SPIR@L Screening: Breakthrough Technology Defines a New Reference

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Keywords: halftone, screening, inksave

Abstract

In 2020, Agfa introduced SPIR@L screening, an innovative technology with major advantages over conventional and other more modern screening technologies. Like its predecessor, Sublima™, SPIR@L screening is an XM screening that allows for highlights and shadows to be reproduced to their full extent.

As in conventional screening, darker tones are created by enlarging the small highlight dots into larger AM dots. However, contrary to the conventional ways, the small highlight dots are now enlarged in the form of a spiral instead of a round dot. The spiral curve has a certain thickness, which we call the 'curve'. The pitch defines the clear space between two windings. This space is called 'groove'. To produce the best output for a particular combination of printing process, ink, and paper, it is possible to adjust the curve and groove dimensions, giving this technology a very large latitude. The relation between these two parameters is key to press stability.

By making the AM dot grow as a spiral, fine details in the mid-tones are rendered with more contrast. The lattice of the screen, however, is less visible.

Last but not least, by using this technology, less ink is needed to get the same density, as the ink is spread more efficiently. Consequently, a significant amount of ink is saved – with an average of 9.1% for the evaluated cases.

This paper contains a technical description of how the screen is built as well as some figures of the tests we have done. Currently, SPIR@L has been installed and shown to be operational for commercial heatset, commercial sheetfed, newspaper, and offset packaging. More than 100 split runs have been performed and have proven that SPIR@L does indeed account for significant ink-saving.

Agfa Offset B.V.

Introduction

Most printing devices are not capable of printing tints. Either they put ink on paper or don't put ink. The ink has a fixed color. It's a binary system, either white or black, without any grays. But we want to render tints. We want to print photographs.

Already in the 16th century, they had this problem in book printing. Craftsmen were hired to make gravures. Fine lines close to each other were used to generate tints.

In contemporary printing techniques, tints are created by small dots printed close to each other. For color printing, a few base colors are used to reproduce the original photograph. In most cases, those colors are cyan, magenta, yellow and black. When looking at the prints with a loupe, one can see many small dots with white spaces in between. The ratio between the area covered with ink and the white area will determine the tint of a color.

Figure 1: *Zoomed in AM screen at the left, and FM screen at the right.*

In the early days of digital halftoning 2 major techniques were used to render tints. To cover a larger area with ink, one could either increase the size of the small dots, which is called Amplitude Modulated (AM) screen, as you can see on the left picture of Figure 1, or increase the number of dots, called Frequency Modulated (FM) screen, as you can see on the right.

The result of these two screening methods is different.

For darker tints, AM screens will render the dots so big that one can see them with the naked eye. However, as the dots are placed in an orthogonal lattice and thus nicely placed in rows and columns, the pattern does not come across as disturbing.

With the FM screens, the dots are smaller and difficult to see, but as they are kind of randomly placed, the pattern looks a bit noisy, which makes us like them less. So, although the dots of an AM screen are more visible, we tend to prefer the cleanness of the dots nicely placed in rows and columns above the randomly placed less visible dots of an FM screen.

History of Agfa screens

In this section, an overview will be given of the halftones developed by Agfa. As we have always tried to deliver the best halftone techniques, up to the desires of the customers, this will give an idea of how screening has evolved in the world of graphic arts.

ABS

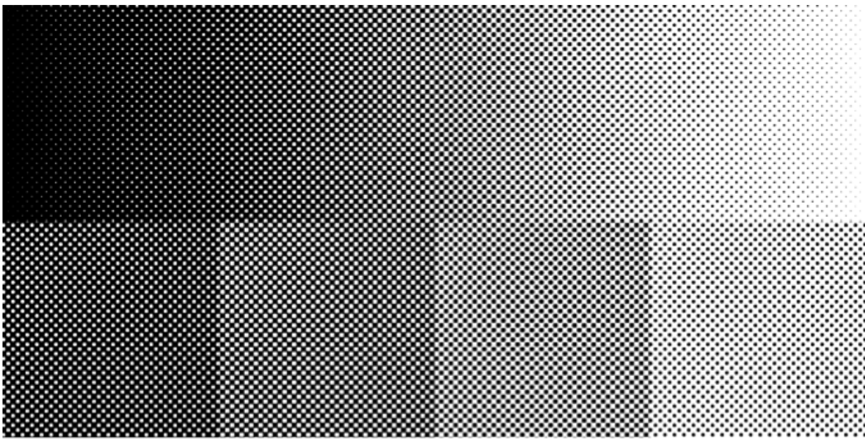

Figure 2: *Agfa Balanced Screen*

In 1992 Agfa introduced Agfa Balanced Screening (ABS). An AM halftoning technique that renders darker tints by making the dots larger. But why balanced? What does balanced mean?

In 4 color prints, the 4 halftones of the colors are printed on top of each other. So 4 times dots are placed in rows and columns. When these grids are put on top of each other, there is a chance of Moiré. Moiré appears when almost identical repetitive patterns are brought together.

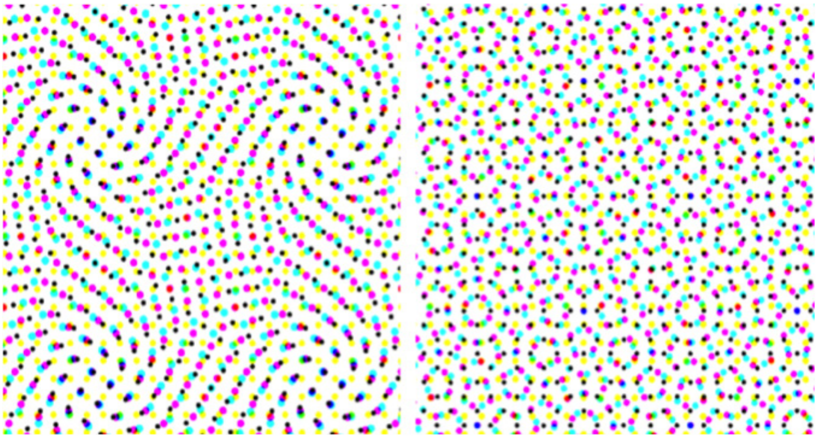

Figure 3: *The effect of 4 lattices laid on top of each other. When you place 4 similar patterns randomly, unbalanced, a low frequent pattern might appear (left image). Mathematically you can calculate what frequencies and line rulings to be used to avoid a low frequent pattern. You can "balance" the lattices to obtain perfect rosettes as in the right picture.*

When you put lattices with a slightly different frequency or a slightly different angle on top of each other, you might get a low frequent pattern. This can be seen in the left image of Figure 3. Mathematically [3], one can calculate what the perfect angles and frequencies are to put lattices on top of each other. If you nicely balance the 4 screens, you get the typical rosette pattern as seen in the right image of Figure 3. Typical C, M, and K, the most visible inks, are placed on angles that differ 30 degrees. The less visible, the Yellow, is placed on an angle that differs 15° from the others.

Cristal Raster

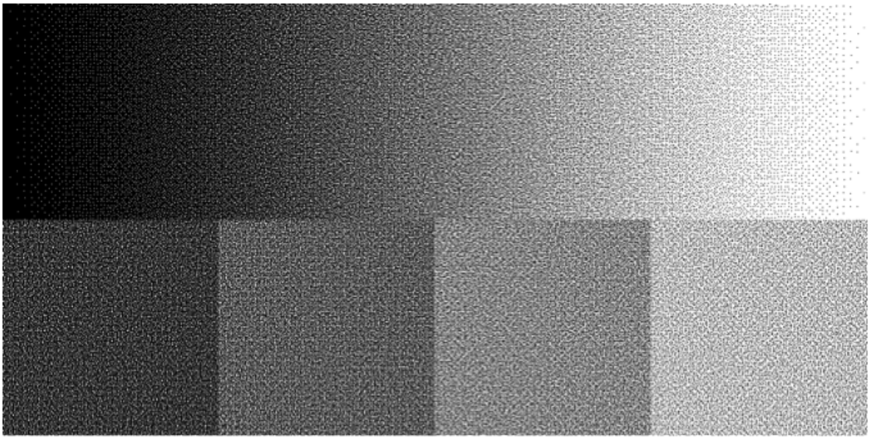

Figure 4: *Agfa Cristal Raster*

In 1994 Agfa released its first FM screen, which was called Cristal Raster. Cristal Raster is based on the Bayer array [4] to guarantee the best distribution of dots over the plane.

As in FM screens, it is the frequency that is modulated, the rendered image will have many small dots, which results in a screened output with more borders between the parts with and without ink. As there are more borders, Cristal Raster will have more dot gain. To get the same contrast in images as with AM screening, this extra dot gain needs to be compensated. As in many cases, images are supplied in 8 bit and compensation curves are applied in 8 bit, it's advisable to put this compensation already in the screen because then no extra quantization is added to the image and no visible banding will appear in vignettes.

An advantage of FM screens is that they can render finer details than AM screens. Therefore, they are often used for super high-quality print works, jewelry catalogs, and art books, for instance.

However, FM screens have disadvantages too. They are very demanding for print and less stable on press. As dots are isolated on the plate, they are more vulnerable to chemical or mechanical erosion. Because of this, the run length of plates is much lower and the press operator will need to follow up the press more precisely checking the control strips more often and adjusting the press when needed. FM screens are more demanding for the CTP. Only proven high quality plate setters are compatible with FM Screening.

So to conclude, FM screens can generate the best quality images, especially high detail images, but require more attention from the press operator and will be more demanding for the press. A side effect of the higher dot gain is that less ink is needed to render the same images.

Sublima

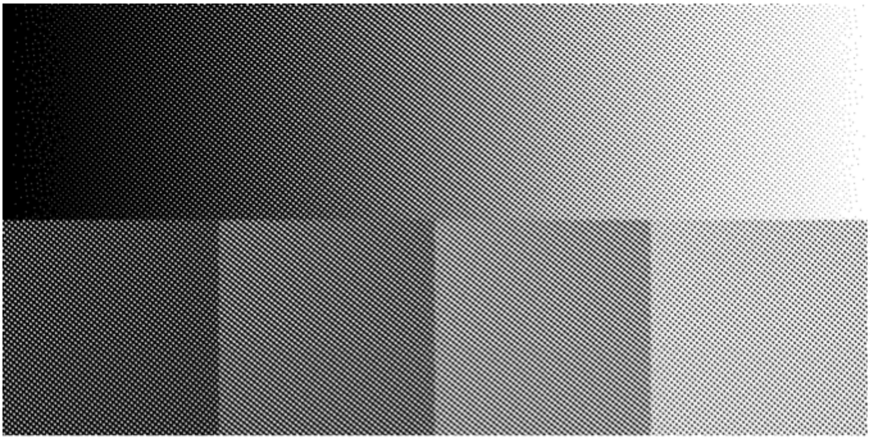

Figure 5: *Agfa Sublima*

The way AM screens can render fine details depends on the frequency of the lattice, the line ruling of the screen expressed in lines per inch (lpi). The higher the lpi, the finer details can be rendered. The dot size of an AM screen is inversely related to the LPI, the higher the lpi, the smaller the dots will be. As a result of that, dots in the highlights might become too small to reproduce. As smaller dots disappear in the chemical process or will erode earlier on the press because of mechanical friction, clipping might occur [5]

Agfa's Sublima Screening, which was released for Newspaper in 2001 and commercial print in 2003, tackles this issue by limiting the decrease in size of the dots. From a given moment on, dots will no longer decrease but will be taken out of the lattice. From that moment on, the AM screen becomes an FM screen. This kind of screening is often called XM screening. FM in the shadows and highlights, AM in the mid-tones.

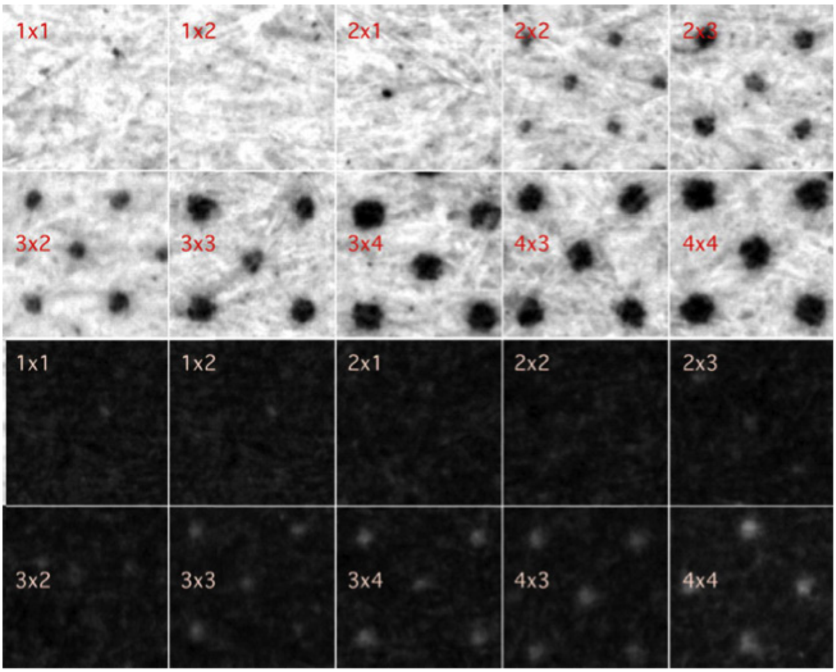

Figure 6: *An example of a pattern that is printed when installing Sublima screening at a customer. The print will tell what the smallest dot size is that holds on print.*

When installing this type of screening, first a test print will be made to find out the minimum size of a dot, to make it strong enough to survive the chemical development phase and the mechanical process on the press [6].

CR III

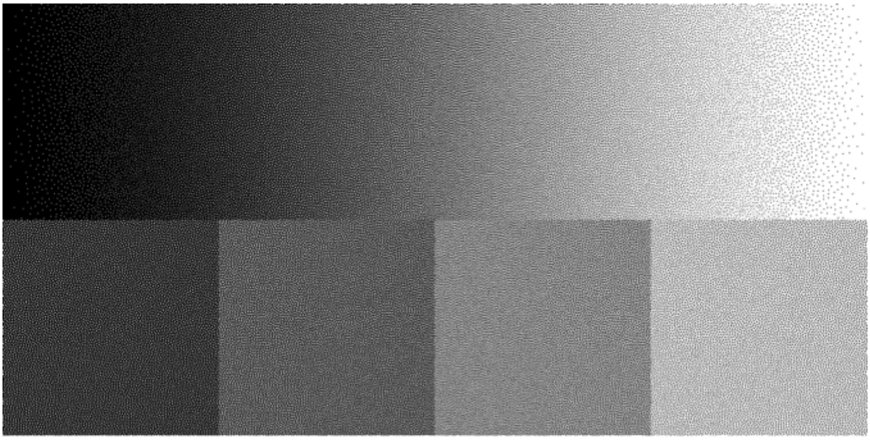

Figure 7: *Agfa Cristal Raster III*

In 2018, Agfa released its second type of FM screen, also in fact its second type of XM screen.

As with an FM screen, small dots are placed more or less randomly in highlights and shadows. In mid-tones however, where dots start to touch, dots are motivated to form clusters with other dots. So from that moment on, small dots merge and grow to larger dots, resulting in a wormy-like structure, a kind of Turing pattern in the mid-tones. The wormy structure in the mid-tones looks better than the noisy grouping in the first Cristal Raster screens. Now the dots start to form clusters, the screen also becomes an AM screen, as clusters grow instead of adding more dots. For this reason, this kind of screening could also be called XM screens.

Cristal Raster III has similar pros and cons as the original Cristal Raster. And, on top of that, it has less noisy mid-tones.

Cristal Raster screens don't have a fixed lattice, so there is no risk of causing a Moiré pattern to appear. For this reason, Cristal Raster screens also have an advantage when more than 4 colors and inks are printed together.

SPIR@L Screening

As we saw, all the previously released screens have their advantages and disadvantages. This led to the question: Can we generate a screen with the same cleanness as an AM Screen, that is guaranteed to be Moiré free, that also has an increased ink/no ink border, and thus a higher dot gain, so less ink is needed and that also has a guaranteed minimal dot reproduction? Can we generate a screen as stable as an AM screen, with a dot gain similar to an FM screen? Our new technology SPIR@L screening is the answer to those questions.

With SPIR@L we have replaced the standard round or elliptical AM dot with spirals. First, similarly to our Sublima, minimum dots are set. When all lattice positions are filled, the dots start to grow. For SPIR@L screens those dots will grow in a spiral. When the full plane is filled with spirals, the inverse process will happen. The white spirals formed by the space between the black spiral curves, these white spirals will shrink.

SPIR@L Screening also follows the stacking principle [9]. The screening is tile-based. In the tile, a dot that is set for a given tint will also be set for all darker tints. This has the advantage that with small changes in a tint, no abrupt changes will occur in the drawn spirals.

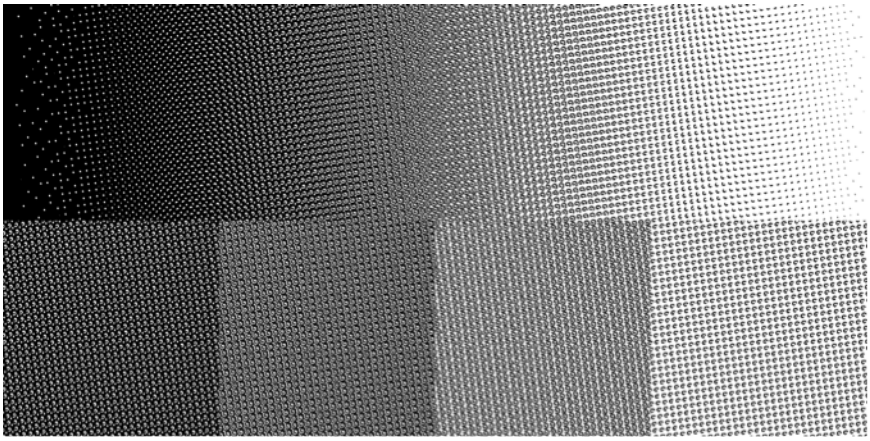

Figure 8: *Agfa Spiral Screening*

Apart from the typical AM screen parameters (lpi, angle, minimum dot in highlights, and the minimum hole in shadows) for spiral we now have 2 extra parameters. The "Curve" and the "Groove" parameter. The curve parameter is the stroke or the thickness of the black curve. The groove is the size of the white space between 2 revolutions of the spiral curve (see Figure 9).

Figure 9: *SPIR@L screening has 2 extra parameters on top of the standard AM parameters. The thickness of the spiral (Curve) and the size of the white space between 2 revolutions (Groove)*

When installing the SPIR@L screen at a customer's site, it is key to find the proper values of those parameters to get the best performance of the screen.

When generating the screens, many more parameters are used to finetune the final SPIR@L screen. The spiral shape can be a dashed line, can have a grove, and can even have the profile of a radial tire. Those dashed spirals might have their advantages when ink is put on a non-absorptive material. We can choose what happens with the growing spirals when they start to touch. We might opt for the addition of a round dot in between the white spirals in the shadows. The angles can also be set. Positional noise can be added. The shape of the start dots can be defined. And much more. As such we can create many flavors of our screen that all have their advantages for some kind of printing process. I'm very happy that I can rely on our application experts, who have built up the expertise to select the proper flavor for each specific customer. A range of different SPIR@L shapes can be seen in Figure 10.

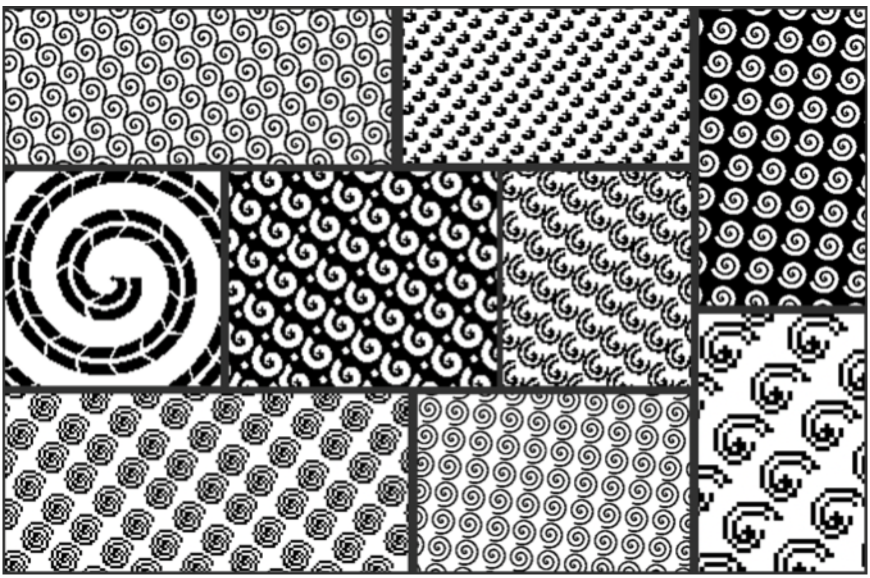

Figure 10: *SPIR@L screen comes in multiple flavors. Many options can be set to optimize the screen towards the press conditions of the customer.*

SPIR@L screens have been installed by Agfa and have already been used for more than 2 years at customer sites. The experience with those early customers gives us a clear answer to the question: Does the new SPIR@L screen do what we hoped for? The answer is yes. The overall appearance of the screens is very similar to AM screens. We get the same cleanness. Still nice rosettes are formed in a 4-color print. We have reproducible highlights and shadows because of the small FM Parts. And also the dot gain is higher for which we have to compensate.

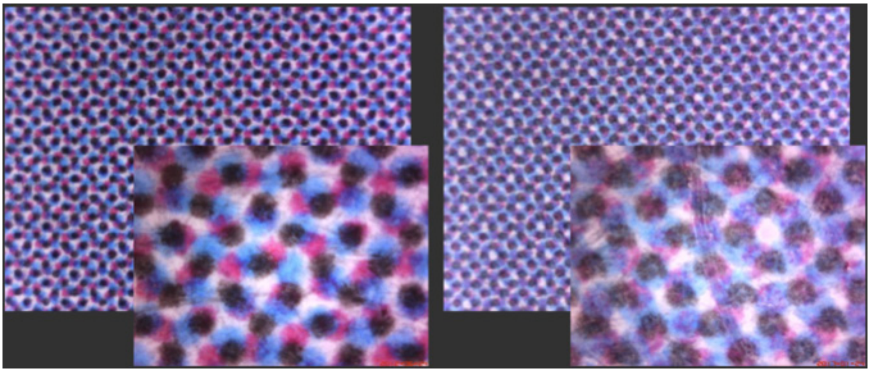

Figure 11: *The appearance of the SPIR@L screen and ABS screen are much alike. When zoomed in (8x image in the back, 30x image in the front), the SPIR@L screen can be recognized by its shrimp-like dot shape.*

We even got more. We got sharper images, we got more saturated colors, we saw examples of disappearing subject Moiré, we need less ink, we saw fewer web breaks, we got less waste, there was less see-through and the time needed to dry was shorter.

When we take high-resolution pictures of the same file rendered by once ABS and once SPIR@L, we can see that the appearance is very similar. SPIR@L dots are slightly larger but the rosettes are still nicely formed. SPIR@L screens can be identified by the shrimp-like shape of the single dots.

Apart from the things we hoped for, we also saw some minor but very positive changes in color. Namedaniana et al. [8] have stated in their paper that the gamut increases when dot gain increases. Something that was also found by FM screening.

We did do some internal tests that clearly showed that different dot shapes for colors might cause different color behavior. For that, we advise making a specific press fingerprinting for the press with the customized SPIR@L screen.

Although we advise making a specific press fingerprinting, for most of the actual customers, however, screens are installed by just applying a different calibration curve. When we then compare the ABS image to the SPIR@L image, we see slight differences in favor of the SPIR@L screening. Slightly more contrast and more saturated colors.

When installing SPIR@L screens at customers, we always measured the dot gain compared to the standard ABS screen. Results showed us that we had a significantly higher dot gain with the SPIR@L screens for which we had to compensate.

We had set up a project in our group to investigate the relation between dot shape and dot gain. This investigation was done on one of our inkjet proofers. One of the outcomes of the research was the conclusion that the larger the border between ink and no ink is, the more dot gain is obtained.

Namedaniana et al. [8] came to a similar conclusion when examing different types of halftoning in their paper. Dot gain increases when the perimeter of dots increases. There is no need to explain that the perimeter of a SPIR@L screen is much larger than the perimeter of an AM screen dot (see Figure 12).

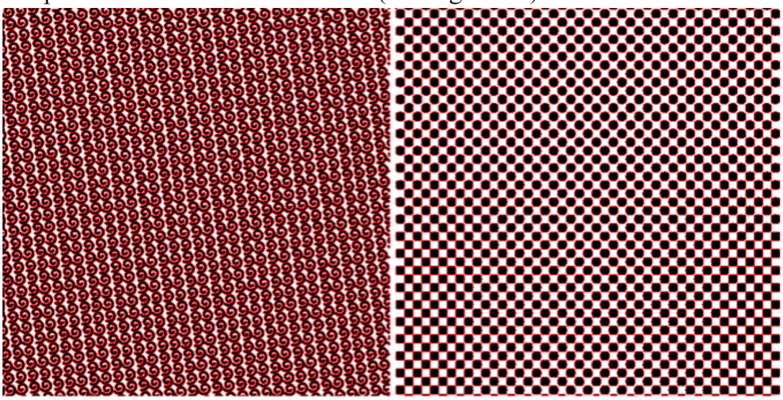

Figure 12: *Number of border pixels, in those images marked in red, is much higher for SPIR@L (left image) as it is for ABS (right image)*

Our tests also showed that the higher the dot gain, the less ink is needed for the reproduction of a job.

To get an indication of the actual dot gain caused by the different Agfa screens, a tool was made that applied the screen and then calculated what fraction of the black raster pixels were located on a border between ink / no ink. For a pixel to be a border pixel, a pixel needed to be 8 connected to at least one white raster pixel.

Screen	% Border
ABS	29
CR	71
Sublima	45
CR3	70
SPIR@L	59

Table 1: *Percentage of border pixels for a typical portrait image.*

We compared Agfa's Sublima XM screen to ABS and to SPIR@L. Table 1 gives the percentage of border pixels for a typical portrait image. ABS has far fewer border pixels than SPIR@L. 240 lpi Sublima lays in between. CR and CR3 have more border pixels than SPIR@L. For typical commercial print work there are also text zones and solid areas which contain fewer tints. Typical a solid is rendered as 100%, so all pixels are colored and will as such have no border pixels.

Figure 13: *Typical document for commercial print work.*
For all the 12 pages the ratio of border pixels has been calculated.

Therefore, we performed the same test on a typical brochure for commercial print with 12 pages (Figure 13). In Table 2 you can also see the ratio of border pixels. Again, we come to the same conclusion. ABS is by far the lowest, SPIR@L is a bit less than the FM screens and 240 LPI Sublima lies in between ABS and SPIR@L.

	1	2	3	4	5	6	7	8	9	10	11	12
ABS	23	30	29	33	36	19	40	36	37	34	35	8
CR	55	65	79	67	70	34	79	77	73	66	72	13
Sublima	34	43	54	46	51	25	55	49	51	47	48	12
CR3	56	65	78	67	70	34	79	77	73	66	72	13
SPIR@L	43	52	71	58	65	29	72	67	66	58	60	9

Table 2: *Percentage of border pixels for pages of figure x for the different Agfa screens*

We tried several methods to prove the effective amount of ink saved. We compared the weight of printed sheets. We cut out fixed shapes and measured them on a highly accurate scale. But in the end, we trusted the most comparing the ink consumption for real artwork in very high run lengths. On presses that were equipped with highly accurate ink consumption measuring devices, we printed half of the job with the conventional screen and half of the job with the new SPIR@L screen.

Up till now, we have done 105 of those split runs. We did this at 17 different sites. We used 15 SPIR@L variants. 12 different media types. In total for those 105 split runs, we printed more than 45 million sheets. Comparing the ink consumption of the original screen and the new SPIR@L screen, gave us, depending on the kind of job, up till 12% of ink saving on press. 12% less ink has a major impact on the total cost of a print job. It also has a major impact on the environmental load.

SPIR@L screening is in production at more than 50 customers in Europe, North-America and Latin America. In most cases, no difference in stability is seen between the former AM screen and the new SPIR@L screen. Although the dot gain and ink saving is nearly as high for SPIR@L, as it is for FM, SPIR@L is much more stable. A reason for this is the fact that with a spiral the dots are supporting each other. Every pixel still has at least 2 neighbors. While with FM screens the pixels are isolated and as such much more vulnerable to erosion.

The installation of SPIR@L is straightforward. After a discussion with the customer, depending on the used media and the installed printing process, a couple of SPIR@L screens are picked.

To avoid the need for an extra press run, extra control strips are added to waste zones on the plate layout. Those extra strips are measured using our PressTune software which will then calculate new calibration curves. Those new calibration curves are uploaded to the RIP and the customer's screen is replaced by the best scoring SPIR@L screen.

In most cases, extra press fingerprinting is not necessary.

Conclusion

In this paper, an overview is given of different halftone screens and their pros and cons. Our new Agfa Screen, SPIR@L screen, is compared to those other screens. By introducing the spiral shape, we have created a dot with a much higher perimeter, giving us a dot gain only slightly smaller than FM screens, with the stability of AM screens.

In the near future, we will do press fingerprinting for our different screens to get accurate numbers for the color behavior and the effect on the gamut due to the SPIR@L screen.

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