ARE FINE SCREENS AN ALTERNATIVE TO FREQUENCY MODULATION SCREENING?

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Abstract: Since frequency modulation screening gains more and more interest and the number of vendors increases almost every week, the question arises whether conventional screens have still a future, and if so, whether fine screens could be an alternative to FM screens.

The following characteristics of fine screens and FM screens are compared:
- visual dot structure
- resolution
- dot gain
- stability of highlight dots during the photomechanical transfer
- sensitivity to overinking.

It is shown that fine screens offer no advantage compared with FM screens as far as resolution, dot gain, dot transfer and printing performance are concerned. Only the visual dot structure may be a problem with some FM algorithms. However, FM screens can be designed to show a low-noise performance meaning they are not necessarily inferior to fine screens.

Arguments in favour of fine screens

Frequency modulation (FM) screening is regarded by many experts as the future of the screening technology. As the number of FM vendors is increasing every month, the question arises as to whether the conventional screening process has still a chance, and if so, whether only fine screens are the alternative. Those supporting the application of fine screens argue that higher screen frequencies impose no additional problems compared with FM screens, as far as the transfer from film to plate is regarded. Moreover, fine screens allow a detail rendering and a continuous-tone appearance being equal to FM screens. In addition, fine screens show a higher evenness in monochrome images and especially in the highlights, whereas FM screens tend to have a certain graininess. The following paper is a critical discussion of the pros and cons of fine screens.

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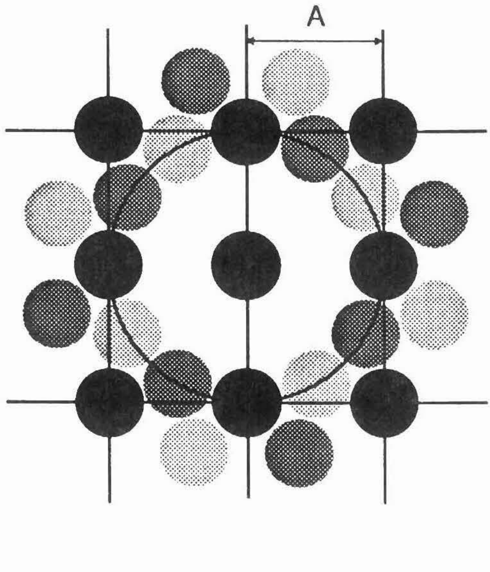
What screen ruling is needed for the human eye?

The resolution power of the human eye is determined by the distance of the light sensitive receptors on the retina. From this distance the angle can be calculated under which two lines are just distinguishable by the human eye. As two lines can only be distinguished, if they are divided by a distance, the correct term to describe the resolution power is a line pair consisting of a solid and a blank line. In order to render a line pair with conventional halftone printing, two halftone dots are required. It has been found that the angle under which two halftone dots can be distinguished is 1.5 minutes of arc. From this the number of halftone dots per cm can be calculated, if the viewing distance is known. In most cases, the viewing distance is between 20 cm and 40 cm. This corresponds to 57 distinguishable halftone dots per cm for 40 cm and to 114 dots/cm for 20 cm (see table 1). Based on this, a screen ruling of 120 lines/cm can be regarded as necessary to simulate a continuous-tone appearance in the human eye. Screen rulings of 80 lines/cm or 100 lines/cm may give the same result, if the viewing distance is longer or if the illumination level is reduced. In multicolor printing, a further factor contributes to visible structures, i.e. the formation of rosettes. In certain tone values the rosettes are exactly circular (see figure 1) with an inner diameter being twice as large as the edge of a 50 % halftone dot. This means that the rosette structure can be seen at even larger viewing distances than single halftone dots. To make the rosette structure invisible at a distance of 30 cm, the screen ruling must be as high as 154 lines/cm.



A = Side length of the screen cell

Figure 1. **Rosette pattern resulting from screen angling with three colors**

Rendering of highlight dots

All photomechanical processes based on conventional halftones are faced with the problem that small isolated halftone dots cannot be transferred to the printing plate without a loss of the dot area. Although modern high resolving offset plates show a minimal dot loss, its magnitude is not negligible at values exceeding 80 lines/cm. The reason why small dots cannot be correctly transferred lies in the exposure process where the halftone film is undercut by light leading to a reduction of the dot diameter. The extent of this reduction is determined by the size and the distance of the halftone dots. The distance is especially relevant in case of FM screens, because the dot size is constant. Although FM dots are very small, a dot loss only occurs in the highlights, i.e. where the dots have a large distance. Investigations have shown that very small dots of 10 µm can be correctly transferred to the printing plate, if ideal conditions are met in the platemaking process. Under practical conditions, however, the minimal dot size which can be printed is much larger. The current platemaking standards are aimed at rendering a dot diameter of 25 µm which is equivalent to a dot area of 2 % at 60 lines/cm. However, the platemaking process can easily be adjusted to render a dot diameter of 15 µm, if the exposure time is reduced. This corresponds to a dot area of 1 % at a screen ruling of 75 lines/cm. Higher screen rulings than 75 lines/cm do not permit to render 1 % dot area. For a screen ruling of 150 lines/cm, the minimum reproducible dot area is no better than 4 %. If this is compared with FM screens, the problem of highlight reproduction is far less critical. The smallest dot diameter used for FM screening is currently 14 µm which corresponds to 1 % dot area at 80 lines/cm. Compared with real fine screens, FM screens give therefore a far better highlight reproduction.

Viewing distance	Screen frequency (lines/cm)
20	114
25	92
30	77
40	57

Table 1. **Minimum screen frequency required to achieve a continuous-tone appearance for different viewing distances**

Dot gain

If a 50 % dot area is printed under standardised conditions on a coated paper with a screen ruling of 60 lines/cm, the dot gain is 18 %. This value is the result of three different influence factors, i.e. (see figure 2)

- the undercut by light in the platemaking process
- the light absorption when halftone patterns are printed on paper (optical dot gain)
- the spread of the ink film (mechanical dot gain).

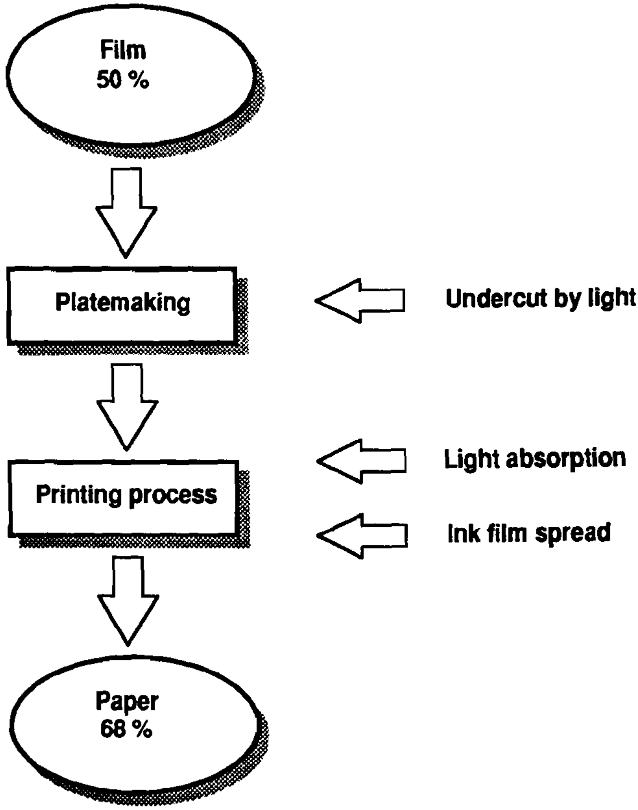


Figure 2 **Standardised transfer of 50 % dot area from film to paper**

For a screen ruling of 60 lines/cm the undercut by light produces a dot loss of 3 % on positive plates. Negative working plates, however, show a dot gain rather than a dot loss. The mechanical dot gain accounts to 6 %, if the printing process is standardised. The light absorption increases the dot gain for another 15 %. If finer screens are printed, the before mentioned values for both the dot loss and dot gain become larger. The total dot gain is then the result of a compensation between the mechanical dot gain and the dot loss in the platemaking stage. An increase of the screen ruling from 60 lines/cm to 120 lines/cm raises the total dot gain from 18 % to nearly 30 % (see table 2).

	Change of dot area in % at 50 %		
	60 lines/cm	**80 lines/cm**	**120 lines/cm**
Platemaking			
Undercut by light	–3	–4	–6
Printing			
Ink film spread	+6	+8	+12
Light absorption	+15	+19	+23
Total	+18	+23	+29

Table 2. **Formation of dot gain for different screen rulings**

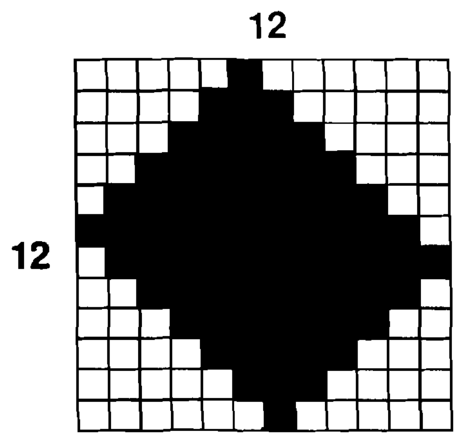
The increase of the dot gain as such is not a disadvantage, because it can be compensated by an adjustment of the image gradation. When, however, a high dot gain is caused by a higher screen ruling, a further disadvantage is the larger dot gain variation. While the dot gain variation is ± 3 % under standardised conditions at 60 lines/cm, it can reach ± 6 % at 120 lines/cm. This is the due to the variation of the solid tone density being usually ± 0.10 density units.

If the situation is analyzed for FM screens, they also show higher dot gains which, however, produce a lower dot gain variation. Tests at UGRA have shown that, if the solid tone density is increased by 0.2 units, the dot gain obtained with FM screens is only 3 to 4 % higher in the middle tones, while a conventional halftone screen of 60 lines shows an increase of 6 %. A theoretical explanation for this phenomenon does not yet exist. Printing of FM screens seems to have a similarity with screenless printing where the plate grain plays the role of ink-receptive microdots. Also in screenless lithography a low sensitivity to variations of the ink film thickness can be observed. An explanation for this could be that the classic dot spread occurring in the printing nip is eliminated when the printing elements have a size comparable with the plate grain. This situation is almost reached for FM screens, because the printing dots are not much larger than the size of the ink-receptive elements in screenless lithography. This theory is also in line with reports that extreme fine screens exceeding 180 lines/cm show a similar behavior.

The conclusion from this is that very fine screens behave similar to FM screens, whereas fine screens below 150 lines/cm show distinct disadvantages in the dot gain variation compared with FM screens.

Number of reproducible tone values

If halftone dots are electronically generated, they are built up from small microdots whose number depends on the recording density of the output system. An imagesetter working with 1800 dots per inch (dpi) generates a halftone dot of 60 lines/cm from a matrix of 12 x 12 = 144 microdots. If the screen ruling is increased, the number of microdots to generate a halftone dot becomes smaller. For 80 lines/cm the matrix is no larger than 9 x 9 microdots and for 120 lines/cm only 6 x 6 microdots (see figure 3). Therefore the number of repro-



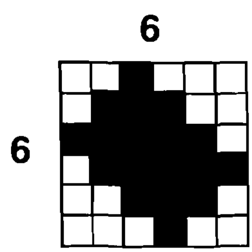


Figure 3. **Bitmap of a 50 % halftone dot generated with 1800 dpi**

ducible tone values shows a trade-off with the screen ruling and decreases with increasing screen frequency. To overcome this, a higher recording density of the imagesetter is needed which can go as high as 5000 dpi. As can be seen from table 3, screen rulings above 100 lines/cm require necessarily a recording density of higher than 3000 dpi. (This statement is not true for every imagesetter, because some models are able to produce overlapping microdots, hence allowing to increase the number of grey values without increasing of the recording density.)

Screen ruling lines/cm	Number of gray values at a recording density (dpi) of 1800	2400	3000	3600
60	144	256	400	576
70	100	169	289	400
80	81	144	225	324
100	49	81	144	196
120	36	64	100	144

Table 3. **Number of reproducible gray values as a function of the recording density and screen ruling**

Unlike conventional screens, FM screens require no increased recording densities and show no trade-off between recording density and the number of grey values. To produce FM films, the recording density of the imagesetter must not exceed 1800 dpi. The number of reproducible grey values is not limited, even though very low recording densities are applied.

Image resolution

The screen ruling is only one parameter determining the image resolution. The even more important factor is the scan resolution which, however, has a trade-off with the screen ruling. The common rule is that the scan resolution should be twice as high as the screen frequency. To avoid large files of image data, the scan resolution is usually never higher than 160 pixels/cm, irrespective of the screen ruling (see table 4). When images are scanned with a higher resolution than the screen ruling permits to print, this is equivalent to a loss of information. Other than in conventional screens, FM screens allow to render the full information content given by the input resolution independent of the spot size of the FM screen. In most cases, the same standard input resolution of 120 pixels/cm can be used for both, conventional and FM screens. If, however, smaller data files are wanted, a lower input resolution is possible, because no oversampling is required. On the other hand, higher input resolutions are also applicable. The theoretical limit for the input resolution being fully reproducible with FM screens is the recording density of the output system. This value can be as high as 500 pixel/cm.

Screen ruling/lines/cm	Scan resolution Pixels/cm
60	120
80	120
100	150
120	120 or 160
150	150

Table 4. **Scan resolution as a function of the screen ruling**

Evenness of the grey tones

A standard argument against FM screens is their graininess. It cannot be denied that the appearance of some FM screens support this opinion, especially if monochrome images are assessed. In some publications FM screens have even been denoted as random screens, because both belong to the category of non-regular screens. However, while random screens produce graininess almost inevitably, FM screens can be designed to show a low-noise performance. Technically, this is achieved by a distribution of microdots showing a certain degree of regularity. As some commercial solutions show, the graininess of FM screens can be eliminated successfully, proving that the evenness of grey tones is not an exclusive feature of regular screens.

Summary of disadvantages of fine screens compared with FM screens

It has been shown that fine screens have the following disadvantages compared with FM screens:

- Visible rosette structure, if the screen ruling is below 120 lines/cm: Due to this structure fine screens are not able to simulate a continuous-tone appearance. To overcome any visible structure, the screen ruling has to be increased to very high values which impose serious printability problems.

- Dot loss in the highlights: While it is true that a dot loss occurs with both regular screens and FM screens, a dot area of 1 % can be more easily rendered with FM screens than with fine screens over 100 lines/cm.

- Limitation of the number of reproducible grey levels: If imagesetters are used having a recording density less than 2400 dpi, screen rulings of 120 lines/cm cannot be rendered with a sufficient number of grey levels. In contrast to this, FM screens show no limitation of grey levels, irrespective of the recording density.

- Limitation of the image resolution: While conventional screens need an oversampling for the input resolution, FM screens can be rendered with the full input resolution.

What has not been mentioned so far is the fact that regular screens need screen angles which, in turn, can produce moiré patterns. Here again, fine screens are more critical than regular screens, because higher recording densities are required to eliminate the potential moiré patterns. FM screens are free from moiré patterns under all circumstances.

To summarize, it can be said that fine screens offer less advantages compared with FM screens with respect to resolution, continuous-tone appearance and printability. This statement refers to screen rulings between 80 lines/cm and 150 lines/cm. For very high screen rulings above 150 lines/cm some aspects may be different, especially the printability which has been reported to be similar to FM screens.