why the information of the picture is visible as different frequencies. This novel screening method is in fact a frequency modulation and is totally different from halftone screening, which has to be understood as amplitude modulation

The main characteristics of frequency modulated pictures are the following:

- The printed microdots cannot be resolved from any viewing distance (fig. 4, page 98, right)
- The brightness is modulated by variation of the number of dots per picture element (fig. 5, page 98, below)
- The resolution power is only limited by the size of the microdots (fig. 2, page 96, right), and finally
- The number of tonal steps is not limited (fig. 3, page 98, right).

The different modulation procedures lead to corresponding differences in picture processing. In the case of amplitude modulation. the positions of the printed dots are fixed by the screen frequency. Therefore only the dot area has to be calculated according to the local densitiy. In the case of frequency modulation, however, there are two variables, namely the number and the individual positions of the dots to be calculated for every picture element.

This means that frequency modulation requires a little more effort than amplitude modulation, although this effort only means the automatic calculation programs in the scanner. The state of the art in random screening development is characterized by the use of a modern scanner/recorder station in the CHROMACOM-System, which was loaded with the System Software and the software for frequency modulation was added to the existing programs. Consequently, the calculation time is impractical and could only be reduced when using special hardware, such as fast modern processors. With respect to the convincing advantages gained, which include possibilities for extended stabilisation of the whole redproduction process, this technological effort for frequency modulation is certainly justified.

Some runability tests on different web-fed offset rotary presses and sheet-fed machines and a lot of different paper qualities in different printing plants enable us to compare the properties of amplitude and frequency modulated pictures. None of these numerous tests could disclose any disadvantage of the random screened pictures in comparison with halftone screening. The following advantages of the random screened pictures were ascertained:

1) Better consistency of tone reproduction over the production run. Fig.1, page VII is a diagram showing the density deviations that arise when the normal ink layer thickness density of about 1.5 is leveled up to 1.7 and down to 1.3 at 90 per cent dot area. Obviously the resulting density deviations vary less at frequency modulation. Furthermore the density deviations show a good linearity.

2) Extended reduction of flooding danger.

Frequency modulated pictures look very similar to rotogravure printed pictures and show better contrasts than halftone prints. For this reason the machine operator is not tempted to adjust for a too thick ink layer. Furthermore the ink-water-distribution on the printing-plate is a fine distribution of very high mechanical stability. In the case of flooding, for example, the frequency modulated 60 %-tone did not show any flooding, while in halftone printing the 40 % tone already began to flood.

3) Enlarged ink-water balance range.

The characteristically fine and stable distribution of ink and water is responsible for this effect, too.

4) Approaching the contrast of a 4-colour halftoneprinted picture without the black printer.

Fig.8, page 99, shows this very distinctly because the frequency modulated picture on the left side is, in fact, printed in only 3 colours.

The facilities of 3 colour printed pictures with high contrast seem to be the main reason for the use of random screening. Apart from the apparent economic advantage, the absence of a black printer already leads to brighter colours. Furthermore, the tonal values of a frequency modulated picture look brighter than in the amplitude modulated picture even if both are printed with the same three inks and on the same paper.

Fig.6, page 98, shows the same sector of a colour chart. By comparison with the randomly screened, the halftone screened colours look a little dirty in fact. This impression is believed to be produced through something like a colour noise level. The halftone screen is responsible for distinct amplitudes in luminosity for example. The difference can be measured exactly by microdensitometer-scanning. Fig.7, page 99, shows the measured density profile of a

3-Colour-Chart field in the middletone region. The amplitude modulated section is characterised by low frequencies and high amplitudes. In contrast to this, the frequency modulation method leads to low amplitudes and high frequencies and that is why frequency modulated pictures seem to look smooth and calm.

Three different influencies are responsible for this effect. First, the little dots are printed like clouds. Second, the light scattering in paper causes a side lighting of good constancy so that the differences, for example, in luminosity, between the printed and not printed picture elements are relatively low. Finally, the distances between the dots are in general much shorter and cannot be resolved by the human eye.