Study on Digital Printing Applying Frequency Modulated Screen

Rossitza Sardjeva

Abstract— In order to print a continuous tone (halftone) it must first be transformed into a binary image, usually called a bitmap, consisting of zeros and ones only (0;1). The transformation from continuous tone into a binary bitmap image is referred to as screening process.
The result of screening is that the dots are small enough and the halftone pattern will not be visible at normal viewing distance, the image is visually integrated and interpreted as varying shades of gray or color. In the different approaches for screening are two main methods: Amplitude Modulated (AM) and Frequency Modulated (FM). With FM technology, small dots are distributed on a surface in such a way that the required gray value appears as an average value, whereas distribution is completely irregularly compared to the normal halftone dots. For this reason, frequency-modulated screening is also referred to as random or stochastic screening.

Index Terms— screening, frequency, amplitude, stochastic, digital printing, electro-photography

I. INTRODUCTION

Printing is a binary system, where ink is either present or not, so all image information to be printed must be translated into dots at same stage of the workflow. The result of half toning is that the dots are small enough and the halftone pattern will not be visible at normal viewing distance (> 30 cm) and the image is visually integrated and interpreted as continuous tone. [1]
Generally in the different approaches for screening are two main methods: Amplitude Modulated (AM) and Frequency Modulated (FM). AM screening, the form of screening used most commonly in the printing industry today, involves creating halftone dots separated by a fixed distance and arranged in a regular pattern. Varying the size of the dots creates areas of higher and lower color density. AM screening results in a highly consistent color appearance, and is easy to print. In amplitude modulated screening (AM) because of the constant distance between the halftone dots, this method is known as periodical screening. Here the different tonal values are reproduced by varying amplitude (size) of the halftone dots. Nowadays the main way to screening is digital methods where the dots are assembled by different number of pixels.
With FM technology the smallest reproducible pixel can generate the dots, but the tone values are simulated by varying the dots distance. The dots have the same size, but are irregularly spaced, referred to as stochastic screening. Individual dots are combined into clusters according with very complex raster image processor's (RIP) algorithm. Small equal dots are distributed on a surface in such a way that the required gray value appears as an average value, whereas distribution is completely random, irregularly spaced, non-periodical, depending of original. Appearance of second generation of FM screens such as *Staccato Satin FM screen*, definitely improved print quality of this type of screening.

Manuscript received May 10, 2016

Rossitza Sardjeva (PhD) is working for Technical University Sofia, br. Plovdiv, as an Associated Professor of Graphic Arts Printing Specialty, where she teaches students for BA and MA educational degrees.

II. THEORETICAL BASE

The concept of AM and FM half toning for different tone levels is shown on the Fig.1
In the case of color tonal printing, which nowadays is commonly used, in order to reproduce a color image, first it must be separated original into three or more color separations, the subtractive primary colors cyan, magenta and yellow (CMY) with the additional black (K) colorant added in CMYK color printing.

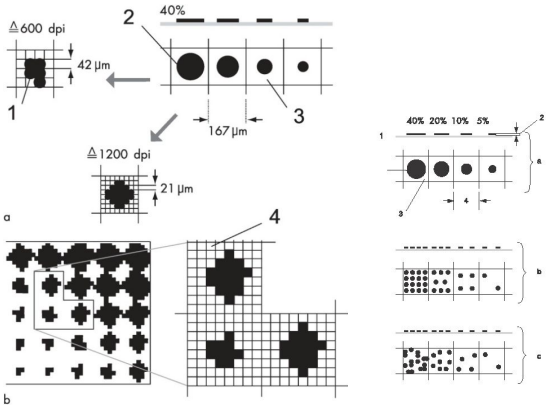
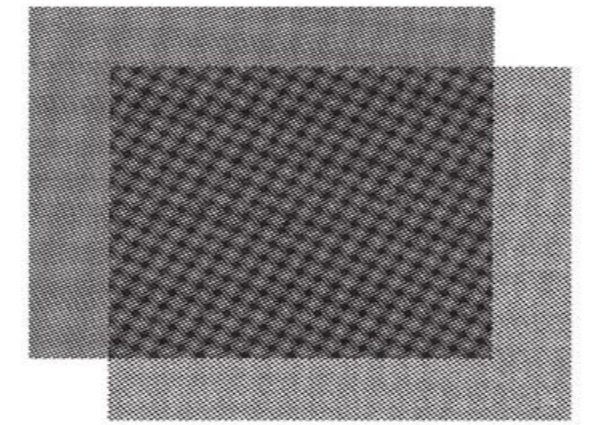


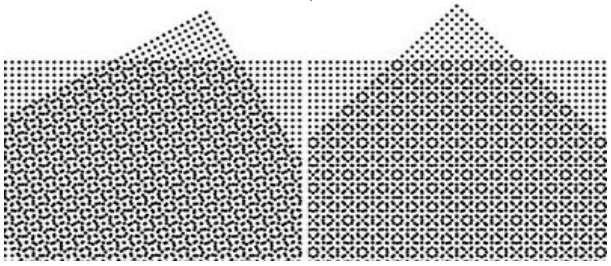
Fig.1 Tonal gradation with AM and FM screening: left –a.) analog AM dots (2, 3); b.) digital AM dots, assembled of pixels (1, 4 - left); c.) FM dots

Normally, the different color separations are half toned independently of each other. Printing three or four color separations on top of each other introduces additional considerations regarding interference between the color separations.[2] Only a slight miss-registration of the AM halftone screens can introduce color errors, named unwanted *moiré patterns*.(Fig.2) The moiré appearance can be seen in the case of overprinting of two periodical structures with different screen ruling. As a result of two colors screen it appears new one (Fig.2, a.)
In order to reduce the sensitivity to moiré effects in AM halftones are commonly used printing the color separations at different screen angles. Usually the four angles correspond to 15°, 75°, 0° and 45° for cyan, magenta, yellow and black, respectively. Rotated screens reduces the effect of miss-registration but, on the other hand, introduce a new type of pattern, referred to as *rosette patterns*, visible for lower screen resolutions. (Fig.2,b.)

In FM color half toning there is no need for rotated screens and the rosette and moiré patterns are generally avoided, since the screen patterns are no longer regular and periodic. Here appearance of disturbing moiré and rosette pattern coming from traditional periodical screening is almost impossible, which is the great advantage of FM screening. While in AM screening is applied super-cell process which tries to match the specified screen angles in order to minimize additional pattern, in FM screening has no screen angles to contend with. As a result, this avoids the moiré resulting from interference patterns between screen angles and items such as lace cloth, stereo mesh and etc.



a.)



b.)

Fig.2 Appearance of moiré pattern in: a.) overprinting of two structures with different screen ruling; b.) rosette patterns in different angles of screen ruling – 30°, 45°

It also eliminates the rosette structure that can occur in dark gray or black areas. However, FM color halftones can sometimes give a somewhat "grainy" and cluster-effect (especially in the the darkness). Also the effect of miss-registration is not completely eliminated but it is certainly less apparent than in traditional screening. This feature is very favorable for printing on rotary machines where the miss-registration is very common due to effects such as web growth. FM color screening can also reduce the amount of ink because of very tiny dots. [3]

In principle frequency modulated screening as a terminology has appeared in the end of 60-ties of last century but its importance for graphic arts increased definitely recently, in last ten years, when has been involved totally computer-to-plate technology (CTP) and digital workflow in prepress. In addition, due to such digital printing technologies like Computer-to-Press and Computer-to-Print it became theoretically possibly the application of FM for different printing products. FM method is accepted as a better way for reproducing fine details, specific structure (human skin, face, different fabrics). Today, when you make a plate with stochastic screening must be used a tone correction curve, which allows to align the tone reproduction of an FM screen to that of an industry standard, to align the stochastic screening to conventional tone reproductions targets (ISO 12647-2).[4][5]

FM not only solves the problems of moiré and broken lines that sometimes occur in AM screening. It also increases the vibrancy of the colors being printed particularly in binary colors (red, green, blue). The result is that more light is filtered by the ink and less light simply reflects off the surface of the substrate. That is why a stochastic dot pattern creates a sharper image and the colors are more pure and saturated. That is why FM screens exhibit a greater color gamut than conventional halftone screen.

In the same time the printers are not always willing to apply FM screening methods in their practice because in the FM screening, compared to conventional AM screening, the small spot size of the laser beam makes higher requirements on the plate making process, higher attention on the real printing process and special care and cleanliness as well.

III. EXPERIMENTAL

One of the best example of digital printing is electro-photographic (EP), known also as "laser" printing [6], where is possible to print with dry powder toner colorants. It is dynamic master-less technology where there is not constant intermediate carrier of information (printing plate). The great advantage of it is possibilities to change printing information after cycle by cycle of process, e.g. to produce so called variable data printing (VDP) and to make personalized products or print-on-demand (PoD).

Digital dry toner electro-photography is the eligible print technology for applying different screening methods in half-toning, including also non-periodic frequency modulated (FM) screening. Nowadays the print quality generated by EP system is definitely at high level. Already are known very narrow particle-sized toners and with stable electronic process with constant re-imaging and thus can produce very high print quality, print by print, free of fluctuations, with good image reproducibility.[7]

But in AM is currently being encountered unstable connection between tone signal and dots areas shown with the halftone dot exposure profiles on the organic photoconductor (OPC) drums.[6]

For the purpose of this research has been used industrial dry toner digital EP system Kodak NexPress2100 Plus. With this digital printing technology the toner transfers to the paper in varying amounts from dot to dot. Also halftone gradation of images depends on the type of toners, their quantity, penetration, smoothness of the printed substrates and thermal fusing process as well. What is important, the print quality here depends also on the kind of screening, size and shape of the individual image element. In digital EP systems the print quality depends also on addressability data of the imaging system (dpi, number of pixels per inch), number of gray values, given per pixel and the toner technology used. The possible reproduction of very fine structures is determined by the addressability and the reproduction of tonal values and gamut as gray values per pixel.[1]

Kodak NexPress2100 Plus is a 5-coloured single-pass digital system, comprises of successive five printing units for each process color. To print a multicolor image, the printing sheet passes through five printing units to receive toner and this happens in one pass.[8] The imaging speed corresponds to the printing speed. The study is processed by help of FM Kodak Staccato DX Screen, belongs to so called second generation stochastic raster with improved algorithm, named Satin screening.

IV. PROBLEM SOLUTION

The objective of the paper experimental is to examine image quality of Kodak Nexpress2100 Plus. In particular, our purpose is to find out how this press can print pleasing stable color images from legacy CMYK files and how can keep uniformity of color quality print by print. Key elements of our experimental work include calibrating the printing system, designing test forms containing CMYK images and color-managed pictorial images, performing quantitative and visual analyses. For this purpose have been used test files as a characterization target for device profiling and for quantitative analysis. Test files have been generated by the help of spectrophotometer x-Rite with i1Profiler software, which offers ICC application, optimized on the real halftone illustrations, using process colors (CMYK) and different PANTONE colors or other spot colors.[9] i1Profiler is equipped with the x-Rite standard Graphic Arts (XRGA) and its software is developed for the series of steps as a methodology aimed for researching of test-tables and profiles. Test files were printed on the Kodak Nexpress2100 Plus, using FM Kodak Staccato DX screening and with conventional AM with screen ruling of 300 lpi. For optimum of FM performance is used Kodak square spot Imaging technology devices, where depending upon its capabilities and screening algorithm, we have used 20 µm stochastic screening dots.

The consideration that main parameter of printed quality with different screening methods is tonal value increase reflected in *Dot Gain,* are absolutely valid here. After printing, the halftone dots generally appear larger than their nominal size in the bitmap image, resulting in increased tonal values than expected, a phenomenon usually referred to as dot gain. It is very important to see what will be the Dot Gain in each printed process color, so we have measured these values and received data are accepted as criteria to make comparison related to half-toning quality obtained by help of FM and AM screening technologies with described above conditions.

The measurements have been done according to ISO12647-2:2004, using X-rite spectrophotometer. Measured values are compared in two cases: for Staccato DX FM screening and for traditional AM screening with screen ruling of 300 lpi. FM half-toning methods generally do not use screen ruling in lpi (line per inch) and therefore only the print resolution (in dpi) is relevant.[2]

For the purpose of this research have been used wood free coated glossy paper (WFC), for digital printing, grade 130 g/m^2. In principal the paper category establishes the target for an optimal screening resolution.[10]

V. RESULTS AND DISCUSSION

In our printouts we obtained all advantages of FM Staccato screening method as: completely free of moiré patterns, resulted in a fine distribution of very small dots, cluster-chains and thus eliminating of empty spot and grained structure, especially in a small tone values. The reproduction color results achievable on the examined conditions are shown in Table 1. The results show that when printing on coated wood free paper, the reproducing ability of Kodak NexPress2100 Plus is enough high, without large deviation of dot gain regarding screening technology. In the way of this study have been received fully acceptable printing results within the whole technological chain.

For black half-tones can be said that with AM screen are obtained a little higher values in the whole tonal range except in 50% mid tone. The results of dot gain in the high lights up to 30% tones with AM, is visible higher.(Table1) For different process colors the results are more or less fluctuated. Middle tones values for cyan and yellow with AM screen are definitely higher compared to the same with FM screen, while for the very highlights in magenta and particularly in yellow, dot gain for FM screen are above those of AM screen.

Table I. Dot gain with Kodak StaccatoDX FM Screening and with conventional AM screening

Staccato DX FM screening								
Tonal value	***10 %***	***20 %***	***25 %***	***40 %***	***50 %***	***60 %***	***70 %***	***90 %***
Cyan	6	15	17	21	22	20	18	7
Magenta	10	13	16	21	22	22	20	8
Yellow	12	15	18	21	22	19	18	6
Black	6	11	14	21	24	22	16	6
AM screening								
Tonal value	***10 %***	***20 %***	***25 %***	***40 %***	***50 %***	***60 %***	***70 %***	***90 %***
Cyan	7	15	17	21	24	23	18	8
Magenta	7	14	16	20	22	22	18	7
Yellow	5	12	16	23	24	23	20	8
Black	8	16	19	23	23	22	18	8

The same can be said and for the darkness in magenta (80%), but middle tone values in magenta are almost equal with two screening technology.

For the rest of tone range some deviations are occurred. Conclusion is there are not sufficient differences when applied high screen rulings in AM screening (300 lpi) and very small dots in FM screening.

In the case of this screening process dot gain is typically explained by so called optical effect. Generally dot gain in halftone prints actually encompasses two fundamentally different phenomena: Physical dot gain (also known as mechanical dot gain) and Optical dot gain (also known as the Yule-Nielsen effect). [2] Physical dot gain is closely related to the printing process, including the operation settings on the press, the ink-transfer and ink-setting processes. Optical dot gain, on the other hand, originates from light scattering inside the substrate, causing light exchanges between different chromatic areas. The result is that the dot area appears larger when the reflective light is perceived/measured, compared to the physical dot size, and hence a darker tone value. The reason for optical dot gain when the light enters the bare paper and then is scattered within the paper under halftone dot and partially absorbed by the ink on its way back. Optical dot gain in digital EP with stochastic screening is more important part of dot gain at all. When the dot size becomes small in relation to the lateral scattering length, the optical dot gain will

increase. Because of optical dot gain, the relationship between the printed dot area fraction and the perceived/measured reflectance is usually nonlinear.

The advantage of the examined digital printing system over reproduction ability can be attributed to the large color strength of CMY dry toners, its stable transfer, fusing and fixing to the paper. This provides permanently high saturation of solid fields and excellent darkness for black. (Fig.3) In solid inks densities (SID) we see higher values for black and yellow in FM case and for cyan and magenta in AM.

In order to print solid areas, the diameter of an individual image dot must be greater than the width of the pixel cell. [1] Perfect quality obtained in Kodak NexPress2100 Plus digital printing also is due to the integrated imaging system, guaranteed 256 levels (2^8) of exposure through the complete data path.

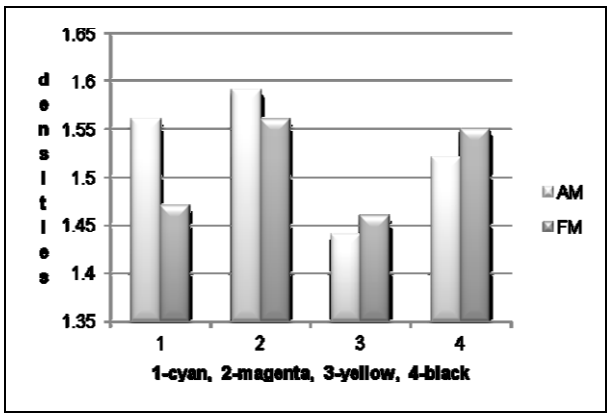


Fig.3 Values of Solid Inks Densities (SID)

CONCLUSION

The quality of print reproducing and all prints made on the coated wood free paper with the help of frequency modulated screening have shown that this screening method can be successfully applied in digital EP printing with dry toner process. STACCATO DX Screening enables high fidelity, consistent presswork that exhibits fine details without halftone rosettes, subject moiré, gray level limitations, or abrupt jumps in tone. On the base of the whole results can be said that FM screening is a better way for reproducing different image structure and the configurability of STACCATO DX makes these benefits accessible to a wider range of applications.

REFERENCES

[1] Kipphan H., In: Handbook of Print Media, Springer-Verlag publ., 2001, ch. 1.4, pp. 94-96,354

[2] Nystroem D., High Resolution Analysis of Halftone Prints, Department of Science andTechnology, LinköpingUniversity, SE- 601 74 Norrköping, Sweden, 2008

[3] Gooran, Sasan, High Quality Frequency Modulated Halftoning. Ph.D. Thesis, Dissertation No. 668,Linköping University,Sweden, 2001

[4] ISO 12647-2:2004, Graphic Technology – Process control for the production of half-tone color separation,proof and production prints, Part 2: Offset lithographic processes

[5] FOGRA 39 color gamut method, www.fogra.org

[6] Kuznetsov, Y. V., Relationship of Old and New Knowledge in Printing Technology Education of Today: Examples of Retrospective Analysis, International Circular of Graphic Arts and Research, 2014, № 7, p.81

[7] Bennett P., Romano Frank, Levenson H.R., The Handbook for Digital Printing and Variable-Data Printing, PIA/GATF Press, Pitsburgh, NPES, 2007,pp.113-126

[8] Kodak NexPress 2100, Digital Production Color Press, www.kodak.graphics.com

[9] Instructions for i1Profiler spectrophotometer Apply,x-Rite XRGA standard, 2012

[10] Hamann J.P., Gerd Carl, Leppanen T., Recommendations for preperess and Printers, Paper vs. Screening+Non Periodic screening, UPM, Helsinki,Finland, 2012, pp. 20-22

Info about the author

Rossitza Sardjeva (PhD) is working for Technical University Sofia, br. Plovdiv, as an Associated Professor of Graphic Arts Printing Specialty, where she teaches students for BA and MA educational degrees.

Also she is a lecturer for many years in Book Publishing Department of Journalism Faculty in Sofia "St. Kl. Ohridski" University. Her scientific interests are in the field of printing technologies and printing materials as well, where she has a long experience. She is a member of Union of Scientist in Sofia, section "Technical Sciences".